Cementation

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Introduction

- PMMA use started as early as **1960s**
- Introduced by Sir John Charnley
- Used for fixation of endoprosthesis
- Bone cement most common non-metallic implant material
- **IT IS NOT A GLUE**
Mechanical Properties

- Poor tensile strength of 25 Mpa
- Moderate shear strength of 40 Mpa
- Strongest in compression of 90 Mpa
- Brittle, notch sensitive
- Low Young’s modulus of elasticity \((E) =2400\) Mpa
- Viscoelastic
Allows secure fixation; implant to bone

It’s not glue; no adhesive properties

Mechanical interlock; space filling

Load transferring material (elastic buffer)
Composition

- Two component system
  - Polymer powder
  - Monomer liquid – MMA
Polymer Powder

- PMMA
- Spherical granules
- Initiator benzoyl peroxide (BPO) 1%
- Radio-opaque material (BaSO4 / ZrO2)
<table>
<thead>
<tr>
<th>Constituent</th>
<th>CMW-1</th>
<th>CMW-3</th>
<th>Palacos R</th>
<th>Simplex P</th>
<th>Zimmer LVC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POWDER COMPONENTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzoyl peroxide (BPO)</td>
<td>2.60</td>
<td>2.20</td>
<td>0.5-1.6</td>
<td>1.19</td>
<td>0.75</td>
</tr>
<tr>
<td>Barium sulphate (BaSO₄)</td>
<td>9.10</td>
<td>10.00</td>
<td>-</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Zirconium dioxide (ZrO₂)</td>
<td>-</td>
<td>-</td>
<td>14.85</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>-</td>
<td>-</td>
<td>200 ppm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PMMA</td>
<td>88.30</td>
<td>87.80</td>
<td>-</td>
<td>16.55</td>
<td>89.25</td>
</tr>
<tr>
<td>PMMA-Methacrylic acid (P(MMA/MA))</td>
<td>-</td>
<td>-</td>
<td>83.55-84.65</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PMMA-styrene copolymers P(MMA/ST)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>82.26</td>
<td>-</td>
</tr>
<tr>
<td><strong>LIQUID COMPONENTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NN Dimethyl P Toluidine (DmpT)</td>
<td>0.40</td>
<td>0.99</td>
<td>2.13</td>
<td>2.48</td>
<td>2.75</td>
</tr>
<tr>
<td>Hydroquinone</td>
<td>15-20 ppm</td>
<td>15-20 ppm</td>
<td>64 ppm</td>
<td>75 ppm</td>
<td>75 ppm</td>
</tr>
<tr>
<td>Mehtylmethacrylate (MMA)</td>
<td>98.66</td>
<td>98.07</td>
<td>97.87</td>
<td>97.51</td>
<td>97.25</td>
</tr>
<tr>
<td>Ethanol</td>
<td>0.92</td>
<td>0.92</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ascorbic Acid</td>
<td>0.02</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>-</td>
<td>-</td>
<td>267 ppm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gentamicin sulphate</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Polymerization process (Curing)

- Mixing phase
- Waiting phase (Dough Time)
- Working phase
- Hardening phase
Curing process time periods

- **Dough time**: from mixing >> till it becomes non sticky
- **Setting time**: starts when surface temperature is half Maximum
- **Working time**: difference between dough and setting time
On the use of bone cements
Four different phases are distinguished:

Setting phase
– chain growth finished,
– no movability,
– cement hardened,
– high temperature

Working phase
– reduced movability,
– increase of viscosity
– heat generation;

Waiting phase
– cement less liquid,
– less movable;

Mixing phase
– wetting and polymerization,
– cement relatively liquid (low viscous),
• 02 Cementation-Mixing Phase and Waiting Phase.mp4

02 Cementation-Mixing Phase and Waiting Phase.mp4
• 03 Cementation Dough Time and Working Time.mp4

03 Cementation Dough Time and Working Time.mp4
• 04 Working Time and Setting Time.mp4

04 Working Time and Setting Time.mp4
Intraoperative Cementation (1).mp4
Intraoperative Cementation (2).mp4
COMPARISON OF PHASES IN OVERALL SETTING TIME
OVERALL SET TIME (IN MINUTES) AT 65°F

HIGH VISCOSITY

CEMENTS

MEDIUM VISCOSITY

0 MINUTES

10 MINUTES

15 MINUTES
Polymerization process (curing)

- Carbon-to-carbon double bonds broken
- New carbon single bonds form
- Long-chain polymers
- Linear, free of cross-linking
- Exothermic reaction
- Volume shrinkage (7%)
Factors affecting cement curing

- Temperature:
  - Increases in room temperature shorten both
    the dough and setting times by 5% per
    degree centigrade
ISO 5833 requirement

..that a graphical representation of the effect of Temperature on the length of the phases in Cement curing, prepared from experimental data, on the particular brand of cement, be provided.
Mechanical Properties

- Creep
  - Time-dependent deformation under constant load
  - Creep rate reduces with time
  - Load of daytime activities causes creep
Stress relaxation

- The change in stress with time under constant strain caused by a change in the structure of the cement polymer

- At night reduced load allows stress relaxation
Loading and stress relaxation

Stem in cam, no load.

Load applied, stem engages (subsides) Cross section of stem enlarges leading to radial compression and hoop tension.

Load reduced, stem remains in place. Stress relaxation of hoop tension. Compression remains.
Cementing techniques

- **First generation**
  - Original technique of Charnley:
    - Hand mixing of the cement
    - Finger packing of cement in an unplugged and uncleaned femoral canal and acetabulum
    - No cement restrictor, no cement gun and no reduction in porosity
Second generation

- Femoral canal plug
- Cement gun / retrograde filling
- Pulsatile lavage
Third generation

- Pressurization of cement after insertion
- Some form of cement porosity reduction (vacuum or centrifugation)
- Surface changes to the implant
Universal agreement does not exist regarding the benefits of porosity reduction via centrifugation or vacuum mixing. Though in vitro studies have identified the increase in fatigue strength with centrifugation or vacuum mixing, the clinical significance of porosity reduction was questioned in the face of surface irregularities.

Rimnac et al. suggested that the existing cracks and surface imperfections may supersede any benefits from porosity reduction.


Cementing technique should:

- maintain a pressure
- above the bleeding pressure in the femoral canal,
- without leading to embolisation and
- cardiovascular instability.
Types of Cements: Viscosity

**Low viscosity:**
- long-lasting liquid
- long mixing phase,
- short working phase

**High viscosity:**
- short mixing phase
- loose their stickiness quickly
- longer working phase
Low Viscosity Cements

- Zimmer® Osteobond
Medium Viscosity Cements

- DePuy® SmartSet® MV Endurance™
- Simplex™ P.
- Simplex™ P with Tobramycin
- Simplex™ P SpeedSet™
High Viscosity Cements

- Palacos® R,
- DePuy® 1 (CMW®),
- DePuy® SmartSet® HV, and
- Biomet® Cobalt™. High viscosity
High Viscosity Cements

• Become *doughy too quickly* !!

• Can be *difficult to mix* hindering the release of entrapped air. This may *increase porosity* and consequently reduce fatigue strength.

• *High viscosity* cements *cannot be pressurized* as easily as *Medium viscosity* cements.
Greater Intrusion Depth of Bone Cement Leads to Improved Fixation and Greater Shear Strength

Is low viscosity beneficial?
The low viscosity dough might not withstand the bleeding pressure....

→ **Blood entrapment within the cement** leads to potential areas of weakness

→ **Increased fracture risk.**
Problem with Low Viscosity Cements

- This phenomenon is the main problem when applying low viscosity cements with their “short application phase”.

- Medium or high viscosity cements in this regard seem to be more user-friendly and forgiving, resulting in better long-term performance.
Cement viscosity has also been examined to determine its clinical role in cemented total hip arthroplasty. Clinical studies examining cement viscosity are sparse.

The largest series is based on the Norwegian Total joint Registry of 17,323 primary Charnley total hip replacements.

Of 17,323 primary Charnley total hip replacements, there was a significantly increased rate of revision of femoral components for loosening with low-viscosity cement.

The 10-year survivorship for low-viscosity cement was 83% versus 92% to 97% for high-viscosity cement!!!

The authors stated that this particular low-viscosity cement is no longer used due to such poor results.

Antibiotics & Bone Cement

- Aminoglycosides are drug of choice:
  - Their action
  - Stability in high temperatures
  - Shelf life
  - Vancomycin, Gentamicin, and Tobramycin
  - 0.5 g Ab/40 Gm cement affects mechanical properties
## How to mix antibiotic in bone cement

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate container (sterile)</td>
<td><strong>Step 1</strong> The whole amount of sterile antibiotic powder is transferred into the container under aseptic conditions</td>
</tr>
<tr>
<td>Spatula (sterile)</td>
<td><strong>Step 2</strong> The same amount of PMMA powder is added to the antibiotic powder</td>
</tr>
<tr>
<td></td>
<td><strong>Step 3</strong> Both quantities are mixed well</td>
</tr>
<tr>
<td></td>
<td><strong>Step 4</strong> The same proportion of PMMA powder as it is now in the container is added</td>
</tr>
<tr>
<td></td>
<td><strong>Step 5</strong> Both quantities are mixed well</td>
</tr>
<tr>
<td></td>
<td><strong>Step 6</strong> Steps 4 and 5 are repeated until no PMMA powder is left</td>
</tr>
<tr>
<td></td>
<td><strong>Step 7</strong> MMA Monomer liquid is added and the procedure is continued in compliance with the manufacture's instructions</td>
</tr>
</tbody>
</table>
Gentamicin and Clindamycin is a combination known to have a Bactericidal effect on more than 90% of the bacteria common to Infected Arthroplasty Cases.
The anatomy of an innovation

**Powder**
The polymer is pre-packed in the cylinder.

**Liquid**
The monomer is contained in aluminum pouches.

**Connection to vacuum pump**

**Blue holders to inject monomer into the powder**