Dental Cements in Restorative Dentistry: A Comprehensive Review

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Abstract: Dental cements are indispensable in modern restorative dentistry, playing critical roles in luting, pulp protection, and cavity lining. Over the decades, continuous innovations have transformed their composition and functionality, aligning them with evolving clinical demands. This review explores the historical evolution and recent advances in dental cements, with a focus on enhanced biological activity, improved adhesion, and simplified application protocols.

Early materials such as zinc phosphate and zinc polycarboxylate cements offered mechanical strength and basic adhesion. The introduction of glass ionomer cements (GICs) marked a pivotal advancement, combining chemical bonding with fluoride release. Recent enhancements to GICs, including nanotechnology and incorporation of bioactive fillers like nano-hydroxyapatite, have significantly improved their mechanical properties and remineralizing potential.

Self-adhesive resin cements (SARCs) represent a breakthrough in adhesive dentistry, enabling efficient clinical workflows without the need for etching and priming. These cements have demonstrated long-term success in bonding to various substrates, including ceramics and metal. Simultaneously, the use of bioactive cements such as mineral trioxide aggregate (MTA) and Biodentine has expanded the scope of vital pulp therapy and endodontics, offering superior sealing ability, biocompatibility, and regenerative potential. This article compiles current scientific findings and clinical applications of advanced dental cements.

Keywords: *Dental Cements, Luting Agents, Bioactive Cements, MTA, Biodentine, Biocompatibility, Sealing Ability, Regenerative Potential.*

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I. INTRODUCTION

Dental cements are crucial in restorative dentistry for luting, pulp protection, and lining cavities. [1]. Over time, their properties have evolved to enhance strength, biocompatibility, and ease of use. [1,2,3]. The historical development of dental cements includes the following milestones:

- 1870s:Introduction of zinc phosphate cement, first widely used cement with good mechanical strength and retention. [2].
- 1960s:Development of zinc polycarboxylate cement, Improved adhesion to enamel and dentin compared to earlier materials. [3]
- 1970s:Emergence of glass ionomer cements (GICs),Provided chemical bonding and fluoride release, making them suitable for preventive dentistry. [2,9]
- 1990s:Introduction of resin-based cements, Offered superior aesthetics, high strength, and excellent bonding to ceramics. [6].
- 2000s–Present: Advancement in bioactive, nanotechnology-enhanced [15,16]., and self-adhesive cements, improved clinical performance, handling, and biological interaction with tooth tissues.

These innovations have significantly influenced modern dental practice by offering more reliable and versatile cementation options.

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II. DEFINITION

Dental cements are materials that harden from a viscous state to a solid form, allowing them to bond two surfaces together. In dentistry, these cements are used as a base, liner, restorative material, or adhesive to attach prostheses and devices to tooth structures (Anusavice et al., 2012). [1].

➢ *Importance of Dental Cements*

Dental cements serve several crucial functions in restorative dentistry:

- Retention and stabilization: Cements provide mechanical retention for crowns, bridges, veneers, and other indirect restorations. [18,20].
- Sealing: Cements create a tight seal between the restoration and tooth, preventing microleakage and recurrent caries. [11,29].
- Pulp protection: Cements protect the dental pulp from thermal or chemical irritation. [7,13].
- Fluoride release: Some cements, like glass ionomer, release fluoride, which helps prevent tooth decay. [14,23]
- Aesthetic integration: Cements can improve the aesthetic outcome especially with resin cements. [6].

➢ *Applications of Dental Cements*

Dental cements are used in various applications, including: Permanent cementation of crowns, bridges, inlays, onlays, and veneers, Temporary cementation of restorations, Luting orthodontic appliances such as brackets and bands, Cavity liners and bases for deep restorations, Endodontic sealers in root canal treatments, Core build-up materials under restorations [20,22].

➢ *Key Factors in Cement Selection*

The choice of dental cement depends on several factors:

- Biocompatibility: Must not cause harm or rejection; should support normal cell function. [7]
- Physical Properties: Includes strength, flexibility, degradation rate—must suit the application (e.g., bone, skin, organs). [6]
- Bioactivity: Materials may be passive (inert) or active (stimulate healing, bond with tissue) [5,28]
- Body Response: Should elicit minimal inflammation and integrate well with surrounding tissue. [13]

III. REVIEW OF DENTAL CEMENTS

➢ *Zinc Phosphate Cements*

- Origin & Composition: Oldest dental cement, comprising zinc oxide/magnesium oxide powder and phosphoric acid liquid; sets via acid–base reaction to form zinc phosphate . [2]
- Properties & Clinical Use: High compressive strength, moderate tensile, low film thickness; used for crowns, inlays, and orthodontic appliances .
- Limitations: Initially very acidic (pH <2), causing pulpal irritation; no adhesive bonding; some solubility; lacks fluoride or antibacterial action 2. Silicate Cements
- Composition: composed of silicate glass with fluoride and zinc oxide; powder with phosphoric acid liquid Properties: High fluoride release and translucency, compressive strength 68–255 MPa; but vulnerable to acid erosion and had unreliable handling
- Clinical Role: Early restoratives, largely replaced by glass ionomer cements.

➢ *Zinc Polycarboxylate Cements*

- Bonding: first cement to chemically bond to enamel and dentin via polyacrylic acid chelation [3].
- Properties: Biocompatible, adhesive, thermal insulator, radiopaque, fluoride-releasing; but slightly acidic and difficult to handle due to sticky consistency.
- Clinical Use: Luting metal crowns, crowns on paediatric patients, provisional restorations, some orthodontic uses

➢ *Zinc Oxide Eugenol (ZOE) Cement*

- Background: powder (zinc oxide, rosin, zinc acetate) and liquid (eugenol in oil); sets to zinc eugenolate chelate
- Advantages: Sedative to pulp, bactericidal, easy to remove prostheses or temporary restorations; low strength favors interim use
- Limitations: Low compressive strength, interference with resin polymerization, microleakage concerns [12].
- Recent Modifications: Reinforcement with 10 wt% E-glass fiber significantly enhanced compressive strength and reduced solubility

➢ *Calcium Hydroxide Cements*

- Composition & Mechanism: Supplied in dual-paste or light-cured systems; alkaline pH creates antibacterial environment and stimulates tertiary dentin formation. [7,27].
- Clinical Use: Pulp capping, liners under restorations, endodontic applications; hydrolysis and compression may limit durability under restorations

➢ *Glass Ionomer Cement (GIC)*

- Emergence & Formulation: Developed in 1972 by combining silicate fluoride release with polycarboxylate adhesion; non-resin formulation that chemically bonds to tooth and releases fluoride [2,9].
- Properties: Adhesive, fluoride-releasing, moderate strength, radiopaque; setting through acid-base reaction, requiring moisture control during initial set [10].
- Applications: Luting crowns, liner/base materials, restorations especially in deciduous teeth, non-load-bearing restorative zones, liners under composites

➢ *Zinc Oxide Eugenol (ZOE) & Non-Eugenol Variants*

- ZOE-based cements: Used for temporary restorations, but interfere with composite polymerization. example: IRM (Intermediate Restorative Material).
- Non-eugenol cements: Compatible with resin restorations. example: TempBond NE.

➢ *Zinc Phosphate & Zinc Polycarboxylate Cements*

- Zinc phosphate cement: Excellent compressive strength, but no adhesion to tooth. example: Harvard Cement; still

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used in crown and bridgework with mechanical retention.
- Zinc polycarboxylate cement: First to chemically bond to enamel and dentin via chelation with calcium. example: Poly F Plus.

➤ *Resin Cements*
- Introduction & Features: Arrived in the 1990s, designed for superior aesthetics, high strength, and reliable bonding to ceramic and composite restorations using adhesive systems [6,17].
- Performance: Excellent retention for ceramic inlays/onlays, fiber posts, veneers; ability to reinforce tooth structure, especially for endodontic posts.
- Considerations: Requires careful bonding protocols; eugenol-based temporary cements must be avoided prior to bonding due to interference

IV. RECENT ADVANCES

A. Bioactive Glass-Ionomer Cements (GICs)

➤ *Bioactive glass (BAG)-modified GICs:*
- Contain 45S5 bio glass to enhance fluoride release, ion exchange, and remineralization. [15]
- Caution: Excess BAG (>20 wt%) may reduce compressive strength.
- Bioactive materials such as ACTIVA™ Bioactive and Ceramir® release calcium, phosphate, and fluoride ions, aiding in remineralization and dentin bridge formation.

➤ *Applications: Ideal for Paediatric, Geriatric, and pulp-adjacent restorations*

➤ *Clinical Effects: Promote healing [19] and seal margins against microleakage (Pameijer, 2012)*

➤ *Natural Compound Incorporation:*
- Additives like acemannan (from Aloe vera), thymol, and sesame oil are used to improve antibacterial properties and ion release.
- Example: RMGIC with acemannan demonstrated better remineralization and antibacterial properties than control.

➤ *Nano-Filler Enhancements:* [16,25].
- Incorporation of nano-hydroxyapatite, zirconia, or reactive glass fibers boosts strength.
- Example: Nano-ZrO_2 reinforced GIC showed 2x higher flexural strength and improved wear resistance.

B. Resin-Modified Glass Ionomer Cements (RMGICs) [10].

➤ *Improved Bond Strength & Handling:*
- Newer RMGICs are formulated with HEMA-free resins to reduce cytotoxicity and postoperative sensitivity.
- Example: Ketac Universal (3M) provides higher bond strength without a separate bonding agent.

➤ *Chlorhexidine or Essential Oil-Loaded RMGICs:*
- Offer long-term antibacterial action and are effective in high-caries-risk patients.
- Example: Thymol-enhanced RMGIC reduces *S. mutans* count for >4 weeks.

C. Self-Adhesive Resin Cements (SARCs) [17,18,21].

➤ *No Etch-Prime-Bond Steps:*
- Ideal for indirect restorations—particularly zirconia, PFM, or lithium disilicate.
- Example: RelyX Unicem 2 (3M ESPE) is widely used for ceramic inlays/onlays and posts.

➤ *Performance in Clinical Studies:*
- SARCs perform comparably to conventional resin cements with selective enamel etching.
- Example: In a 2-year clinical trial, ceramic crowns cemented with SARC had 96% survival rate, equal to conventional resin cements.

➤ *Additive Strategies:*
- Bond strength can be enhanced with additional universal adhesives or silane coupling agents.
- Example: Pre-treatment with silane on lithium disilicate improves bond strength of SARCs.

D. Conventional Resin Cements

➤ *High Aesthetic Performance:*
- Resin cements remain the gold standard for all-ceramic restorations due to superior bonding.
- Example: Variolink Esthetic (Ivoclar) used for veneers, crowns, and bridges.

➤ *Dual-Cure Systems:*
- Light- and chemically cured for deep or opaque restorations.
- Example: Panavia V5 (Kuraray) offers dual-curing with MDP-based bonding to zirconia and enamel.

➤ *Low Water Solubility:*
- Enhances long-term retention and marginal adaptation.

E. Bioceramic and Calcium Silicate Cements [5,28,30].

➤ *Tricalcium Silicate-Based Cements (e.g., Biodentine, Theracal LC):*
- Promote dentin bridge formation, ideal for vital pulp therapy.
- Example: Biodentine shows superior outcomes in pulp capping vs. $Ca(OH)_2$.

➤ *Mineral Trioxide Aggregate (MTA):*
- Long-term biocompatibility, sealing, and antimicrobial action.
- Example: ProRoot MTA used in apexification, perforation repair, and retrograde filling.

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➢ *Calcium Silicate-Based Sealers:*

- Used in endodontics; promote regeneration and are non-cytotoxic.
- Example: EndoSequence BC Sealer (Brasseler USA).

F. Future Directions & Experimental Developments

➢ *Smart/Stimuli-Responsive Cements:*

- Can respond to pH changes, bacteria, or enzymes by releasing therapeutic agents.

➢ *Graphene Oxide-Reinforced GICs:*

- Improve mechanical strength and provide broad-spectrum antimicrobial effects.

➢ *Hybrid Materials:*

- Resin-GIC hybrids and ceramic-filled adhesives combine durability and bioactivity.

➢ *Photodynamically Enhanced Cements:*

- Contain light-activated photosensitizers for added disinfection during placement.

V. CONCLUSION

Dental cements are indispensable in restorative dentistry, providing crucial roles such as retention, sealing, and pulp protection. With continuous advancements in materials science, modern cements now offer better adhesive properties, higher strength, biocompatibility, and more efficient clinical application. Self-adhesive cements, bioactive materials, and nanotechnology-enhanced cements represent the future of restorative dentistry, providing enhanced clinical outcomes and patient satisfaction. (15,17,28)

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