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Research Article

Reinventing Polymethylmethacrylate as Bone Saver- A Systematic Review

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Abstract

Polymethylmethacrylate (PMMA), a synthetic resin produced by polymerisation of methyl methacrylate has been commonly used for prosthetic dental applications including the fabrication of artificial teeth, denture bases, dental relining, dentures, obturator for cleft palate, orthodontic retainers etc. Recently it is found to be useful as bone cements, contact and intraocular lenses, filler material for bone cavities and skull defects as well as vertebrae stabilization in osteoporotic patients. In addition to this, the silver nanoparticles and zeolites present in the PMMA have been a topic of research due to having strong antimicrobial properties through photocatalysis. This property has been incorporated in treatment of staphylococcus activated bone diseases in head and neck region especially osteomyelitis. Antibiotic-loaded bone cement (ABLC) can be an effective tool for local antibiotic delivery. This systematic review aims to highlight the significance of Polymethyl methacrylate as a bone saver material against staphylococcal infections.

Keywords: Polymethyl Methacrylate; Antibiotic Loaded Cement; Osteomyelitis

Introduction

Polymethylmethacrylate [PMMA] is a synthetic polymer derived from methyl methacrylate. PMMA has received significant attention in recent years and is regarded as one of the most efficient and promising polymer with applications in diverse fields. It has been commonly used for dental applications such as fabrication of denture bases and artificial teeth, final dentures, obturator for cleft patients,, temporary or provisional crown and for repair of dental prosthesis [1]. Additional applications of PMMA include fabrication of occlusal splints and orthodontic retainers. It has recently been employed as bone cement, contact and intraocular lens, filler material for bone cavity and skull defects as well as vertebrae stabilization in osteoporotic patients. The unique properties of PMMA such as low density, aesthetics, cost effectiveness, and ease of manipulation have been highlighted in our study.

Antibiotic-loaded bone cement (ABLC) is an effective tool for local antibiotic delivery. Bone cement is a biomaterial created by combining a liquid phase and a powder phase. It can be molded and implanted as a paste that undergoes setting once implanted within the body. These bone cements serve as a matrix for administering antibiotics locally. Due to the high local concentration of antibiotics, bone cements laden with antibiotics provide a substantial advantage over conventional antibiotic therapy. This particular study aims to highlight the significance of Polymethylmethacrylate in Staphylococcus aureus mediated bone infections, predominantly osteomyelitis [2].

Aims and objectives.

To determine the significance of Polymethylmethacrylate in Staphylococcus aureus mediated bone infections.

Research question

Does Polymethylmethacrylate have a potential to regrow degenerated bone due to Staphylococcus infections?

Materials and Methods

With the Cochrane collaboration taken as source for authenticated scientific research data, around 35 articles were chosen having undergone randomized control trial. The articles were screened and 20 articles were selected which met the criteria for our systematic review.

The inclusion and exclusion criteria were based on PRISMA guidelines as highlighted below Figure 1.

Results

Based on statistical analysis, the study was found to be highly significant thereby implying that PMMA indeed have the potential to treat the bone infections caused by Staphylococcus aureus.

Discussion

Poly Methyl MethAcrylate is an acrylic polymer. The liquid MMA monomer and the powdered MMA-styrene copolymer (Table 1)

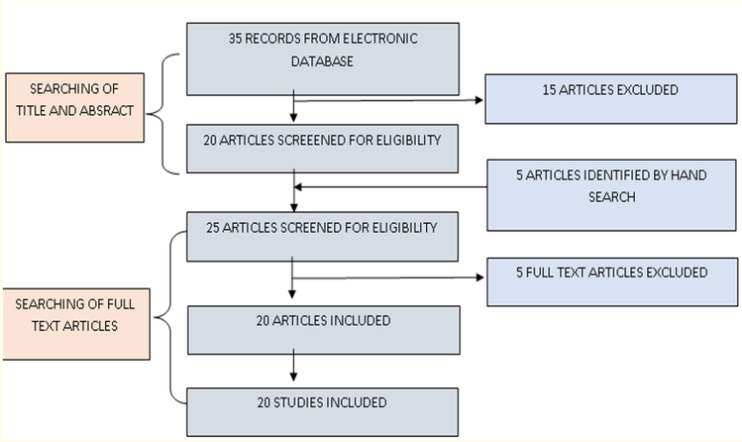

Figure 1: Inclusion and exclusion criterion based on PRISMA guidelines.

POWDER	LIQUID
Polymer: Polymethyl methacrylate/copolymer (PMMA)	Monomer: Methyl methacrylate (MMA)
Initiator: Benzoyl peroxide (BPO)	Accelerator: N, N-Dimethyl para-toluidine (DMPT)/di-Methyl para-toluidine (DMpt)
Radio-opacifier: Barium sulfate (BaSO4)/Zirconia (ZrO2)	Stabilizer: Hydroquinone
Antibiotics (e.g., Gentamicin)	

Table 1: Constituents of PMMA bone cement.

are combined to create PMMA. When the two components are combined, the liquid monomer forms rigid PMMA by polymerizing around the pre-polymerized powder particles.

Bone cement has been of special use since it allows for the addition of certain active components, such antibiotics, to the powder component. Bone cement serves as a state-of-the-art system for delivering drugs to the surgical site. The use of antibiotic-loaded cement as an efficacious method of delivering high local antibiotics for the treatment of musculoskeletal infection is well established. It has been shown that a ratio of at least 3.6 g of antibiotic per 40 g of acrylic cement is desirable for effective elution kinetics and sustained therapeutic levels of antibiotics [3].

The mechanical properties of bone cement, such as its compressive or diametrical tensile strengths, are not negatively impacted by the addition of different types of antibiotics in amounts less than 2g per standard packet of bone cement, according to research, but amounts higher than 2g do weaken them. Bone cements have been used in conjunction with several antibiotics, such as Gentamicin, Erythromycin, Tobramycin, Vancomycin, Cefuroxime, and Colistin, with enhanced effectiveness [4]. The antibiotics added to PMMA must meet the fundamental requirements of being heat resistant and lasting a longer period of time. Staphylococcus aureus employs a range of pathogenic mechanisms during skeletal infection. Gram-positive S. aureus cells are found at the center of an abscess surrounded by a fibrous pseudo capsule encasing bacterial cell, followed by layers of dead and live immune cells [5].

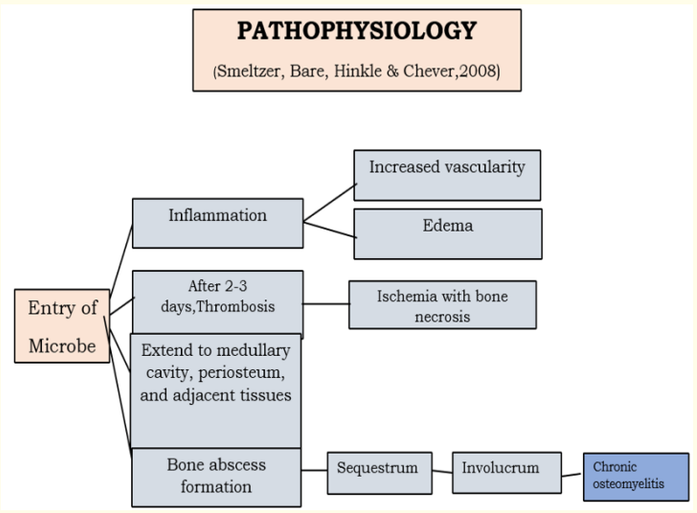

Figure 2: Pathogenesis of *Staphylococcus aureus* (Smeltzer, Bare, Hinkle and Chever, 2008).

Most frequently, the invasion of bacterial pathogens into the skeleton results in osteomyelitis, or bone inflammation. The fact that the predominant etiologic agent, the Gram-positive bacterium Staphylococcus aureus, has extensive antibiotic resistance contributes to the notoriously challenging nature of treating bacterial osteomyelitis. Bacterial osteomyelitis promotes pathological bone remodeling, leading to sequestration of infected foci from innate immune effectors and systemically administered antibiotics [6].

Numerous attempts have been made to address chronic osteomyelitis and implant-related infections locally via antibiotic-loaded acrylic bone cement. It is considered to be the gold standard in the treatment of osteomyelitis. The beads are typically inserted to fill anatomic defects secondary to surgical debridement. Locally-made antibiotic-loaded bone cement beads can be antibiotic-specific, cheaper, and readily available.

Based on research antibiotic loaded bone cements used in clinical trials has shown the potential to curb the degenerated bone which is usually seen in osteomyelitis caused by *Staphylococcus.*

Antibiotic loaded polymethyl methacrylate reduces the ischemic bone necrosis and bone abscess formation caused by *Staphylococcus aureus*. It holds the infection from progressing bone degeneration and osteomyelitis. Thus, ALBC prevents and/or reduces the severity of bone infections caused by Staphylococcal infections.

Shortcomings of bone cement

Bone cement generates heat during curing and undergoes contraction. It later expands due to water absorption. Since it releases heat (35-90°C) during coagulation, the peripheral tissues and nerves will be burned in the event of a leak, causing serious complications. Due to its poor biocompatibility, degradability and absorbability, PMMA becomes a permanent foreign body once injected and cannot form chemical bonds with surrounding bone tissue. Therefore, mechanical instability occurs due to looseness between bone and bone cement over time. It does not remodel and neither is osteoinductive nor osteoconductive. The monomer is toxic and might trigger allergic reactions. The PMMA macromonomer has cytotoxicity to vascular endothelial cells, which promotes thrombogenesis. Therefore, its reflux to the vein after extravasation can lead to significant complications, such as pulmonary embolism, myocardial infarction, cerebral infarction and decreased blood pressure, which may greatly affect elderly patients [7].

Conclusion

Various literature have proved antibiotic loaded bone cement has the potential in curbing the bone degenerative effects of Staphylococcus infections. Chronic osteomyelitis can be effectively treated with antibiotics containing PMMA beads, and may aid in preventing recurrence. They are effective in both sensitive and resistant organisms. This effect is probably due to a high local minimum inhibitory concentration (MIC) for bacteria. The preventative and therapeutic uses of antibiotic-loaded bone cement have been reliably established. The toxicity, drawbacks, and inadequacies of bone cement are being addressed recently. Further researches are needed and continued in the field of nanoparticle additives, enhanced bone cement interface and other developments in quest for improving the quality and eliminating or reducing undesired side effects of bone cement.

Conflict of Interest

The authors have no conflict of interest to declare.

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