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## Review Article

# Multifarious bone cement and its applications in endodontics – A review

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### ABSTRACT

Polymethyl methacrylate (PMMA), commonly known as bone cement, is widely used in orthopaedic surgery, mainly for prosthesis fixation, stabilizing compressive vertebral fracture or filling bone defects. Bone cement is a potentially new repair material that has been investigated recently in dentistry because of its properties like low cytotoxicity, excellent biocompatibility and resistance to a moist environment. In Endodontics, bone cement can be used as a furcation repair material, retrograde filling material and in apexification. Modified bone cements are introduced by adding fillers, adhesives, antibiotics, and nanoparticles that make it well suited as an endodontic repair material. This review paper highlights the importance of bone cement and its possible applications in Endodontics.

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## 1. Introduction

Polymethyl methacrylate (PMMA), commonly known as bone cement, is widely used in orthopaedic surgery, mainly for prosthesis fixation, stabilizing compressive vertebral fracture or filling bone defects.<sup>1</sup> Bone cement is a potentially new repair material that has been investigated recently in dentistry to stabilize implant prostheses because of its properties like low cytotoxicity, excellent biocompatibility, and resistance to a moist environment. In endodontics, bone cement can be used as a furcation repair material, retrograde filling material and in apexification. Even though the uses and availability of various types of bone cement have greatly evolved over the past century, further research still develops its more clinical applications associated with their use.

## 2. Historical Perspective

Otto Rohm was the early pioneer who worked extensively on bone cement's physical properties and uses. In 1933, he patented and registered it under the brand PLEXIGLAS.<sup>2</sup> The era of modern PMMA bone cements comes from the patent by Degussa and Kulzer (1943), who described the polymerization mechanism of PMMA.<sup>3</sup> The first bone cement used in Orthopaedics is widely credited to the famous English surgeon, John Charnley, who in 1958 used it for total hip arthroplasty.<sup>4</sup> After the U.S. Food and Drug Administration (FDA) approved bone cement in hip and knee prosthetic fixation in the 1970s, the trends of bone cement usage have greatly evolved.<sup>5</sup>

## 3. Constituents of Bone Cement

PMMA is an acrylic polymer formed by mixing two sterile components: a liquid MMA monomer and a powered MMA-styrene co-polymer, in the ratio of 2:1. The constituents of bone cement powder are depicted in Table 1

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and bone cement liquid in Table 2.

**Table 1:** Constituents of bone cement powder

Powder constituents	
Polymer	Polymethyl methacrylate (PMMA) (15%) and Methylmethacrylate-styrene copolymer (75%)
Initiator	Benzoyl peroxide (BPO)
Radio-opacifier	Barium sulphate (BaSO <sub>4</sub> )/ Zirconia (ZrO <sub>2</sub> )
Additives	Antibiotics Fillers Adhesives and Nanoparticles

**Table 2:** Constituents of bone cement liquid

Liquid Constituents	
Monomer	Methyl methacrylate (MMA)
Accelerator	N, N-Dimethyl para-toluidine (DMPT)/ Dimethyl para-toluidine
Stabilizer	Hydroquinone

#### 4. Properties

Bone cement has many properties that make it well suited as a repair material for various endodontic treatments. Its properties are good strength and load-bearing capacity, good handling and working properties, faster setting time of around 15 minutes,<sup>6</sup> and good marginal adaptation.<sup>7</sup>

The bone cement is said to exhibit low cytotoxicity compared to MTA, and the powder was non-toxic in nature. Its excellent biocompatibility allows for tissue reattachment. Badr et al. evaluated the marginal adaptation and cytotoxic effect of polymethylmethacrylate (PMMA) bone cement and MTA. The obtained data revealed that PMMA bone cement and MTA exhibited better adaptation to the dentinal walls than amalgam. The proper adaptation of bone cement to the dentin wall despite the well-known polymerization shrinkage of acrylics might be explained by the fact that the volume of cement increases to a maximum during polymerization before shrinking slightly. Also, the cytotoxicity testing showed that bone cement had a comparable cytotoxic effect on fibroblast cells with MTA. In addition, bone cement tolerates a moist environment very well.<sup>8</sup> Table 3 depicts the setting and mechanical properties of bone cement.

#### 5. Applications of Bone Cement

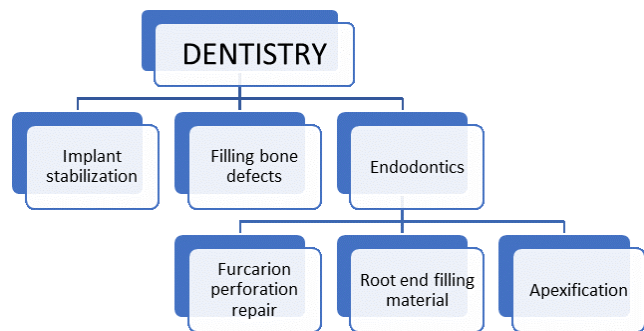
Bone cement has been widely used in orthopaedics for the past four decades. It was recently introduced into dentistry a decade ago. The applications of bone cement in dentistry are depicted in Figure 1.

Some of the commercially available bone cements are:

1. Surgical Simplex<sup>®</sup> P, Stryker Australia Pty Ltd, Australia

**Table 3:** Setting and mechanical properties of bone cement

Properties <sup>9</sup>	Setting properties	Mixing time 1-1.5min
		Waiting time 2-3 min
		Working time 5-8 min
		Setting time 8-10 min
	Mechanical properties	Compressive strength 93.0 Mpa
		Tensile strength 35.3 Mpa
		Shear strength 42.2 Mpa
		Bending strength 64.2MPa



**Fig. 1:** Applications of bone cement in dentistry

2. Simplex<sup>®</sup> HV, Stryker Australia Pty Ltd, Australia
3. PALACOS<sup>®</sup> R Bone cement; Zimmer Biomet, Warsaw, Indiana, United States
4. BIOMET<sup>®</sup> Bone cement R, Zimmer Biomet, Warsaw, Indiana, United States
5. C-ment<sup>®</sup> and C-ment<sup>®</sup> NXT, Leader Biomedical, India
6. Cemad and Cemad LV, Aditus Medical, Berlin, Germany.

#### 6. Modified Bone Cements

Although bone cement displays high strength, under cyclic bending and tensile stresses, the brittle nature of PMMA is exposed, and fracture occurs at much lower loads than the predicted ultimate strength values. Bone necrosis may occur due to the high exotherm of the polymerization reaction and the toxicity of the MMA. So, the modified bone cements are introduced by adding fillers, adhesives, antibiotics, and nanoparticles that make it well suited as an endodontic repair material to improve the:<sup>3</sup>

1. Mechanical properties
2. Interface integrity
3. Osteoconduction
4. Thermal reduction

5. Radiopacity
6. Antibacterial properties
7. Bioactivity

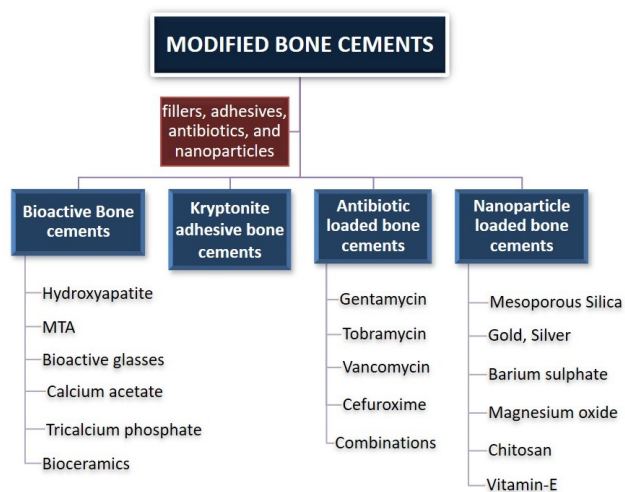


Fig. 2: Depicts the modified bone cements

### 6.1. Bioactive bone cements

Bone cement cannot directly bond with tooth structure and hence needs to be modified by adding bioactive filler particles like hydroxyapatite, bioactive glasses, MTA to incorporate bioactivity in the cement. Figure 3 depicts the composition of Bioactive bone cements. The modified powder and liquid are mixed in the ratio of 2:1 under ambient conditions at room temperature.

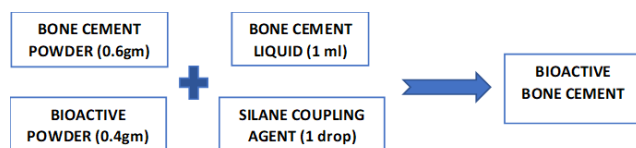


Fig. 3: Composition of bioactive bone cements

The essential requirement for an artificial material to show bioactivity is by forming a biologically active bone-like apatite layer on its surface in the body environment. Miyazaki et al. have shown that apatite formation can be induced by releasing calcium ion (Ca<sup>2+</sup>) from the modified bone cement into the body fluid and by a catalytic effect of Si-OH groups formed on the surface of the material. The addition of MTA powder to bone cement acts as a source of calcium ions. In contrast, the addition of silane to liquid components provides Si-OH group due to hydrolysis of alkyloxysilane after exposure to the body environment that induces heterogeneous nucleation of hydroxyapatite. The addition of silane also improves the mechanical properties

of bone cement because chemical bonding can be formed with polymerized MMA.<sup>10</sup> These cements display improved compressive strength by bringing a chemical bond between bone cement and dentinal wall. These bioactive bone cements are osteoinductive and act as a medium for apatite crystal growth and nucleation.

#### 6.1.1. Advantages

1. Highly biocompatible
2. Osteoinductive
3. Adhesion with the dentinal wall
4. Better sealing ability compared with other types of bone cements

#### 6.1.2. Applications

1. Bioactive bone cements exhibit comparable sealing ability to MTA. Bioactive Bone cement can be used as furcal perforation repair material in cases where easy handling and quick setting of repair material is needed. This can be attributed to the fact that on exposure to simulated tissue fluid, it gets covered with a layer of apatite crystals which nucleate and grow, filling the microscopic space between bone cement and the dentinal wall.<sup>11</sup>
2. Bioactive bone cement is a viable alternative for conventional root-end fillings due to its ease of manipulation and cost-effectiveness associated with good sealing ability.
3. Apical re-surgery cases.

### 6.2. Kryptonite adhesive bone cement

Kryptonite is a castor oil-derived polymer adhesive, biocompatible and was developed as radiopaque bone adhesive cement introduced in 2006. The adhesive bonds specifically and directly to bone, and within 24 hours, results in rigid bone fixation and stability. The porous network within the product allows osteointegration with host bone over time. It provides an optimal seal in 24 hours when used as a retrograde filling material. Kryptonite also possesses osteoconductive properties and does not interfere with normal healing.

This adhesive has three components:<sup>12</sup>

- A: Castor oil derived polymer
- B: polyol, Fatty acid, water, catalyst
- C: Calcium carbonate

#### 6.2.1. Advantages

1. An immediate strong bond with the dentinal wall
2. Superior sealing ability

#### 6.2.2. Applications

1. When used as a retrograde filling material, kryptonite exhibits comparable sealing ability to MTA. The calcium carbonate component in the kryptonite bone

cement is responsible for osteoconductive properties by providing mechanical strength, structure, and scaffold for bone growth.<sup>13</sup>

### 6.3. Antibiotic loaded bone cement

The addition of antibiotics to the bone cement must be considered a support strategy in preventing the onset of infections. The antibiotic must have a broad antibacterial spectrum and a low percentage of resistant species.

The most commonly used antibiotics are:

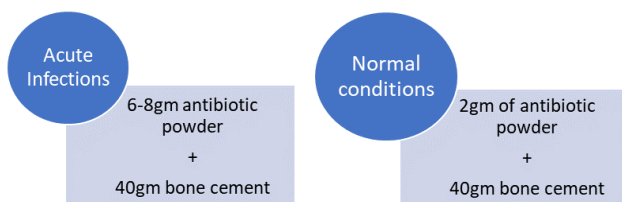
1. Gentamicin and Tobramycin (aminoglycosides with particular effectiveness against gram-negative bacteria)
2. Vancomycin (glycopeptide active mainly on gram-positive like, e.g., *Staphylococcus aureus*)
3. Combinations with other antibiotics

These antibiotics can be mixed manually into the bone cement before use. The preparation of the bone cement should be as porous as possible to increase the spread of the antibiotic, but not excessively porous to weaken the structure of the cement itself. Few commercially available pre-mixed antibiotic bone cements are:

1. PALACOS<sup>®</sup> R+G Bone cement, Zimmer Biomet, Warsaw, Indiana, United States
2. Simplex<sup>®</sup> P with Tobramycin; Simplex<sup>®</sup> HV with Gentamycin, Antibiotic Simplex<sup>®</sup>, Stryker Australia Pty Ltd, Australia
3. Rifobacin<sup>®</sup> Bone cement, Zimmer Biomet, Warsaw, Indiana, United States

#### 6.3.1. Dosage of antibiotic<sup>14</sup>

The antibiotic dosage varies according to the use for which the cement is destined. Figure 4 depicts the dosage of Antibiotic in Bone cement that is required for different conditions.



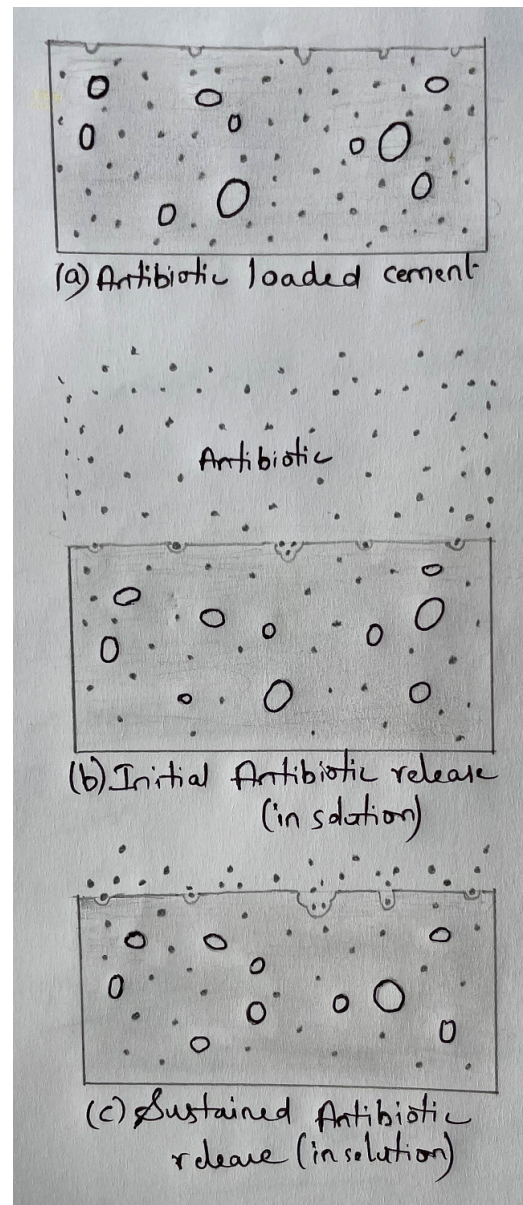
**Fig. 4:** Dosage of antibiotic for various conditions

#### 6.3.2. Advantages

1. Broad antimicrobial coverage against gram-positive and gram-negative bacteria.
2. Local drug delivery
3. Reduces post-operative infection rates

#### 4. Biocompatible

5. Limited drug release of 5% for one day and sustained release upto 50 days<sup>15</sup>



**Fig. 5:** Sustained antibiotic release from bone cement

#### 6.3.3. Disadvantages

1. Development of drug resistance
2. Increasing the dose of antibiotics in the bone cement (>2gm) decreases the mechanical properties by 5%.<sup>14</sup>

#### 6.3.4. Applications

1. It can be used effectively in apical resurgery cases for treating recalcitrant infectious osseous defects of

periapical lesions associated with failed periapical surgery.<sup>15</sup>

## 2. Furcation perforation repair

### 6.4. Nanoparticle loaded bone cement

These bone cements are not being widely used in the field of Endodontics. There is scant data focusing on the effect of combining various additives into the cement powder. The area of nanoparticle technology holds promise. Table 4 depicts the nanoparticle additives and their properties.

**Table 4:** Nanoparticle additives into the bone cement and their properties

Additives <sup>9,16</sup>	Property
Mesoporous Silica 2-50 $\mu$ m (8 wt%) 2-8gm antibiotic	Drug carrier and filler Sustained release of antibiotic for up to 80 days
Magnesium oxide <sup>17</sup>	Reduces harmful exothermic reactions of PMMA Improves osteoblast adhesion
Zirconium oxide (upto 10%)	Improves radiopacity
Chitosan, gold and silver	Improve the antimicrobial properties
Vit-E (upto 10%)	Improves cement cytocompatibility

## 7. Conclusion

Modified bone cements can be used for different case scenarios because they are mouldable to fill complex defects, cost-effective and easy to manipulate. The field of nanoparticle technology holds promise. Clinical trials focusing on the nanoparticle additives and their apparent effect on bone cements' mechanical and chemical properties need to be evaluated. Further research is warranted to assess the bioactive property of the bone cement, especially on the longevity of calcium release that can occur from the cement.

## 8. Source of Funding

None.

## 9. Conflict of Interest


The authors declare no conflict of interest.


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