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BONDING MECHANISM OF DEFINITIVE LUTING CEMENTS- A REVIEW

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ABSTRACT
Numerous factors determine the long-term clinical success of fixed prosthodontic restorations, one of which is the choice of luting agent. As no single luting agent can meet all of the necessary requirements, a wide range of luting agents, from traditional water-based to contemporary adhesive resin cements, is currently available. This article attempts to review various definitive luting agents, their bonding mechanisms, properties, and clinical implications in order to assist clinicians in selecting the most appropriate luting agent for a specific clinical situation.

KEYWORDS: Resin Cements, Adhesives, fixed dental prosthesis.

INTRODUCTION
Since centuries the primary objective of all restorations is to create a bond between two dissimilar surfaces i.e., mineralized tooth structures and the restorative materials, at the same time it also resists dislodgement of restoration during function. The long-term success of a restoration dependent on the proper selection and manipulation of dental cements.[1]

A luting agent is a type of dental cement used to hold indirect restorations in place on prepared teeth. Dental luting agents use some form of surface attachment to bond the restoration and prepared tooth together, which can be mechanical, micro-mechanical, chemical, or a combination of these.[2] Metal, porcelain fused to metal, low- and high-strength ceramics, full or partial coverage, all require proper cement selection based on knowledge of physical, biological, and other characteristics of both restorative materials and luting agents.[3] Zinc phosphate cement, zinc polycarboxylate cement, conventional glass-ionomer cement, and resin-modified glass-ionomer cement are the four types of luting cements currently in use. Resin cement is the only type of bonding cement available, and it comes in a variety of subtypes. Dental cements have improved in strength and durability as a result of advances in material science. The choice of dental cements has become increasingly complicated as new materials become available and application procedures are being changed accordingly.[4] Therefore, the purpose of this review is to help the clinicians understand the specifics of the dental cements being used as well as to boost the dentist's ability to make intelligent cementation choices and application.

Ideal requirements of luting agents
The biological, chemical, rheological, physical, mechanical, thermal, and aesthetic requirements of a luting material can be classified as a guideline in the selection of a suitable luting agent in clinical practice.

As mentioned in the table below[5-8]

Properties	Ideal requirements
Biological	Nontoxic and non-irritant Noncariogenic Should not cause any systemic reaction Should be cariostatic thus preventing secondary caries formation
Chemical	Should be chemically inert Solubility of the cements in oral fluids being taken by the patient should be negligible Should bond chemically to enamel and dentin PH should be neutral
Rheological	Low film thickness to enable the easy flow of luting cements Longer mixing and working time

	Shorter setting time
Mechanical	High compressive strength High tensile strength High modulus of elasticity Exhibit minimum dimensional changes on setting Restoration should take and retain a smooth surface finish Should bond chemically to enamel and dentin
Thermal	Good thermal insulator Coefficient of thermal expansion should be similar to the tooth and artificial prosthesis
Esthetics	Should not alter the color of the tooth and artificial prosthesis
Miscellaneous	Easy to manipulate Inexpensive Longer shelf life

Dental cements are classified as follows

1. Based on chief ingredients (craig)[9]

a) Zinc phosphate
b) Zinc silicophosphate
c) Zinc oxide eugenol
d) Zinc polyacrylate
e) Glass inomer
f) Resin

2. Based on matrix bond type (O'Brien)[10]

a) Phosphate
b) Phenolate
c) Polycarboxylate
d) Resin
e) Resin modified glass ionomer

3. Based on knowledge and experience of us (Donovan)[11]

a) Conventional (zinc phosphate, polycarboxylate, glass ionomers, resin)
b) Contemporary (resin-modified glass ionomers, resins)

4. Based on principal setting reaction (Wilson)[12]

a) Acid – base cement
b) Polymerization cements

Bonding to tooth structure

Buonocore reported in 1955 that acids could change the surface of enamel to make it more receptive to adhesion[13]. In the meantime, he discovered that acrylic could bond to human enamel that had been conditioned with 85 percent phosphoric acid for 30 seconds, based on the common industrial use of phosphoric acid to enhance adhesion of paints and acrylic coatings to metal surfaces. For over 20 years Enamel bonding has been widely and successfully employed in dentistry. However, bonding of resins to dentin is much harder when compared to bonding to enamel. The histologic structure of dentin is more complex than that of enamel. Dentin is only 45 percent inorganic, while enamel is 92 percent inorganic hydroxyapatite by volume. Dentinal hydroxyapatite crystals are randomly arranged in an organic matrix which consists primarily of collagen, and not regularly arranged as they're in enamel.[14] From the pulp to the dentinoenamel junction, it contains numerous fluid-filled channels or tubules (DEJ). The formation of a "smear layer" complicates the inherent complexity of the dentin morphology when materials are bonded to dentin exposed during tooth preparation.[15] The smear layer consists of debris that burnished against the surface of dentin during instrumentation. On the basis of the cutting instrument used, the smear layer is usually just 0.5-5.0 mm thick, but it occludes the orifices of the dentinal tubules. As the smear layer acts as a "diffusion barrier" which decreases dentinal permeability and also prevent resin from reaching the underlying dentin substrate.[16] Total-etch and self-etch are the two main strategies for bonding resin to dentin currently available. In addition, there are four different types of dentin adhesives: (1) 3-step total-etch; (2) total-etch with combined primer/adhesive ("one-bottle"); (3) self-etch primers with a separate bonding agent; and (4) self-etch, or "all-in-one," adhesives.

Bonding to prosthesis

Resin-Metal bonding

The attachment of a resin matrix to a metal framework in prosthodontics can be challenging. The main issues are adhesion strength and the amount of space available for restorative materials. Microleakage, discoloration, and breakage can all be caused by a weak bond between the resin and the metal. Until recently, the resin matrix's attachment to a metal framework was primarily maintained through mechanical retention. Latticework, mesh, beads, and various posts can all be used to achieve mechanical retention. Alternative attachment mechanisms, such as micromechanical and chemical attachment systems, are now available. Sandblasting, electrochemical etching, and chemical etching can all be used to achieve micromechanical attachment.[17] Adhesive cements, porous metal coatings, tribochemical coating, Silicoating,[18] and the Kevloc system, on the other hand, can be used to achieve chemical attachment. These alternative attachment systems can be used in conjunction with or instead of traditional macro-mechanical retention systems. The "ideal" attachment system should result in a strong and consistent bond between the resin and the metal. The increased bond strength between the resin and metal, the decrease in microleakage at the resin-metal interface, the reduction in metal impingement on the space needed to place the resin and teeth, and the improvement in aesthetics due to opaquing and increased space are all potential advantages of alternative resin-metal attachment systems.

Bonding to ceramics

Micromechanical and/or chemical bonding mechanisms can be used to adhere adhesive resin cement to ceramic. Although the effects of different surface treatments on bonding are strongly dependent on the type and microstructure of the ceramic surface to which it bond, there are several methods to condition ceramic surfaces to enhance bonding to resin-luting cements.[19] Grinding, abrasion with a diamond rotary instrument, airborne-particle abrasion with aluminum oxide, and etching with different types of acids like hydrofluoric acid and phosphoric acid can all improve mechanical bonding to ceramic surfaces. Over-etching with high HF concentrations or for long periods of time may result in a lower bond strength,[20] which would affect the resin–ceramic bond strength.[21] Excessive sandblasting to improve bond strength, on the other hand, can cause chipping and negatively affect the fit of all-ceramic restorations without improving bond strength,[22,23] Chemical as well as micromechanical bonding should be attempted for an effective and long-lasting resin ceramic bond. The use of silane coupling agents is the most common and effective method of forming a chemical resin–ceramic bond. Silane coupling agents are bifunctional molecules that improve the wettability of the ceramic surface while also forming a covalent bond with the ceramic and resin cement.[24]

Bonding to pre-processed composite restoration

The ability of hydrofluoric acid (HF) to alter the pre-processed composite surface is generally influenced by the nature of the reinforcing filler, similar to all-ceramic restorations. Because it has a roughening effect by preferentially attacking the SiO2 glass filler, the HF has been shown to improve bond strength to microfilled composite inlays.[25] An additional silane treatment of the surface would improve bond strength even more, because the surface filler particles are primarily potential silanization sites, and the well-cured resin matrix has few remaining double C=C bonds to bond with. HF, on the other hand, has an aggressive etching effect on glass-filled hybrid composites, causing partial resin matrix degradation and total dissolution of exposed glass filler particles, as well as a decrease in resin bond strength.[26,27] It appears that roughening the bonded surface followed by the application of an intermediate bonding agent is the most effective method for improving bonding to pre-processed composites.[28,29]

Definitive cement

Zinc phosphate

Introduced in 1878, the oldest of the luting agents having a clinically successful track record of over more than 100 years It is available in the form of powder and liquid system/encapsulate and sets by an acid–base reaction. The main component of powder is zinc oxide with 2–10% of magnesium oxide. Liquid is basically an aqueous solution of phosphoric acid (45–64%) buffered by adding small quantities of zinc oxide/aluminum oxide. These compounds contain phosphates which stabilize the pH of the acid and reduce its reactivity. Unsuccessful attempts of combining this cement with fluoride and eugenol had been done to improve the biological properties.[30] Taper, length and surface area of the tooth preparation are a critical in its success as it retains the prosthesis purely by mechanical means. By using the Frozen Slab technique, working time of the cement can be prolonged (4–11 min) and shortened setting time for simultaneous cementation of multiple restorations Having a low initial pH (1–2), Brannstrom and Nyborg found no irritating effect on the pulp. This cement is routinely recommended for cementation of cast posts, crowns, FPD's, metal inlays and onlays.[31]

Glass-Ionomer cements

Introduced in 1969, a new cement was developed by Wilson and Kent[32] based on acid–base reaction between aluminosilicate glass powder and an aqueous solution of polymers and copolymers of acrylic acid, including itaconic, maleic, and tricarboxylic acid. This cement was given the genetic name Glass-ionomer cement (GIC) and the trivial name was ASPA (Aluminosilicate polyacrylate. It possesses advantages of both silicate cement (translucency and fluoride release) and polycarboxylate cement (kindness to pulp and chemical adhesion to tooth structure). In the powder the fluoride content ranges from 10 to 23%, which has anticariogenic property. Its sensitivity to early moisture contamination and desiccation which compromises the integrity of the material. Until the first 24 to 72 hour of placement the GIC doesn't not mature but when it set fully, it has better resistance to dissolution[33],the cement chemically bonds to prosthesis.

Resin-Modified Glass-Ionomer cements

Introduced in 1990 to combine the properties of glass-ionomer cements (fluoride release and chemical adhesion) with high strength and low solubility of resins. It is available in the form of powder/liquid, pre-proportioned encapsulate or as a two-paste system (Fujicem, GC America, IL). Compressive strength, diametral tensile strength, and flexural strength are improved in comparison to zinc phosphate, polycarboxylate, and glass-ionomer cements but is less than resin composites.[34]

When compared to GIC, it is less sensitive to early moisture contamination and desiccation during setting and also less soluble because of covalent crosslinking of the polyacrylate salt to from free-radical polymerization. Recommended for luting metal or porcelain-fused-to metal crowns and FPD's to tooth, amalgam, resin composite, or glass ionomer core buildups.[35]

Resin cements

Introduced in the mid-1970s, it was an alternative to acid-base reaction cements. The cement micromechanically bonds to prepared enamel, dentin, alloy and ceramic surfaces. Because of the low filler content, methyl methacrylate-based resin cements had poor physical properties, such as high polymerization shrinkage and increased microleakage. They also had high residual amine levels which contributed to significant color shift after polymerization.[36] Resin Cement Based on Aromatic Dimethacrylate Dr. Rafael Bowen invented bis-GMA, or Bowen's resin, the first multifunctional methacrylate used in dentistry in 1963. The bis-GMA {2,2-bis [4-(2 hydroxy methacryloxypropoxy) phenyl] propane} resin is as an aromatic ester of dimethacrylate, synthesized from an epoxy resin and methyl methacrylate.[37] To reduce the viscosity of Bis-GMA, a low viscosity dimethacrylate, such as triethylene glycol dimethacrylate (TEGDMA), is blended with it. Nowadays, resin cements used are composed of resin matrix of bis-GMA or urethane dimethacrylate and filler of fine inorganic particles (20–80%) to ensure thin film thickness. There are three types based on the method of polymerization as chemical-cured, light-cured and dual-cured, and are also available as powder/liquid, encapsulated, or paste/paste systems.

Adhesive resin cements

Adhesive monomers have been added to improve the adhesive bond of traditional bis-GMA resin cements, allowing chemical bonding to both the tooth structure and suitably prepared metal surfaces. 10-methacryloyloxydecyl dihydrogen phosphate (MDP), a bifunctional phosphate monomer, was developed in 1981, as was 4methacryloxyethyl trimellitic anhydride, a carboxylic monomer (4-META). The 10-MDP monomer has the potential to interact with hydroxyapatite; the bond formed by 10-MDP-containing adhesives appears to be very stable, as evidenced by the calcium salts' slow dissolution in water. Etching capacities are dependent on the substrate on which they are applied, the monomer incorporated, and the bonding potential of other commonly used functional monomers (4-META, phenyl-P). The affinity of these monomers for the metal oxides present on the base metal alloys facilitates resin bonding without the need for acid etching. Due to the lack of surface oxide coating and low chemical reactivity, these resins have a low affinity for precious metal alloys, necessitating some surface modification to achieve chemical bonding (tin-plating, silicoating or tribochemical coating or use of new metal primers).[38]

Panavia was the first commercially available liquid that contained MDP. Bond strength to etched base metals greatly exceeded that of the tooth[39] and was available as a powder/liquid in a single shade. Panavia 21 (Kuraray Co., Osaka, Japan), a paste/paste formulation containing HEMA, N-methacryloyl 5-aminosalicylic acid(5-NMSA), and MDP, was introduced in 1993. Because air and water could become trapped in the mechanical irregularities, inhibiting cement polymerization, the base metal retainers were air-abraded, ultrasonically cleaned, but not etched. Etching the tooth was required for bonding to uncut enamel. To ensure complete polymerization, a polyethylene glycol gel is used to isolate the exposed cement margin from oxygen. Panavia F- is a fluoride-releasing cement that is self-etching, self-adhesive, dual-cure, and can be cured with any halogen, plasma ARC, or LED light. To metal-oxide ceramic systems, MDP provides the strongest bond. C&B Superbond (Parkell, Farmingdale, New York) is a 4-META based adhesive resin cement with the addition of tributyl boron as a polymerization initiator to aid in chemical bonding to the dentin.[40]

CONCLUSION

Even the most experienced clinicians may find choosing a luting agent to be difficult. Restorations of metal, porcelain fused to metal, low- and high-strength ceramics, full or partial coverage, necessitate prudence, and proper selection should be based on knowledge of physical and biological properties, as well as other attributes of both restorative materials and luting agents. Choosing an adhesive system to bond resin-based materials is one of the most difficult challenges in adhesive dentistry today. The advantages and disadvantages of definitive luting cements have been examined, and none of them is perfect. The choice of luting agent for a specific restoration should not be a difficult one. Many factors influence the long-term clinical success of fixed prosthodontic restorations, one of which is the choice of an appropriate luting agent. Because no single luting agent can meet all of the stringent requirements, there is currently a wide range of luting agents available, ranging from traditional water-based to contemporary adhesive resin cements. Adhesive resin systems have completely transformed fixed prosthodontic practice, resulting in an increase in the use of bonded all-ceramic crowns and resin-retained fixed partial dentures. In order to achieve clinical success, the clinician must be aware of the qualities, benefits, and drawbacks of each type of cement.

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