REVIEW ARTICLE

Conventional and Contemporary Luting Cements: An Overview

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Abstract Long-term clinical success of fixed prosthodontic restorations is influenced by many factors, one important factor being the selection of an appropriate luting agent. No single luting agent is capable of meeting all the stringent requirements, which is one reason why there is such a wide choice of luting agents currently available from conventional water-based to contemporary adhesive resin cements. Introduction of adhesive resin systems has completely changed the face of fixed prosthodontic practice leading to an increased use of bonded all-ceramic crowns and resin-retained fixed partial dentures. This article makes an effort to review various conventional and contemporary luting agents, their properties & associated clinical implications thereby trying to help the clinician select an appropriate luting agent for a given clinical situation.

Keywords Luting cements · Properties · Advantages · Shortcomings · Chief concerns · Clinical recommendations

Introduction

Multiple factors affect the success of fixed prosthodontic restorations with preparation design, oral hygiene/microflora, mechanical forces, and restorative materials being some of them. However, key factor to success is the choice of a proper luting agent and the cementation procedure. Loss of crown retention was found to be the second leading cause of failure of crowns and fixed partial dentures [1] while a study listed uncemented restorations as the third leading cause of prosthetic replacement with failure occurring after only 5.8 years of service [2].

The word 'luting' is derived from a latin word Lutum-which means mud. Dental luting agents provide a link between the restoration and prepared tooth, bonding them together through some form of surface attachment, which may be mechanical, micro-mechanical, chemical or combination. Luting agents may be definitive or provisional depending on their physical properties and planned longevity of the restoration.

This article reviews several luting cements, their properties, characteristics, recommendations for usage along with their advantages and disadvantages. Cements in this article have been classified into water-based and anhydrous.

Conventional Water-Based Luting Agents

Zinc Phosphate Cement

It is the oldest of the luting agents having a clinically successful track record of over more than 100 years since its introduction in 1878 [3]. The inherent stability of this cement was reported in a study which analyzed the chemical structure of zinc phosphate cement samples obtained from 27 fixed prosthesis that were in clinical service from 2 to 43 years [4].

It is available as powder and liquid system/encapulated forms and sets by an acid–base reaction. The main component of powder is zinc oxide with 2–10% of magnesium oxide. Liquid is essentially an aqueous solution of

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phosphoric acid (45–64%) [5] buffered by adding small quantities of zinc oxide/aluminium oxide. These compounds form phosphates which stabilize the pH of the acid and reduce its reactivity. Unsuccessful attempts of combining this cement with flouride and eugenol had been done to improve the biological properties [6].

Water content of liquid (30–55%) is significant because it controls ionization of acid, which influences the rate of setting reaction. Loss of water can lengthen the setting reaction and vice versa. Water evaporation should be suspected if the liquid appears cloudy on dispensing. Water contamination should be avoided when the cement is setting, as phosphoric acid leaches out and greatly increases the solubility of cement.

This cement retains the prosthesis purely by mechanical means. Taper, length and surface area of the tooth preparation are therefore critical to its success [7].

Mixing of the cement is critical and must be accomplished on a cool slab in small increments over a wide area. Failure in this speeds up the reaction and affects the consistency of the final cement. Optimum seating requires proper mixing and a constant heavy cementation force [8–10].

Working time of the cement can be greatly extended (4–11 min) and setting time shortened to achieve simultaneous cementation of multiple restorations using the *Frozen Slab* technique. In this method, a glass slab is cooled in a refrigerator at $6°C$ or a freezer at $-10°C$. The amount of powder incorporated is 50–75% more than the normal, offsetting the possible deleterious effects of incorporating water into the mix from the condensed moisture. Compressive and tensile strengths are not significantly different from normal mixes [11].

Setting time can be extended by a process known as "*slaking the fluid*", in which a small quantity of powder is added to the liquid about a minute before the main mixing procedure is started [12]. Setting time is strongly influenced by small variations in spatulation time, temperature, powder: liquid (P:L) ratio & water content of the liquid component.

Despite the low initial pH (1–2), Brannstrom and Nyborg [13] found no irritating effect on the pulp per se and, in practice, this potential irritant effect does not seem to be significant. Use of resin-based sealer and other pulp protection agents such as calcium hydroxide or potassium oxalate is not recommended over the preparation because of marked reduction in retention [14].

This cement is routinely recommended for cementation of prefabricated and cast posts, crowns, FPD's, metal inlays and onlays.

Advantages:

- Good compressive strength (if correctly proportioned) [5]

- Adequate film thickness (<25 μm)
- Reasonable working time
- Can be used in regions of high masticatory stress or long span prosthesis [15].

Disadvantages:

- Low tensile strength
- No chemical bonding
- Solubility in oral fluids

Modified Zinc Phosphate Cements: Copper and silver cements (not widely used), Fluoride cements

Historically, copper-containing cements consisted of zinc phosphate cement to which copper (2–97%) was added in the powder [16]. Pure copper phosphate cement was also used but it discolored teeth and proved to be toxic. In the past, dentists have discovered old, ill fitting and worn-out gold swaged crowns with the red cement still present and an absence of recurrent decay [17]. Cements containing low concentrations of copper were shown to be just as germicidal as those with higher concentrations [16]. This fact was not fully explainable until around 2000 when the biofilm research entered dentistry [18]. However, this cement was not much used due to its high acidity, high solubility and low strength [19].

Main indications of this cement were, as a filling material in deciduous teeth where it was not possible to remove all caries and in cementation of cast silver cap splints-in facial fractures [20].

Silver cements contained small percentage of silver phosphate. In fluoride cements, stannous fluoride (1–3%) was added to provide anticariogenic properties to zinc phosphate. However, these cements had low strength and were highly soluble due to dissolution.

Zinc Silicophosphate Cement

This cement was introduced in 1878 [21]. Powder is a combination of zinc oxide and silicate glass (contains 12–25% fluoride) and liquid is concentrated phosphoric acid.

Advantage:

- Addition of silicate glass contributes to translucency, improved strength, fluoride release, low solubility.

Disadvantage:

- High initial pH than zinc phosphate cements, so not biocompatible
- High film thickness(88 μm) [22] due to short working time and coarse grain size

Zinc-Oxide Eugenol Cement

Zinc oxide eugenol cement was developed by Dr. J. Foster Flagg in 1875 [23]. This cement was developed from zinc oxychloride cement by substitution of the liquid with, first creosote, then eugenol. The first proprietary ZOE product was "pulpol", introduced by Wessler in 1894 [24]. Various additives have been combined with zinc oxide eugenol cement to improve its strength and reduce solubility, example, silica, alumina, rosin, dicalcium phosphate, polystyrene, polymethylmethacrylate, and ortho-ethoxy-benzoic acid (EBA) [25–29].

Improvement in strength resulted particularly from addition of polymethylmethacrylate (20–40%) to powder and EBA to liquid. Addition of heat-treated fused quartz to the powder also improved the dimensional stability and strength of EBA cements [30]. However, studies have demonstrated that deterioration and breakdown occurs even with the modified materials [31], so their use is confined primarily in situations in which tooth sensitivity is a problem and as short term luting agents for provisional acrylic crowns and fixed partial dentures.

Some significant modifications of this cement are:

1. Use of vanillic acid (4-hydroxy-3-methoxybenzoic acid) esters [32, 33] in which liquid is composed of 12% n-hexyl vanillate EBA with powder containing zinc oxide, alumina and hydrogenated rosin.
   Replacement of eugenol by vanillate resulted in odourless cement with high strength, low solubility and no inhibition of vinyl polymerization. Adhesion to non-noble metals and polymers is good but minimal to enamel and dentin.

2. Addition cured silicone based ZO cement with silane agent (non-eugenol cement)
   It is firm yet elastic temporary cement, insoluble in oral fluids, which cleans up easily by peeling off. It is available commercially in an automix syringe kit (Prime-Dent).

3. Eugenol free cement with calcium hydroxide
   It is bacteriostatic and supports formation of secondary dentin. It is available as quickmix syringe/cartridge/tubes.

Main problem with the eugenol containing cements is that the residual free eugenol due to the phenolic hydrogen acts as a free radical scavenger and interferes with the proper polymerization of resin composites affecting their microhardness and color stability. It is recommended that non-eugenol formulations should be used as provisional luting cements when resin-based luting agents are used for permanent cementation.

Zinc Polycarboxylate Cement

This cement was developed by Dr. Dennis Smith, a Manchester dentist in 1968 [34] as a basic set of two liquids and one powder. One liquid was used for luting purpose, while the other for lining purpose. He replaced phosphoric acid with a new polymeric acid, polyacrylic acid and it was the first chemically adhesive cement.

The cement sets by an acid–base reaction when zinc oxide powder is mixed with viscous (because it is partially polymerized) solution of high molecular weight polyacrylic acid. The powder contains 4% stannous fluoride but it does not impart any anticariogenic property because fluoride released is only 10–15% of that released by the glass ionomer cement. However, it acts as a strengthening agent.

The adhesive bond is primarily to enamel although a weaker bond to dentin also forms as a result of chelation reaction between the carboxyl groups of the cement and calcium in the tooth structure; hence, the more mineralised the tooth structure, the stronger the bond. This cement is hydrophilic so is capable of wetting dentinal surfaces [19, 34, 35]. It forms weak bond with gold due to highly inert nature of gold alloys usually resulting in an adhesive failure at the interface. It forms no perceptible bond with porcelain. They will, however, bond with the non-precious alloys, probably related to the presence of oxide layer. So, failure if it occurs is cohesive rather than adhesive.

Anhydrous water-mixable polycarboxylate cements are also available commercially with freeze-dried acid incorporated into the powder for reliable mixing, setting and handling of the cement (Tylok Plus, Poly F Plus, Aqualat-Promedica).

Freshly mixed cement has honey-like consistency with the property of being pseudoplastic and shows shear-thinning behaviour. Therefore, though the mixed cement appears too thick, it flows adequately under pressure to a film thickness of 25–35 μm. This property is not appreciated by the dentist who make an error of reducing the P:L ratio to make thinner mixes, thinking that the cement will flow well; however this results in reduced strength and increased solubility [5, 36]. During setting, the cement passes through a rubbery stage and should remain undisturbed to prevent it from being pulled away from the margins.

Polycarboxylate cement exhibits significantly greater plastic deformation than zinc phosphate (modulus of elasticity being one-third that of zinc phosphate) thus, it is not well suited for use in regions of high masticatory stress or in cementation of long-span prosthesis [37].

It is recommended for vital or sensitive teeth with preparations close to the pulp and for cementing single units or short span bridges in areas of low stress.

Advantages:

- Chemical bonding
- Biocompatibility with the dental pulp due to:

  - Rapid rise in pH after mixing
  - Polyacrylic acid being weaker than phosphoric acid
  - Lack of tubular penetration from large and poorly dissociated polyacrylic acid molecules [15, 38],

- Favourable tensile strength(8–12 MPa) [3]
- Adequate resistance to water dissolution

Disadvantages:

- Not resistant to acid dissolution
- Deforms under loading
- Manipulation critical
- Early rapid rise in film thickness that may interfere with proper seating of a casting

Glass-Ionomer Cements (Glass-Polyalkenoate Cements)

In 1969, a new translucent cement was developed by Wilson and Kent [39] based on acid–base reaction between aluminosilicate glass powder and an aqueous solution of polymers and copolymers of acrylic acid, including ita-conic,maleic, and tricarboxylic acid. This cement was given the genetic name Glass-ionomer cement (GIC) and the trivial name was ASPA (Aluminosilicate polyacrylate) [40].

Glass-ionomer cement has been defined by McLean, Nicholson and Wilson as the "cement that consists of a basic glass and an acidic polymer which sets by an acid–base reaction between these components" [41]. The word 'Ionomer' was coined by the Dupont company to describe its range of polymers containing a small proportion of ionized or ionizable groups, generally of the order of 5–10% [42].

This cement possesses advantages of both silicate cement (translucency and fluoride release) and polycar-boxylate cement (kindness to pulp and chemical adhesion to tooth structure) [43]. Fluoride content of the powder ranges from 10 to 23%, so it has potential anticariogenic property.

Water-settable GIC's have also become available in an effort to increase the working time of the cement. The acids in the liquid are freeze-dried and incorporated in the powder, whereas water or water with tartaric acid consti-tutes the liquid. So, when powder and water are mixed, the acid powder dissolves to reconstitute the liquid acid, which is followed by an acid–base reaction. These formulations lengthen shelf life by preventing gelation [15]. Tartaric acid provides flow and increases the working time [44].

Chief concern with this cement is its sensitivity to early moisture contamination and desiccation which compro-mises the integrity of the material [15]. Water absorption during the initial setting stage leads to deterioration of the cement, loss of translucency and significantly decreases the ultimate hardness of glass-ionomer and zinc phosphate cements [45–47]. Extended protection of the crown margin after bulk removal of the cement with petroleum jelly/varnish is suggested to prevent adverse effect of water upon cement maturation, although it is difficult when the margin is subgingival [48].

Simultaneously, when a freshly mixed cement is exposed to ambient air without any protective covering, the surface will craze and crack as a result of desiccation, leading to cohesive failure from microcrack formation [15, 49]. When the excess cement extruded around the margins has become doughy, covering it with petroleum prevents it from dehydrating [50]. Avoid over desiccation as it increases the incidence of post-operative sensitivity.

GIC does not mature completely until 24–72 h after placement (initial loading of the cemented restoration should be avoided), but when fully set shows better resistance to dissolution [51]. It has been suggested that small amounts of cement must be placed in the crown to prevent the build-up of hydrostatic pressure due to excess cement [52].

Advantages:

- Chemical bonding [44, 53],
- Sustained fluoride release and ability to absorb fluoride from the oral environment (fluoride recharge) makes it the cement of choice in patients with high caries rate.
- Coefficient of thermal expansion similar to tooth
- Translucent, can be used with porcelain crowns
- Adequate resistance to acid dissolution
- Low film thickness and maintains constant viscosity for a short time after mixing, so better seating of restora-tions [54, 55],

Disadvantages:

- Initial slow setting and sensitivity to early moisture contamination and desiccation
- Modulus of elasticity lower than zinc phosphate, so potential of elastic deformation in areas of high masticatory stress [15].
- Initial low setting pH was assumed to be associated with post cementation sensitivity [56]. However, a randomized double blind trial of GIC versus zinc phosphate cement reported no significant difference in the postoperative sensitivity [57]. Dentin desiccation, thin cement mix together with an excessive hydraulic force, and micro leakage may sometimes be responsible for the sensitivity [58].
- Insufficient wear-resistance

Resin-Modified Glass-Ionomer Cements

This cement was introduced in 1990s with an objective to combine some of the desirable properties of glass-ionomer cements (fluoride release and chemical adhesion) with high strength and low solubility of resins [59].

Polymerizable functional groups were added to the conventional glass-ionomer cements to achieve rapid curing activated by light/chemical while still allowing acid–base reaction to take its course along with the polymerization. Wear resistance was also improved [15].

Antonucci et al. originally used the term resin-modified glass-ionomer as the trivial name and resin-modified glass-polyalkenoate as the systematic name [60].

It is available as powder/liquid, preproportioned encapsulated form or as a two paste system (Fujicem, GC America, IL).

Powder—consists of an ion-leachable glass and initiators for chemical/light-curing

Liquid—contains four main ingredients

- A methacrylate resin (bis-GMA) which enables polymerization reaction.
- A polyacid which reacts with the ion-leachable glass to allow acid–base reaction.
- Hydroxy-ethyl methacrylate (HEMA), a hydrophilic methacrylate which enables both the resin and acid components to coexist in an aqueous solution; HEMA also takes part in the polymerization reaction.
- Water, to allow ionization of the acid component so that acid–base reaction can occur.
- Other components include polymerization activators and stabilizers [20].

Setting reaction of this cement is a dual mechanism. Acid–base reaction is induced after the powder and the liquid are mixed, forming a polyacrylate salt. Polymerization (*the primary setting reaction*) is initiated as soon as sufficient free radicals become available. Slow acid–base reaction is responsible for the final maturation and strength of the cement while polymerization reaction provides the initial set [20].

Chemically-activated polymerization of the resin-modified glass-ionomer cement is referred to as "Dark Cure" [20].

These cements can be chemical-cured, light-cured, dual-cured (chemical-cured/light-cured + acid–base reaction) or tri-cured (chemical-cured + light-cured + acid–base reaction).

Advantages:

- Compressive strength, diametral tensile strength, and flexural strength are dramatically improved in comparison

to zinc phosphate, polycarboxylate, and glass-ionomer cements but is less than resin composites [61].

- Less sensitive to early moisture contamination and desiccation during setting and less soluble than the glass-ionomer cement because of covalent crosslinking of the polyacrylate salt from free-radical polymerization [58, 62],
- Easy manipulation and use
- Adequately low film thickness [63, 64],
- Fluoride release similar to conventional GIC [65]
- Polymerization is not significantly affected by the eugenol-containing provisional materials, as long as the provisional cement is completely removed with thorough prophylaxis [66].
- Minimal post-operative sensitivity.
- High bond strength to moist dentin (14 MPa)

Disadvantages:

- Dehydration shrinkage due to the glass-ionomer component has been observed as late as 3 months after maturity together with the polymerization shrinkage [67]. This may create stress fractures at exposed cement tooth-restoration interface [68].
- HEMA is responsible for increased water sorption, subsequent plasticity and *hygroscopic expansion*. Initial water sorption may compensate for the polymerization shrinkage stresses, but continual water sorption leads to substantial dimensional change [69, 70], contraindicating their use for the cementation of all-ceramic crowns and posts in non-vital teeth as expansion induced fracture occurs [35, 71]. However, two pilot studies carried out in 2003 concluded that expansion alone was not responsible for the fracture of all-ceramic crowns [72].
- Although rare, may elicit an allergic response due to free monomer. Careful handling is therefore recommended during mixing [73, 74],
- Cement bulk is very hard and difficult to remove.

Recommended for luting metal or porcelain-fused-to-metal crowns and FPD's to tooth, amalgam, resin composite, or glass ionomer core buildups [35].

Anhydrous Luting Cements

Poly-Acid Modified Composites (Compomer)

Introduced in the European market as a restorative material in 1993[75], this cement also lies between the glass-ionomer and the resin composites but with the predominant characteristics of microfilled resin composites. The term

'Compomer' is derived from composite and glass ionomer, having fluoride releasing capability of conventional GIC and durability of composites [15].

Restorative compomers are available as one-component, light-curable material which consists of silicate glass particles, sodium fluoride and poly-acid modified monomer but no water. Initially, setting occurs due to photopolymerization which is followed by an acid–base reaction when the set material absorbs water. This eventually results in fluoride release, although limited [15, 76]. Because of the absence of water in restorative compomers, they are not self-adhesive like conventional GIC and resin-modified GIC, thereby requiring separate dentin bonding agents [76].

Compomers for luting purposes are available as a two component system, either powder/liquid or as two pastes

Powder: strontium aluminofluorosilicate, metallic oxides, chemical-activated and/or light-activated initiators.

Liquid: polymerizable methacrylate/carboxylic acid monomers, multifunctional acrylate monomers, water.

Because of the presence of water, these materials are self-adhesive and an acid–base reaction starts at the time of mixing [15]. Tensile strength, flexural strength and wear resistance of compomer is superior to the conventional glass-ionomer cement but less effective than resin composites [75].

They are recommended *primarily* for cementing prosthesis with a metallic substrate. Like resin-modified GIC's, compomers also absorb water and undergo hygroscopic expansion which may fracture all-ceramic crowns (Tables 1, 2, 3).

Resin Cements

Based on Methyl Methacrylate

Methyl methacrylate based resin cements were developed in 1950s but had poor physical properties, that is, high polymerization shrinkage and increased microleakage because of low filler content. They also had high residual amine levels which contributed to significant color shift after polymerization [77].

Based on Aromatic Dimethacrylates

Aromatic Dimethacrylate-Based Resin Cement In 1963, Dr. Rafael Bowen developed the first multifunctional methacrylate used in dentistry, called bis-GMA or Bowen's resin. The bis-GMA {2,2-bis[4-(2 hydroxy-methacryloxypropoxy) phenyl]propane}resin can be described as an aromatic ester of dimethacrylate, synthesized from an epoxy resin and methyl methacrylate [78]. Bis-GMA is extremely viscous and a low viscosity dimethacrylate, such as triethylene glycol dimethacrylate (TEGDMA) is blended with it to reduce the viscosity.

Table 1 Properties of luting cements

Cements	Film thickness (μm)	Solubility (wt%) in water at 24 h	Setting time (min)	Working time (min) at room temp.	Strength (MPa)		Elastic modulus (GPa)	pH	
					Compressive	Tensile		2 min	24 h
Zinc phosphate	25	0.2% max.	5–14	3–6 4–11 (frozen slab)	80–110	5–7	13	2.14	6
Copper phosphate	20	0.2–6.0			80–85			Highly acidic	
Silicophosphate	88	1% after 7 days	5–7	3–4	140–170	7–9		1.43	5.5
Zinc-oxide eugenol	25–35		2–10	Long, moisture needed for setting	2–14	0.3–2	0.22	Mild	7
Polymer-reinforced	25	0.08–0.2	7–9		35–55	5–8	2–3	Mild	
EBA-alumina reinforced	25–40	0.2	7–9		55–70	3–6	3–6	Mild	
Zinc polycarboxylate	25–30	0.06	6–9	2.5–3.5	55–90	8–12	4–5	3.42	5.94
Glass-ionomer	25	0.4–1.5 Less in organic acid (0.5 mm/h)	6–9	2–3.5	93–226	6–7	8–11	2.33	5.68
Resin-modified glass ionomer	25	0.07–0.4	5.5–6	2–4	85–126	13–24	2.5–7.8		
Composite resin	>25	0.13	4–5		180–265	34–37	4.4–6.5		
Adhesive resin	>25				52–224	37–41	1.2–10.7		

Source: Refs. [19, 84, 85]

Table 2 Choice of luting agents in different clinical situations

Clinical condition	Luting agent type preferred	Luting agent to be avoided
Hypersensitive vital teeth	Zinc polycarboxylate [19], Reinforced zinc-oxide eugenol (biocompatibility with pulp)	Zinc phosphate, Glass-ionomer, chemically cured composite resin
Hypersensitive teeth with average retention form	Zinc polycarboxylate [19] (only crowns and short-span bridges)	Zinc phosphate, Glass-ionomer, chemically cured composite resin
Hypersensitive teeth with more than average/excellent retention and resistance form and minimal dentin layer	Reinforced zinc-oxide eugenol [19]	Zinc phosphate, Glass-ionomer, chemically cured composite resin
Long-span fixed partial dentures in areas of high masticatory stresses when abutment teeth are not sensitive	Zinc phosphate (favourable modulus of elasticity) [15], Glass-ionomer, Resin-modified glass-ionomer (RMGI)	Zinc polycarboxylate [37]
Non-vital teeth with average to excellent retention form	Zinc phosphate [19]	
Non-vital teeth with average/less than average retention form (might have fractured cusp/wall)	Glass-ionomer, RMGI, Adhesive resin	
Mutilated teeth with post and core restorations	Adhesive resin	
Patients where complete isolation is difficult/in areas difficult to isolate (posterior mandibular region)	Zinc polycarboxylate, RMGI	Zinc phosphate, Glass-ionomer
Patients with reduced salivation (xerostomia)	Glass-ionomer, RMGI (fluoride release)	
High caries index	Glass-ionomer, RMGI	
Children teeth with large pulp chambers	Zinc polycarboxylate [19]	Zinc phosphate, Glass-ionomer
Teeth prepared to receive partial veneer crown or retainer	Adhesive resin, RMGI (less solubility and microleakage)	Glass-ionomer (being translucent makes enamel adjacent to metal castings appear slightly gray) [50], Zinc phosphate [7]

Source: Refs. [19, 15, 37, 50, 7]

Resin cements used today are composed of resin matrix of bis-GMA or urethane dimethacrylate and filler of fine inorganic particles (20–80%) to ensure thin film thickness.

They are available as powder/liquid, encapsulated, or paste/paste systems and are classified into three types based on the method of polymerization as chemical-cured, light-cured and dual-cured.

Advantages:

- Superior compressive and tensile strengths (20–50 MPa) with low solubility
- Micromechanical bonding to prepared enamel, dentin, alloys and ceramic surfaces
- Available in wide range of shades and translucencies [19].

Disadvantages:

- Meticulous and critical manipulation technique
- High film thickness
- Marginal leakage due to polymerization shrinkage
- Severe pulpal reactions when applied to cut vital dentin
- Offers no fluoride release or uptake
- Low modulus of elasticity, so cannot support long span prosthesis.

- Difficulty in removing hardened excess resin cement from inaccessible areas, precluding its use when subgingival margins are placed.
- Use of eugenol-based provisional luting agents inhibited the complete polymerization of the resin cement [19, 36, 79, 80].
- Due to low early bond strength and a maturation period of 24 h, patients must be advised to avoid loading restorations luted with chemically-cured resin cements in the first hour after cementation. Excess cement must be removed before it sets to avoid damaging the weak early bond [81].

Adhesive Resin Cements

In order to improve the adhesive bond of conventional bis-GMA resin cements, adhesive monomers have been added that will enable chemical bonding to both the tooth structure and the suitably prepared metal surfaces. These include a bifunctional phosphate monomer, 10-methacryloyloxydecyl dihydrogen phosphate (MDP) developed in 1981 and a carboxylic monomer, 4-methacryloxyethyl trimellitic anhydride (4-META). Resin bonding is facilitated

Table 3 Luting agents for different fixed prosthodontic restorations

Restoration	Reinforced zinc-oxide eugenol	Zinc phosphate	Zinc polycarboxylate	Glass-ionomer	Resin-modified glass-ionomer	Adhesive resin
Cast metal crowns, FPD's, inlays, onlays			Only crowns and short-span FPD's			
Metal-ceramic crowns and FPD's			-do-			
Aluminous all-ceramic crowns & other reinforced core all-ceramic systems						
Pressable glass ceramic crowns						
Ceramic veneers						
Resin-retained FPD's						
Ceramic inlays and onlays						
Cast post & core						
Partial veneer crowns/ and retainers for FPD's						
Implant-supported crowns						
Multiple-unit implant-supported prosthesis						

■ cements indicated, ■ cements not indicated, ■ cement most preferred, ■ cement not preferred

Sources: Refs. [36, 86]

by the affinity of these monomers for the metal oxides present on the base metal alloys without the need for acid-etching [12]. However, these resins have low affinity for precious metal alloys due to the lack of surface oxide coating and low chemical reactivity requiring need for some surface modification to achieve chemical bonding (tin-plating, silicoating or tribochemical coating or use of new metal primers) [12].

Panavia was the first commercial product that contained MDP in the liquid. Available as powder/liquid, in a single shade, bond strength to etched base metals greatly exceeded that of the tooth [82]. In 1993, Panavia 21 (Kuraray Co.,Osaka, Japan) was introduced, a paste/paste formulation which included an enamel/dentin(ED)primer containing HEMA, *N*-methacryloyl 5-aminosalicylic acid(5-NMSA) and MDP. Base metal retainers were air-abraded, ultrasonically cleaned but not etched as air and water may get entrapped in the mechanical irregularities inhibiting polymerization of the cement. Bonding to uncut enamel required etching of the tooth. A polyethylene glycol gel is provided to isolate the exposed cement margin from oxygen ensuring complete polymerization [58].

The current product, Panavia F- is self-etching, self-adhesive, dual-cure, fluoride releasing cement that can be cured with any halogen, plasma ARC or LED light. MDP provides strongest bond to metal-oxide ceramic systems.

Commercially available C&B Superbond (Parkell, Farmingdale, New York) is a 4-META based adhesive resin cement with an additional polymerization initiator, tributyl boron added to aid in chemical bonding to the dentin [83].

Summary

Dental luting agents seal the interface between the restoration and the prepared tooth. This article tries to provide an insight into the various luting agents available for the clinician from the traditional water-based cements to the newer adhesive resins. No single luting agent is ideal in all the clinical situations. The article discusses the properties, advantages and shortcomings of various cements intending to help the clinician in selecting an appropriate luting agent suitable in a particular clinical condition.

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