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Dental Cements in Prosthodontics: A Review and Comparative Analysis of Modern Materials

SUMMARY

Dental cements play a crucial role in contemporary dentistry, as they are used in various clinical procedures, including the fixation of fixed prosthetic restorations, fabrication of temporary and permanent restorations, as well as in preventive and restorative therapy. The development of new materials has led to significant improvements in their physicochemical, mechanical, and biological properties, enabling broader and safer clinical application. Today, different types of dental cements are in use, such as zinc phosphate, polycarboxylate, glass ionomer, resin-modified, and resin cements, which differ in their indications and clinical performance. The aim of this review article is to present the contemporary classification of dental cements, their basic properties, mechanisms of adhesion to dental and prosthetic tissues, as well as their advantages and limitations in clinical practice. Special emphasis is placed on the criteria for selecting an appropriate cement depending on the clinical situation, which may contribute to the longevity of restorations and improvement of therapeutic outcomes.

Keywords: dental luting agents; fixed restorations.

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Concept of dental cements

Dental cements represent a heterogeneous group of dental materials used for temporary or permanent cementation of fixed dental restorations onto prepared teeth. Their primary function is to provide a stable bond between hard dental tissues and prosthetic constructions, thereby achieving functional, biological, and aesthetic integrity within the stomatognathic system. Properly performed cementation ensures adequate transmission of occlusal forces, contributes to marginal sealing, and prevents microleakage, thus reducing the risk of secondary caries and periodontal complications[1, 2].

In contemporary dental practice, dental cements are not merely passive materials used for the fixation of restorations, but active components of therapy that significantly influence the long-term prognosis of prosthetic treatment. Their role includes protection of the dental pulp from chemical, thermal, and bacterial stimuli, as well as preservation of the integrity of the interface between the tooth and the restoration. Therefore, dental cements are considered a key factor in the success of fixed prosthetic restorations, regardless of the quality of the restoration itself [3].

The proper selection of a dental cement, as well as its precise and controlled application under clinical conditions, requires detailed knowledge of the material's chemical composition, mechanisms of bonding to dental tissues and restorative materials, as well as its physico-mechanical and biological properties. Special attention should be paid to the interactions between the cement and enamel, dentin, and various types of prosthetic materials, since inadequate compatibility may lead to reduced retention, postoperative hypersensitivity, or premature failure of the therapy.

Given the continuous development of dental materials and the emergence of new adhesive systems, the choice of dental cement must be individualized and adapted to the specific clinical situation, taking into account the preparation design, type of restoration, tooth vitality, and aesthetic requirements. Only such an approach enables optimal clinical outcomes and long-term stability of fixed prosthetic restorations[1, 3, 4].

Composition of dental cements

According to their chemical composition, dental cements can be divided into oil-based, water-based, and resin-based cement systems. This classification is of significant clinical importance, as the chemical composition of a cement directly affects its physico-mechanical properties, biocompatibility, setting reaction, and the mechanism of bonding to dental tissues and prosthetic materials.

The contemporary dental market offers a wide range of temporary and definitive cements, which differ in their chemical components, clinical indications, and the predictability of long-term outcomes[5].

Temporary cements were traditionally manufactured on an oil base, most commonly clove oil and eugenol, which exhibited a sedative effect on the dental pulp. However, although these materials had certain biological advantages, it has been shown that eugenol can negatively affect the polymerization process of resin-based materials as well as the quality of permanent bonding of definitive restorations. For this reason, eugenol-free temporary cements are increasingly used in contemporary clinical practice[6].

Temporary cements are characterized by weaker mechanical and physical properties compared with definitive cements, which requires a greater cement film thickness in order to achieve satisfactory retention of temporary restorations. Their increased solubility and lower strength make them suitable exclusively for short-term use[7].

Before definitive cementation, complete removal of all temporary cement residues from the tooth surface and the internal surface of the restoration is mandatory, as the presence of oily components can seriously compromise the long-term bonding of the restoration. This fact further justifies the use of modern eugenol-free temporary cements[6, 7].

Definitive (permanent) cements are most commonly water-based or resin-based. Water-based cements undergo an acid–base setting reaction, which may temporarily reduce their biocompatibility and cause pulpal irritation, especially in vital teeth. These cements do not bond adhesively to dental tissues but achieve retention exclusively through mechanical means[8].

On the other hand, resin-based cements enable the establishment of an adhesive bond to the tooth surface, achieving micromechanical and chemical adhesion to enamel and dentin. This bonding mechanism provides numerous functional, biological, and aesthetic advantages, including increased retention, reduced microleakage, improved distribution of occlusal forces, and enhanced aesthetic integration of the restoration with the dental tissues[9, 10].

Division of Dental Cements

The classification of dental cements is based on different criteria, including chemical composition, setting mechanism, and clinical application. The general classification of dental cements is presented in Figure 1, which includes the materials most commonly used in contemporary dental practice. Such systematization facilitates a better understanding of their basic characteristics and clinical indications[8].

From a clinical perspective, the classification of dental cements according to the mechanism by which retention is established between tooth structure and the prosthetic restoration is particularly important, as shown in Table 1.

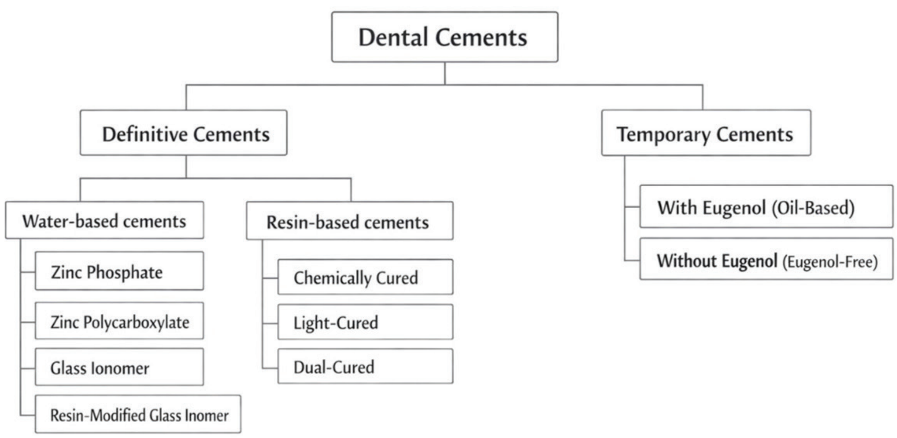

Figure 1. Division of dental cement

Table 1. Overview of dental cements – bonding mechanism, advantages, disadvantages and indications

Type of cement	Bonding mechanism	Main advantages	Disadvantages	Indications
Zinc phosphate	Mechanical retention	High compressive strength, long clinical history, low cost	Low pH, pulpal irritation, high solubility, no adhesion, no fluoride release	Metal and metal–ceramic restorations on non-vital teeth, elderly patients
Zinc polycarboxylate	Chemical adhesion (chelation with Ca^{2+})	Biocompatibility, chemical bonding to enamel and dentin	High viscosity, short working time, lower compressive strength	Metal and metal–ceramic crowns and bridges, vital and non-vital teeth
Glass ionomer cement (GIC)	Chemical adhesion (ionic bonds)	Fluoride release, anticariogenic effect, good adhesion, low thermal expansion	Low initial pH, possible postoperative sensitivity	Metal–ceramic and ceramic crowns and bridges
Resin-modified GIC (RMGIC)	Chemical + resin adhesion	Higher strength, lower solubility, thin film thickness, fluoride release	Expansion due to water absorption, contraindicated for fragile ceramics	Crowns, bridges, inlays, orthodontic appliances, core build-ups
Resin cements	Micromechanical + chemical adhesion (hybrid layer)	Superior mechanical and aesthetic properties, insoluble, high retention	Moisture sensitivity, no anticariogenic effect, technique-sensitive	Ceramic restorations, veneers, inlays, onlays, crowns and bridges
Temporary cements	Weak mechanical retention	Pulp protection, easy removal, biocompatibility	Low stability, short-term use	Temporary cementation of provisional and definitive restorations

Table 2. General characteristics of non-adhesive and adhesive dental cements[12]

Non-adhesive cements	Adhesive cements
Retention is purely mechanical	Micromechanical and chemical retention; adhesive bonding between the restoration and the tooth
Require a long clinical crown with low taper (approximately 6°)	Bond strength depends on several factors (tooth surface, restorative material, and cement)

Based on this criterion, dental cements can be divided into non-adhesive and adhesive cement systems. This classification has a direct impact on the choice of preparation design, the cementation technique, as well as the long-term stability and success of prosthetic treatment[11] (Table 2).

Non-adhesive cements achieve retention exclusively by mechanical means. Their bonding is based on micromechanical interlocking of the cement film between the tooth surface and the internal surface of the restoration. These cements are most commonly based on water-based systems and do not form a true chemical bond with dental tissues. In order to achieve adequate retention, tooth preparation must provide a long clinical crown with a small taper, optimally around 6°, as well as high precision of restoration fabrication, with a marginal gap tolerance of approximately 30–100 µm. The tooth surface must be thoroughly cleaned and dried prior to cementation, as the presence of contaminants may further reduce retention[13].

In contrast to non-adhesive cements, adhesive cements establish an adhesive bond both with hard dental tissues and with restorative materials. Their composition includes anhydrous, silanized non-reactive fillers, which enable chemical and micromechanical adhesion. The bond strength of adhesive cements depends on numerous factors, including tooth surface characteristics, type of restoration, cement composition, and the conditions under which cementation is performed[14, 15].

Adhesive cementation is particularly sensitive to environmental factors, primarily the presence of moisture. The absence of contamination and strict moisture control of the operative field are prerequisites for achieving optimal bonding. The tooth surface must be prepared and treated in accordance with clearly defined protocols, as deviations at any stage may result in reduced bond strength, microleakage, and long-term restoration failure[16].

Properties of Dental Cements

An ideal dental cement should provide long-term protection of hard dental tissues and exhibit high mechanical resistance to tensile, compressive, and fatigue stresses. It should demonstrate high fracture strength, optimal wetting properties (low contact angle), and appropriate viscosity to allow uniform and continuous material flow. The cement film should be of minimal thickness, easy to apply, slightly soluble in the oral environment, and possess adequate optical properties, including translucency and radiopacity. In addition, optimal working and setting times, as well as easy removal of excess material, represent important clinical characteristics[5] (Table 3).

Table 3. Properties of Dental Cements[12]

Dental cement	Film thickness (µm)	Working/ setting time (min)	Compressive/ tensile strength (MPa)	Elastic modulus (GPa) *(dentin = 13.7; enamel = 84–130)*	Pulp irritation	Solubility	Microleakage	Color stability
Zinc phosphate cement	≤ 25	1.5–5 / 5–14	48–133 / 0.65–4.5	19.8	Moderate	High	High	Low
Zinc polycarboxylate cement	< 25	1.75–2.5/ 5–9	57–99 / 1.4–6.3	16.1–19.5	Low	High	High	Low

One of the key properties of dental cements is biocompatibility. Ideally, the cement should also provide additional biological benefits, such as antimicrobial activity and anticariogenic effects through controlled fluoride release, thereby contributing to marginal sealing and prevention of secondary caries[17].

Dental cement should ensure reliable adhesion to both dental tissues and various restorative materials, preventing caries development at the adhesive[18, 19].

Water-based cements, such as glass ionomer and resin-modified glass ionomer cements, are characterized by their ability to release fluoride, which gives them significant preventive potential. In contrast, resin-based cements, which are chemically similar to composite materials, allow the achievement of maximum mechanical strength and functional integration with indirect restorations. Surface etching of the restoration further enhances the micromechanical retention of these cements[20].

Due to their excellent optical properties, ability to match the shade of the restoration, and high aesthetic value, resin-based cements represent the material of choice for the cementation of ceramic restorations, particularly in transparent ceramic systems such as glass and feldspathic ceramics[21].

Dental cements differ in their composition not only among different types of materials but also among manufacturers offering products with the same intended use. For this reason, during the preparation of cements for luting, strict adherence to the manufacturer's instructions is of crucial importance, as well as the implementation of all necessary preparation procedures for both the restoration and the tooth substrate. Inadequate material handling or improper substrate preparation may compromise the cementation process and jeopardize the success of the entire restorative therapy.

The stability and long-term durability of luting cements are not always fully predictable, and their dissolution in the oral environment may lead to the development of marginal caries or periodontal disease. These undesirable effects are observed less frequently with resin-based and glass-ionomer cements, due to their ability to establish an adhesive bond with dental tissues and their higher mechanical strength. Resin cements are particularly indicated in cases where tooth preparation follows the principles of minimally invasive dentistry and when all preparation margins are located supragingivally[18, 19].

Since adhesion, by definition, requires the absence of moisture, ensuring a dry and well-controlled operative field represents a key prerequisite for the successful application of adhesive cements.

Use of dental cements

The cementation process represents one of the key steps in restorative dentistry, as inappropriate cement selection or improper cementation technique may lead to impaired marginal integrity of the restoration, aesthetic deficiencies, occlusal disturbances, and reduced bond strength between the prosthetic restoration and tooth structure. The choice of cement depends on the preparation design, type of tooth, and the restorative material used[8].

Conventional cements have traditionally been used for cementation of metal–ceramic crowns and bridges. Among them, zinc phosphate cement has the longest history of clinical use, exceeding one century, and was long considered the "gold standard" for fixation of indirect restorations. Although largely replaced by more modern materials today, it still retains certain clinical indications. It is characterized by high compressive strength and relatively favorable working and setting time (approximately 5 minutes)[8, 22].

Zinc phosphate cement is a two-component system consisting of powder and liquid. The powder contains approximately 90% zinc oxide and 10% magnesium oxide, with small amounts of other oxides (silicon, calcium, aluminum) to improve mechanical properties and influence color. Its main advantages are good mechanical retention and low cost[23, 24]. However, major disadvantages include high solubility in the oral environment, low viscosity, low tensile strength, lack of anticariogenic effect, and potential pulpal irritation due to its initially low pH (around 2), which increases to approximately 4.5–5.0 after complete setting[25].

Due to the presence of residual orthophosphoric acid, which can diffuse through dentinal tubules and irritate the fibers of Tomes, zinc phosphate cement is not recommended for the cementation of restorations on vital teeth, especially in younger patients. Its indications include the cementation of metal cores (cast and prefabricated), as well as metal and metal–ceramic restorations on non-vital teeth or in older patients in whom physiological pulp recession has occurred. The use of protective varnishes may reduce the irritating effect of the acid, but at the same time may decrease the retention of the restoration. Excess cement should be removed after complete setting of the material[25].

At the end of the 1960s, the era of adhesive dental materials began with the introduction of zinc polycarboxylate cements. These cements exhibit higher tensile strength compared with zinc phosphate cements, but somewhat lower compressive strength. They are most commonly two-component systems, in which the powder contains zinc oxide, magnesium oxide, and small amounts of tin fluoride and aluminum trioxide, while the liquid consists of an aqueous solution of polyacrylic and/or itaconic acid[13].

Zinc polycarboxylate cements are used for the cementation of metal and metal–ceramic crowns and bridges, as well as various types of cores, on both vital and non-vital teeth. Their significant advantage is relative biocompatibility, since the large molecules of polyacrylic acid are unable to penetrate dentinal tubules and irritate the dental pulp. These cements also achieve chemical adhesion to dental tissues through the formation of chelate bonds with calcium in enamel and dentin. The main disadvantages are high viscosity, difficult handling, and a short working time (approximately 2.5 minutes), which is why they are not recommended for less experienced clinicians, especially in the case of large bridge constructions. Excess cement should be removed before complete setting[26, 27].

Glass-ionomer cements were first introduced in the 1970s as restorative materials and were later widely adopted as luting cements. They are characterized by good strength, favorable mechanical properties, and the ability to chemically bond to dental hard tissues. They have a low coefficient of thermal expansion and a relatively broad range of indications, including the cementation of metal-ceramic and all-ceramic crowns and bridges, due to their semitransparency after setting[28, 29].

Glass ionomer cements are most commonly supplied as a powder–liquid system. The powder consists of calcium fluor aluminosilicate glass, while the liquid is an aqueous solution of a copolymer of polyacrylic acid with itaconic, tartaric, or malic acid. The large acid molecules do not penetrate the dentinal tubules, thereby reducing the risk of pulp irritation. These cements are less soluble than zinc phosphate cements and have the ability to release fluoride ions, which contribute to the remineralization of dental tissues and exhibit anticariogenic and bacteriostatic effects[30, 31].

Despite their many advantages, glass ionomer cements also have certain drawbacks, such as an initially low pH (around 3.5), which may be associated with transient postoperative hypersensitivity. This sensitivity may result from dentin dehydration or bacterial contamination during the cementation procedure. Compared with zinc phosphate and zinc polycarboxylate cements, glass ionomers generally exhibit superior mechanical properties. Excess material should be removed before complete setting[30].

Resin-modified glass ionomer cements, also known as hybrid ionomer cements, were developed in the early 1990s. They combine the properties of conventional glass ionomers and resin materials, achieving adhesion through ionic bonding with an additional increase in bond strength due to the composite component. They are characterized by favorable physio-mechanical properties, fluoride release, lower solubility, and a thin cement film[31-33].

They are indicated for the cementation of various types of crowns, bridges, inlays, orthodontic appliances, and aesthetic cores/build-ups. However, they are contraindicated for the fixation of fragile ceramic restorations, as water absorption may lead to volumetric expansion and fracture of the restoration. They are available in powder–liquid, paste–paste, and capsule systems[34].

Resin-based cements represent the newest generation of dental cements and are characterized by an exceptionally strong chemical bond to enamel and dentin. Adhesion is achieved through monomers such as HEMA (2-hydroxyethyl methacrylate), 4-META (4-methacryloxyethyl trimellitate anhydride), and organophosphonates, during which a hybrid layer is formed by impregnation of collagen fibers during polymerization. These cements are composite materials, consisting of a resin matrix (Bis-GMA (bisphenol A-glycidyl methacrylate) or urethane dimethacrylates) and inorganic fillers in a lower concentration than in restorative composites[35, 36].

Resin cements are insoluble and exhibit superior mechanical and physical properties, including high resistance to compressive, flexural, and fatigue stresses, low marginal permeability, excellent aesthetic characteristics, and the possibility of shade selection. They are particularly indicated for the cementation of all-ceramic restorations, veneers, inlays, onlays, crowns, and bridges. Polymerization may be chemical, light-activated, or dual-cure, with dual-cure systems enabling reliable setting even in areas inaccessible to light[37, 38].

The main disadvantages of resin cements are the absence of an anticariogenic effect, which is present in glass-ionomer systems, and their high sensitivity to moisture. Therefore, strict adherence to the manufacturer's instructions and the provision of an absolutely dry operating field are essential for their successful clinical application[39, 40].

Cements for temporary cementation

Temporary cements play an important role in protecting the dental pulp and in the temporary retention of prosthetic restorations during the transitional phase of treatment. In certain clinical situations, even definitive restorations may be temporarily cemented in order to preserve the health of the pulp and periodontal tissues, as well as to allow the patient to evaluate the aesthetic and functional characteristics of the restoration over a certain period of time before final fixation[11].

Ideal temporary cements should be easy to handle, provide sufficient retentive strength to stabilize fixed restorations over a short period of time, and allow easy removal and cleaning from both the tooth surface and the internal surface of the restoration. In addition, they should have optimal working and setting times, appropriate viscosity to allow easy application, biocompatibility, and chemical inertness with respect to the adhesive properties of cements intended for definitive cementation[41].

Materials for temporary cementation are recommended to be applied primarily along the marginal edges of the restoration, which ensures adequate sealing while simultaneously facilitating easier removal of the restoration in the subsequent phase of therapy. Since temporary cements do not provide absolute stability, possible displacement of the restoration may cause patient discomfort and lead to exposure of tooth tissues, thereby increasing the risk of caries development. For this reason, the patient must be clearly informed about the temporary nature of the cementation, its expected duration, and the importance of promptly contacting the dentist if the restoration becomes detached.

Due to the potentially irritating effects of eugenol and clove oil on odontoblasts, modern temporary cements increasingly contain more biologically favorable components, such as calcium hydroxide and hydroxyapatite, which contribute to maintaining pulp vitality and improving the biocompatibility of the material.

Conclusion

Dental cements play a key role in contemporary restorative dentistry, as their proper selection and correct application directly affect the longevity, functionality, and aesthetic quality of dental restorations. Given the wide variety of available materials, there is no universal cement suitable for all clinical situations, which requires thorough knowledge of their properties and indications.

The success of cementation depends not only on the material itself but also on precise clinical technique, control of the working field, and adherence to established protocols. By integrating modern materials with proper application, it is possible to achieve reliable adhesion, adequate marginal sealing, and long-term stability of prosthetic restorations while preserving the health of dental and supporting tissues.

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