

Modified Bone Cement: A Reprieve for Horizontal Bone Defects

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ABSTRACT

Introduction: Periodontitis results in defects of the bone, of which the horizontal defects are the most common. Treatment options for horizontal defects are minimal with unpredictable results.

Background: Polymethyl methacrylate (PMMA) bone cement has been effectively used in orthopedic surgeries. The material has excellent interface integrity with bone and hence would develop an efficient micromechanical bond to both bone and tooth. This material can be used to reconstruct the lost alveolar bone, especially in areas with horizontal bone defects where regeneration is difficult to achieve.

Results: The PMMA bone cement has certain properties that make it a not very apt replacement of the dynamic alveolar bone. However, modification of the cement through addition and replacement of appropriate materials would make it an effectual foundation for the teeth deprived of their alveolar bone.

Conclusion: Bone cement, with appropriate modifications, might prove a novel substitute for the lost alveolar bone structure.

Clinical significance: Horizontal bone defects that form the majority of periodontal bone defects require a definitive treatment modality to allow for retention of the affected teeth. Modified bone cement could prove to be the much required miracle agent in the treatment of horizontal bone defects.

Keywords: Bone cement, Horizontal bone defects, Polymethyl methacrylate.

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BACKGROUND

Periodontitis, an infectious and inflammatory disease of the periodontium, is one of the major causes of tooth mortality, especially in the adult population. The inflammatory process usually begins in the soft tissue and then spreads to involve the underlying alveolar bone. Involvement of the bone results in gradual breakdown of the bone

architecture; eventually the bone support collapses and it results in tooth loss.¹

On reflection, it can be said that the ultimate cause of tooth loss is the loss of bone.¹ The pattern in which bone loss occurs is varied. Alignments of teeth, position of root within the alveolar process, and proximity with another tooth surface are a few of the factors that determine the pattern of bone loss.² The bone destruction patterns may be horizontal, vertical, ledge-like, reversed architecture, or furcation involvement.³

Of all the bone destruction patterns that are present, horizontal bone loss is the most common.³ Therefore, treatment modalities that help in repair and rebuilding of horizontal defect are vital in total periodontal reconstruction. Attempts have been made to correct the horizontal defects using bone graft materials, biological mediators, and guided tissue regeneration.^{4,5} However, the supra-crestal bone regeneration has remained a mirage⁶ with very little recorded success.^{4,5}

The use of PMMA bone cement in orthopedic surgery is a time-proven and effective treatment modality for vertebral body reconstruction, total joint arthroplasty, repair of open fractures, etc.^{7,8} The interface integrity of the material can be considered a valuable asset in its use as a bone cement.⁸ The same property can be considered pivotal in its use as a material to reconstruct the horizontal ridge defect. It can be theorized that the cement can act as a foundation for the teeth lacking in support from the natural alveolar process, thereby stabilizing the teeth. The cement may be used even in dentulous areas as its natural properties would allow it to establish a micromechanical bond with the tooth. This material, with certain modifications, may very well prove to be a savior for a horde of teeth.

REVIEW RESULTS

German chemist Dr Otto Rohm patented the PMMA product Plexiglass in 1933, which was used for non-medical purposes.⁹ The discovery made by Kulzer that the dough formed by mixing PMMA powder and a liquid monomer hardens under appropriate conditions and with the addition of the required materials¹⁰ was made use of in 1938 for the first time to close cranial defects in monkeys. Later, PMMA was used to close cranial defects in humans in the form of heat-stable polymer Paladon 65.¹⁰

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Degussa and Kulzer introduced the era of modern PMMA bone cements.¹⁰ This technology was put into use by dental surgeons for the preparation of dental appliances and fixatives. Charnley¹¹ used this “dental acrylic” in 1958 for total hip arthroplasty as it had the ability of micromechanical bonding to bony structures. Nevertheless, the initial clinical results were poor due to mechanical and biological reasons.¹⁰ In order to overcome the shortcomings of the “dental acrylic” as an orthopedic cement, a newer material called “bone cement” was developed by Charnley¹² which had more compliant biological properties.¹³ However, this material also proved to have many shortcomings. Several modifications of this material have been developed using additives to improve the properties of the cement.¹⁴

There is no evidence in the literature that points toward the use of PMMA bone cement, in a modified form, in the treatment of horizontal bone defects. When deliberated over as a possible synthetic part of the periodontium, PMMA bone cement can be considered as a material with certain surmountable shortcomings. The development of modified PMMA cement for horizontal defects will prove to be a milestone in the treatment of horizontal bone defects.

DISCUSSION

Mechanical weakness of the cement due to the presence of additives like barium sulfate and zirconium oxide is a drawback of using the cement as it may cause the entire foundation to loosen.¹⁵ However, addition of steel fibers, glass fibers, carbon fibers, and titanium fibers improves the mechanical strength,¹⁶⁻¹⁸ while PMMA matrix interspersed with rubber particles can increase the fracture toughness of the material.¹⁹ Embedded stainless steel coil increases the compressive strength of the material,²⁰ but the steel coils may interfere with its usefulness as a reconstructive material in dentulous sites.

Interface integrity, which refers to the strength of bonding of the cement to the bone and the degree of cement penetration, is a critical element in the success of alveolar reconstruction. The addition of glutaraldehyde, an amphiphilic bonder, may lead to significant improvements in the surface integrity and longevity of the cement.²¹

Osteoconduction, a property that allows the migration of osteogenic cells; osteoinduction, the capability of a material to cause the cells adjacent to the implanted site to become osteogenic; and osteogenesis, the ability of the material itself to generate new bone allow for development of a natural bone structure to replace lost bone. This regeneration of new bone would require the addition of bioactive materials and biological factors into the cement. The addition of more than 60% by weight of bioactive ceramic powder into PMMA would make the

cement osteoconductive.²² Bone morphogenetic proteins and transforming growth factor or platelet-rich fibrin, which is a storehouse of growth factors, when added into the cement, would increase its biocompatibility and might also make it osteogenic.²³

The exothermic reaction that occurs during setting of PMMA is hazardous for the survival of the vital tissues adjacent to the implanted material; 1-dodecyl mercaptan²⁴ and N-acetyl cysteine²⁵ are additives that can reduce the polymerization temperature.

Apart from being an exothermic reaction, the polymerization of PMMA utilizes a redox system that produces amine- and benzoate-free radicals. These free radicals can induce local inflammation and modify the activity of macrophages.²⁶

Vitamin E, a free radical scavenger, can be added to PMMA to improve its properties.²⁷ Addition of 10% vitamin E to PMMA reduces peak polymerization temperature without affecting the mechanical strength significantly. It also improves cement cytocompatibility.⁸

Barium sulfate and zirconium oxide, which are used to render the PMMA radiopaque, reduce its mechanical strength.²⁸ But addition of radiopaque ceramic nanoparticles like nanoMgO and nanoBaSO₄ does not have a significant effect on mechanical strength of the material. They also improve osteoblast adhesion; nanoMgO has also been shown to minimize tissue necrosis.²⁹

A site with periodontal disease is a storehouse of microorganisms. Debridement of the site during open flap debridement removes a bulk of the microbiota. However, a minute quantity of the organisms might persist, which in turn can result in the collapse of the implanted material. The addition of certain antibiotics into PMMA would serve to protect the material from microbial attack. Tobramycin and gentamicin can be used as antibiotic additives.³⁰ 2g per 60g or 2g per 40g of Gentamicin has been shown to reduce post-operative infection rates³¹ without a significant alteration in the compressive or diametral tensile strength.⁸ Chitosan nanoparticles have been shown to have significant antibacterial activity against *Staphylococcus aureus* and *Staphylococcus epidermidis* in *in vitro* studies.³² The 1% silver nanoparticles have antibacterial activities against *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, *Proteus mirabilis*, and *S. aureus*. However, there is a reduction in mechanical strength of the cement with the addition of silver nanoparticles.³³

CONCLUSION

Development of a bone cement material that includes all the desired properties while excluding all the undesired properties is a task that requires to be addressed. Further research has to be conducted to ensure the viability of the material for clinical use.

CLINICAL SIGNIFICANCE

Horizontal defects form the majority of periodontal bone defects. Reconstruction of these horizontal bone defects has been a much sought after treatment outcome, yet it remains an elusive target for periodontists. Modified bone cement could prove to be the much required miracle agent in the treatment of horizontal bone defects.

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