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Commentary

Polymethylmethacrylate (PMMA) Bone Cement in Orthopedic Applications

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DESCRIPTION

In order to create a stable cement-bone interface, polymethylmethacrylate bone cement is unable to produce an adhesive chemical bond. Bioactive bone cements have the capacity to connect with bone, but their clinical usage is restricted due to post-implantation bone resorption. While carboxymethylcellulose, alginate, and gelatin microparticles can be used to create porous polymethylmethacrylate to encourage bone ingrowth, the mechanical qualities are insufficient for orthopedic applications. Bone ingrowth into cement may help to provide a solid interface and reduce the likelihood of bone resorption.

For a total joint replacement to be successful there must be a tight bond between the bone and the Polymethylmethacrylate (PMMA) bone cement. Mechanical interlocking plays a major role in the attachment strength of PMMA cement to bone. The surface of the bones must be uneven and rough in order to achieve interlock. Although fitting into the pores of implants and bone can effectively install PMMA cement, a fibrous tissue layer always stands between cement and bone. The layer, often referred to as the weak-link zone, might cause the prosthesis to become loose.

The methyl methacrylate monomer's structure enables solid PMMA to be produced *via* polymerization at room temperature. This reaction is aided by the polymer's propensity to dissolve in monomer and the components, including additives, of commercial cement packets. PMMA's molecular weight varies depending on the sterilization process and among proprietary brands. Gamma radiation causes the polymer chains to shorten, likely altering several mechanical properties, whereas ethylene oxide sterilization does not cause this.

Shear stress (F)/shear rate (S) are used to describe the dynamic viscosity (η) of fluids (η=F/S). If the relationship between shear stress and shear rate is linear, a fluid is said to be Newtonian. In its liquid state during curing, cement exhibits non-Newtonian fluid behavior, with viscosity dropping as shear rate rises. This type of behavior is known as pseudo-plastic or shear thinning. However, when the polymer chains lengthen during polymerization, the viscosity of all cements rises. Manufacturers can change the molecular weight, use co-polymers, and use different sterilizing techniques to change the viscosity of cement. Additionally, the working qualities can be changed by adjusting the ratios of the initiator (Toluidine) and the monomer, which controls the curing process itself.

PMMA polymerization is an exothermic process. By creating free radicals, catalysts can attach to the extending polymer chains by dissolving the monomer's covalent C=C bonds. This reaction generates heat equivalent to 1.4 to 1.7 × 108 J/m^3 of cement at a rate of 52 KJ/mole of monomer.

Using finite element analysis, the heat produced by the curing cement has been examined *in vitro* and *in vivo*. The creation of heat is boosted by thicker cement mantles, higher ambient temperatures, and an increased ratio of monomer to polymer, according to *in vitro* research. Temperatures have been recorded between 70°C to 120°C. A number of scientists have addressed the possibility of thermally damaging bone because collagen denatures when exposed for an extended period of time to temperatures higher than 56°C.

In order to enhance PMMA-based cement-bone interactions, several techniques are used. One of the methods tried is to incorporate various bioceramics into PMMA bone cement in an effort to create bioactive bone cements. Bone, glass, and calcium phosphate substances like hydroxyapatite and tricalcium phosphates have all been explored as bioceramics. Although the bioactive bone cements can adhere directly to the bone, the pre-clinical outcomes are not at all promising. The mechanical and handling qualities of the PMMA cement are negatively impacted by the excessive addition of ceramic powder. Additionally, the bioactive bone cement group has experienced bone loss following implantation, which will gradually jeopardise fixation. This is so that wear debris particles and bone resorption aren't stimulated by the calcium-phosphorous layer that forms on the surface of the bioactive bone cement. Another method is to add Carboxymethylcellulose (CMC), alginate, and Gelatin Microparticles (GMPs) to PMMA bone cement to create porosity. The porous PMMA can encourage the ingrowth of both soft and hard tissue into the substance, increasing interlocking and the PMMA's anchoring.

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