3.1

Properties of Bone Cement: What is Bone Cement?

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Summary

Bone cements based on polymethylmethacrylate are essential products in joint arthroplasty. Originally developed for dental applications, they have been used successfully in arthroplasty surgery for more than 40 years.

Though they seem to be simple cold curing powder/liquid systems, there are many details in which bone cements can differ leading to significantly varying properties.

Acrylic Bone Cements – Bone Cements Based on Polymethylmethacrylate

History

Polymethylmethacrylate (= PMMA) was known in 1902 by the chemist Otto Röhm. As »Plexiglas«, a glass-like hard material, it has been used for many purposes since then. By 1936, the company Kulzer (1936; patent DRP 737058) had already found that a dough can be produced by mixing ground polymethylmethacrylate (PMMA) powder and a liquid monomer that hardens when benzoyl peroxide (BPO) is added and the mixture is heated to 100 °C in a stone mould. The first clinical use of these PMMA mixtures was an attempt to close cranial defects in monkeys in 1938. When these experiences became known, surgeons were anxious to try these materials in plastic surgery on humans. The heat curing polymer Paladon 65 was soon used for closing cranial defects in humans by producing plates in the laboratory and later adjusting the hardened material on the spot [7].

When chemists discovered that the polymerization of MMA would occur by itself at room temperature if a co-initiator is added, the companies Degussa and Kulzer (1943, patent DRP 973 590) by using tertiary aromatic amines established a protocol for the chemical production of PMMA bone cements in 1943; this process is still valid to this day. These studies must be considered the hour of birth of PMMA bone cements.

Judet and Judet [6] were the first to introduce an arthroplastic surgical method. Soon, however, it became apparent that the PMMA (Plexiglas) prosthesis used could not be integrated in the body (for biological and mechanical reasons). In 1958, Sir John Charnley first succeeded in anchoring femoral head prostheses in the femur with auto-polymerizing PMMA [2]. Charnley called the material »bone cement on acrylic basis«. His studies described a totally new surgical technique [3].

PMMA bone cements originally were only cold-polymerized materials based on methyl methacrylate, whereas for some years the term has been used for bone substitute materials, too, hoping to substitute the biologically inert polymethylmethacrylate by biologically active materials.

Note: Historical Development

1901 Thesis of Otto Röhm »Polymerization products of acrylic acid«
1928 Röhm and Haas patented application of PMMA as plastic material
1936 Kulzer patented heat-curable dough
1943 Kulzer and Degussa patented a cold-curing material
1958 Sir John Charnley succeeded in anchoring femoral head prostheses with self-curing cement = bone cement on acrylic basis
Clinical Use and Function

Bone cements are used for the fixation of artificial joints. The cements fill the free space between the prosthesis and the bone and constitute a very important zone. Owing to their optimal rigidity, the cements can evenly buffer the forces acting against the bone. The close connection between the cement and the bone as well as cement and the prosthesis leads to an optimal distribution of the stresses and interface strain energy.

The transfer of the forces bone-to-implant and implant-to-bone is the primary task of the bone cement. The ability to do so reliably for a long time is crucial for the long-term survival of the implant. An adequate cement interdigitation/interlock and reinforcement of the spongious bone are of utmost importance. If the continuous stress from outside exceeds the capability of the bone cement to transfer and absorb forces, a fatigue break is possible [8].

Antibiotic-loaded bone cements are also drug-delivery systems. It is well known that artificial implants are especially susceptible to bacterial colonisation on their surfaces because the germs can then escape the natural protection via the body and cause a periprosthetic infection. When applying antibiotics locally, bone cements can have the function of the carrier matrix.

### Note: Functions of Bone Cements

- Fixation of artificial joints
- Anchoring of the implant to the bone
- Load transfer from the prosthesis to the bone
- Optimal stress/strain distribution
- Release of antibiotics

Composition

PMMA bone cements are offered as two-component systems (powder and liquid). The polymer powder component consists of PMMA and/or methacrylate copolymers (Figs. 3.1 and 3.2). Additionally, it contains benzoyl peroxide (BPO) as initiator of the radical polymerization being included in the polymer beads or simply admixed to the powder. The powder also contains a radiopacifier and optionally an antibiotic (Fig. 3.3).

In the liquid phase methyl methacrylate (= MMA) is the main ingredient and sometimes other methacrylates such as butyl methacrylate (Fig. 3.4).

In order to be used for bone cements the methacrylates must be polymerizable. As a pre-condition for that they must bear a C=C double bond. As an activator for the forming of radicals the liquid contains an aromatic amine, such as N,N-dimethyl-p-toluidine (DmpT). Additionally, it contains an inhibitor to avoid a premature polymerization during storage and optionally a coloring agent (e.g. chlorophyll with Palacos).