BONE CEMENT IN ORTHOPAEDICS

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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

Indications

- Joint Replacement Surgery
- Spinal Compression Fractures
- Chronic Osteomyelitis
- Tumours

Working In Arthroplasty

- Allows secure fixation; implant to bone
- It's not glue; no adhesive properties
- Mechanical interlock; space filling
- Load transferring material (elastic buffer)

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

Functions in Joint Arthroplasty

- Fixation of implant component in bone
- Transmission of load from the component into bone
- Maintenance/restoration of bone stock

Composition

- Two component system
  - polymer powder
  - monomer liquid – MMA

Monomer Liquid

- MMA
  - Clear
  - Colorless
  - Flammable
  - Intense odour
  - Ester of methacrylic
  - Boiling point 100^0C
  - Activator, *N,N-dimethyl-p-toluidine (DMpT)*
  - Stabilizer, Hydroquinone

Polymer Powder

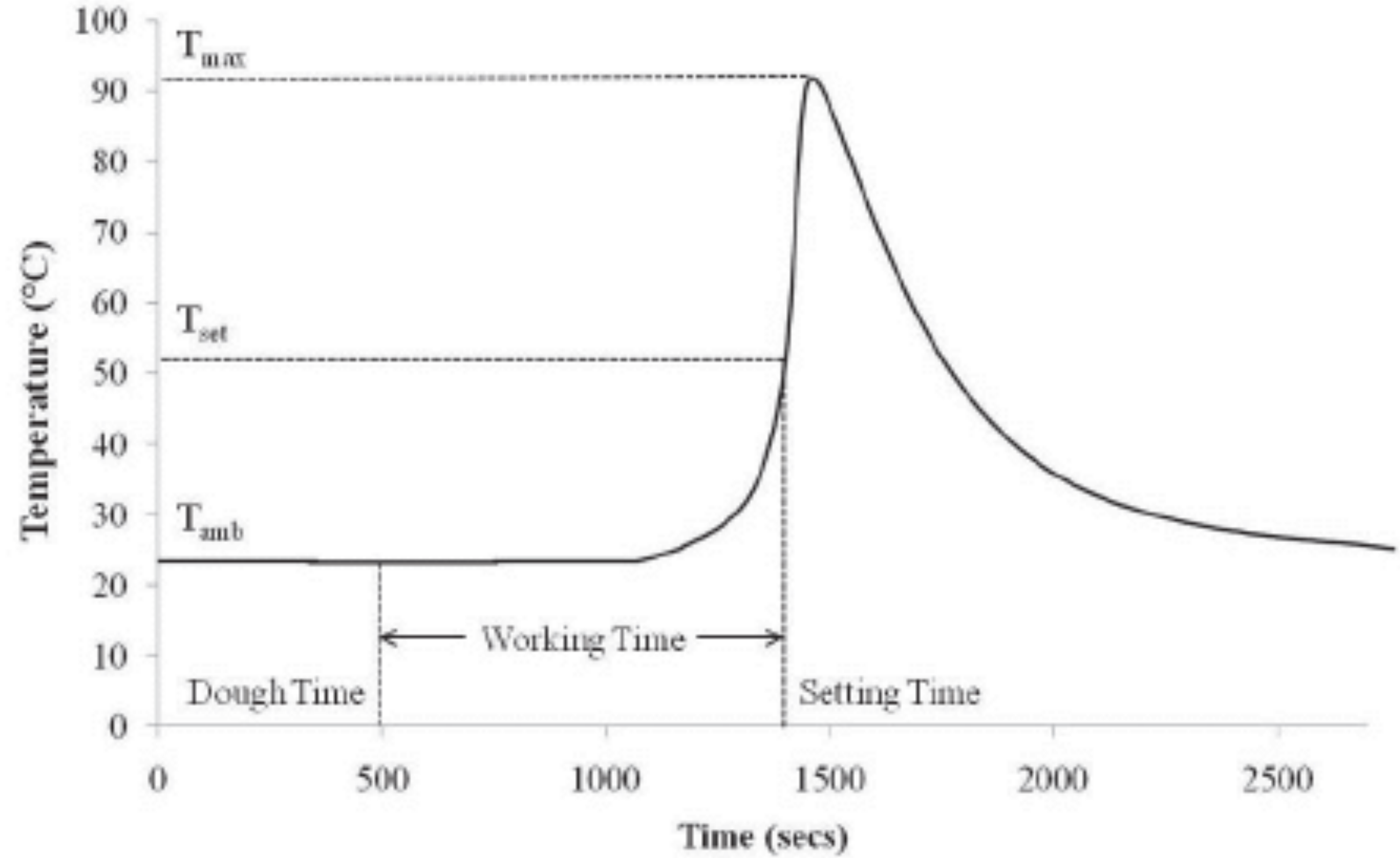
- PMMA
  - Spherical granules
  - Initiator benzoyl peroxide (BPO) 1%
  - Radio-opaque material ($BaSO_4$ / ZrO_2)

Constituent	CMW-1	CMW-3	Palacos R	Simplex P	Zimmer LVC
POWDER COMPONENTS					
Benzoyl peroxide (BPO)	2.60	2.20	0.5-1.6	1.19	0.75
Barium sulphate ($BaSO_4$)	9.10	10.00	-	10.00	10.00
Zirconium dioxide (ZrO_2)	-	-	14.85	-	-
Chlorophyll	-	-	200 ppm	-	-
PMMA	88.30	87.80	-	16.55	89.25
PMMA-Methacrylic acid (P(MMA/MA))	-	-	83.55-84.65	-	-
PMMA-*styrene* copolymers P(MMA/ST)	-	-	-	82.26	-
LIQUID COMPONENTS					
NN Dimethyl P Toluidine (DmpT)	0.40	0.99	2.13	2.48	2.75
Hydroquinone	15-20 ppm	15-20 ppm	64 ppm	75 ppm	75 ppm
Mehtylmethacrylate (MMA)	98.66	98.07	97.87	97.51	97.25
Ethanol	0.92	0.92	-	-	-
Ascorbic Acid	0.02	0.02	-	-	-
Chlorophyll	-	-	267 ppm	-	-
Gentamicin sulphate	-	-		-	-

Table 1. Compositions of six commercial formulations of bone cement (Lewis 1997).

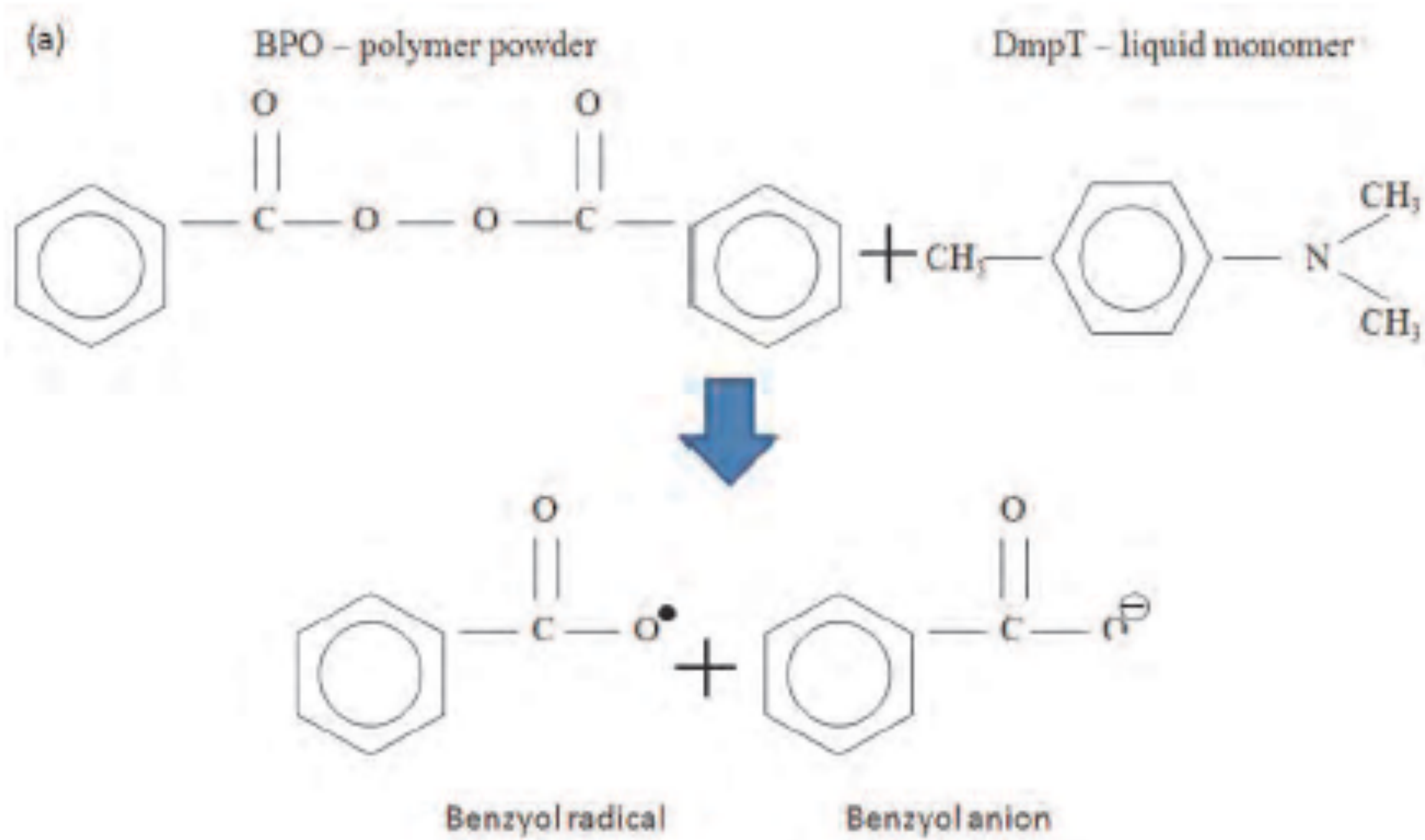
Polymerization process (curing)

- carbon-to-carbon double bonds broken
- new carbon single bonds form
  - long-chain polymers
  - linear
  - free of cross-linking
- exothermic reaction
- volume shrinkage (7%)

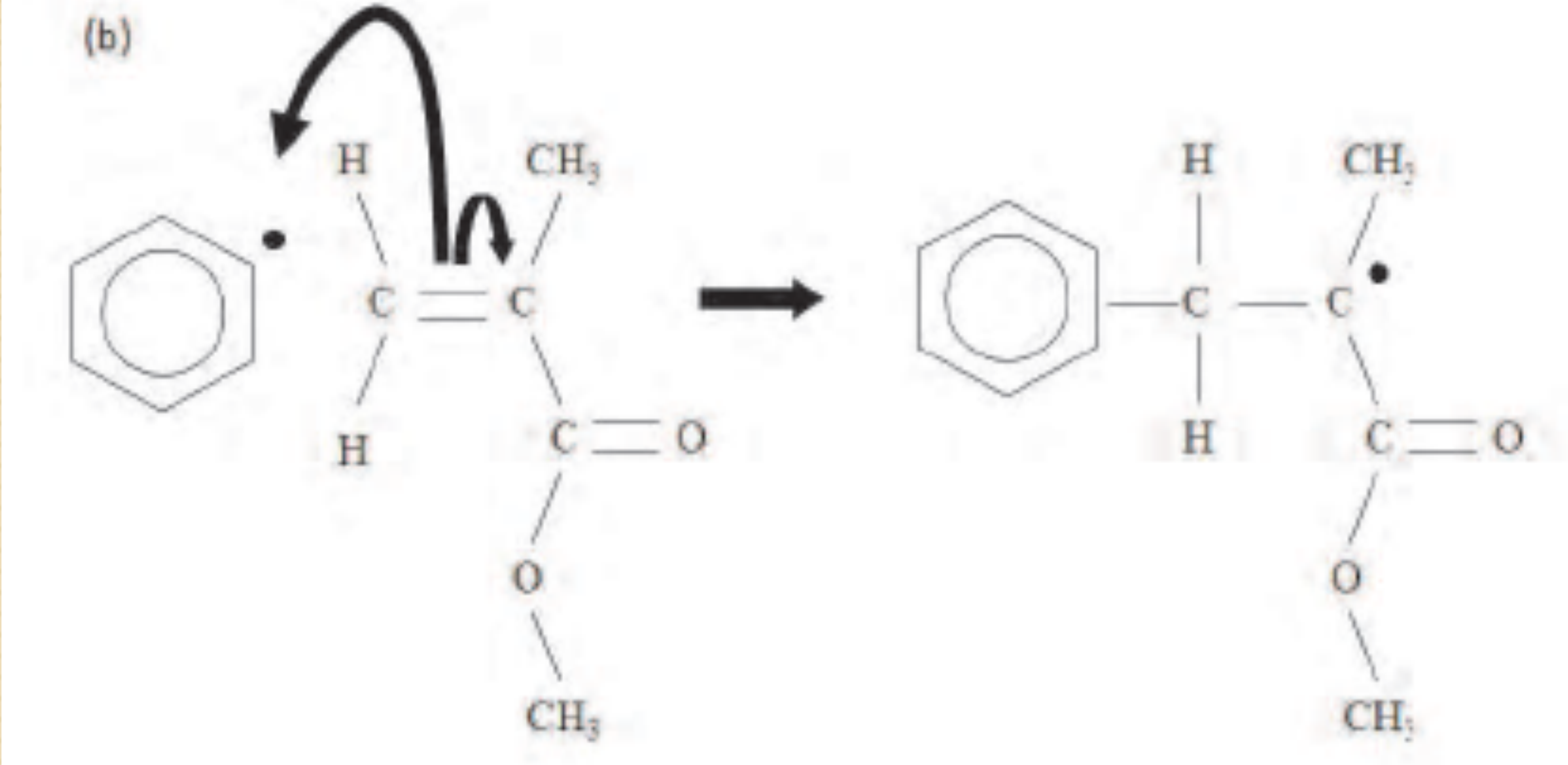


A typical curing curve for acrylic bone cement where Tmax is the maximum temperature reached, Tset is the setting temperature and Tamb is the ambient temperature.

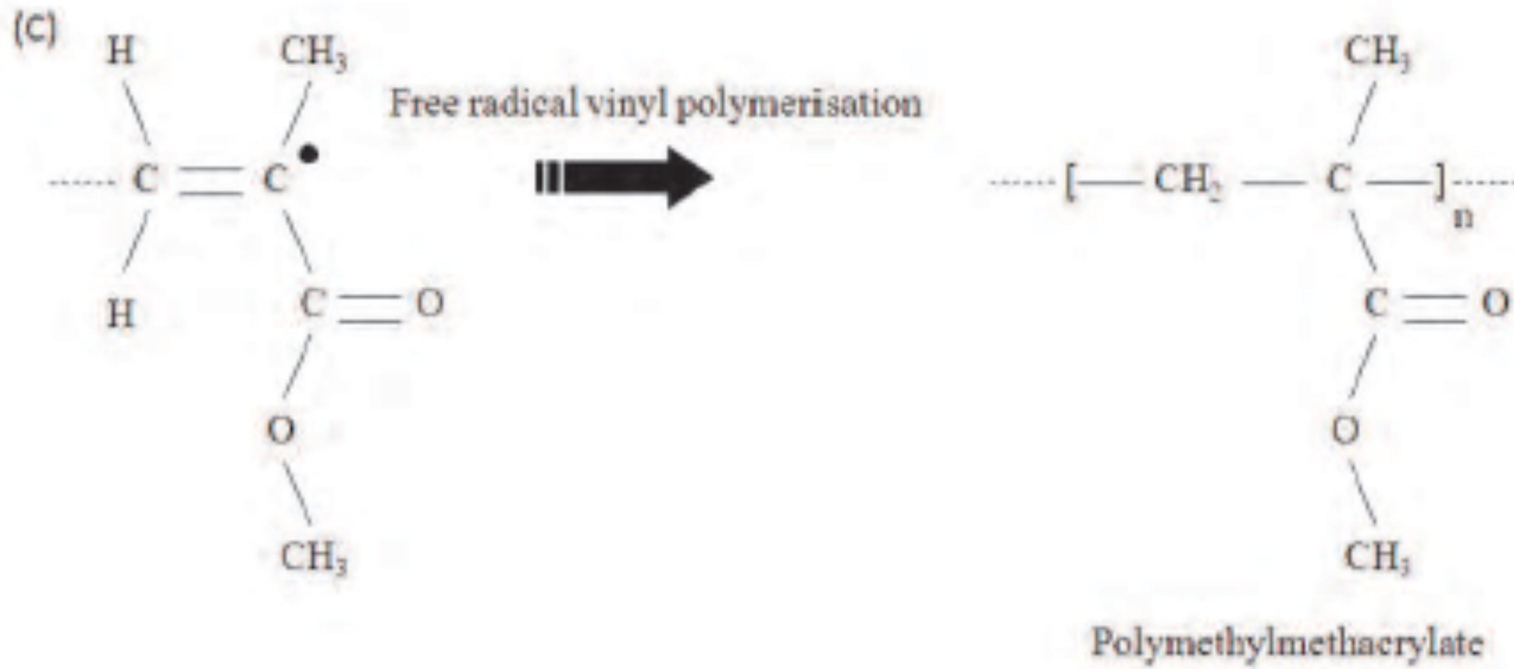
- Initiator BPO + Activator DMpT = free radicals
- Results in growing polymer chain
- When two growing polymer chains meet the chains are terminated



(a) Schematic diagram showing the decomposition of BPO leaving a benzoyl radical and a benzoyl anion



(b) How these benzoyl radicals initiate polymerisation of MMA



(c) formation of a polymer chain.

Curing process time periods

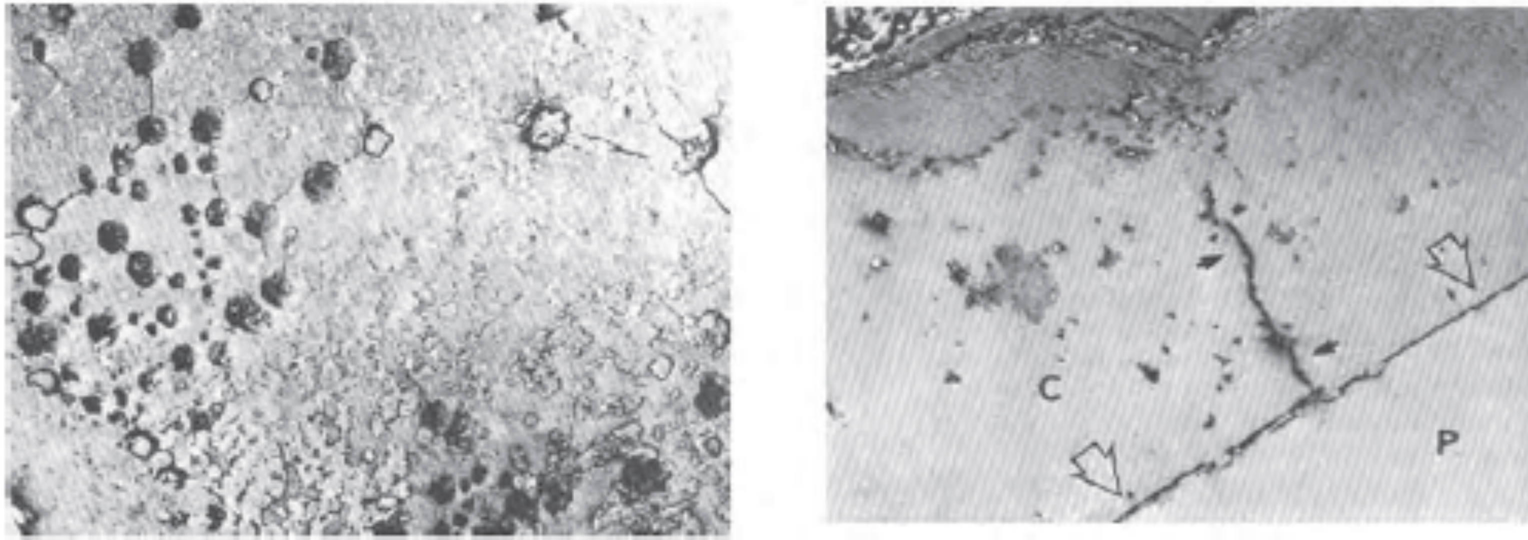
- Dough time: mixing >> non sticky
- Setting time: mixing >> surface temperature is half maximum
- Working time: difference between dough time and setting time

Factors affecting cement curing

- Temperature:
  - Increases in room temperature shorten both the dough and setting times by 5% / degree centigrade

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



Scanning electron micrographs showing

(a) micro fractures through pores near distal end of prosthesis and

(b) (b) an incomplete fracture through the cement mantle originating at the cement-prosthesis interface, Jasty et al. (1991).

- Second generation
  - Femoral canal plug
  - Cement gun to allow 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

Mechanical Properties

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

- Fatigue
  - Effect of repeated load cycles below failure in a single-application load
  - Usually 10^6 cycles at half-ultimate stress will produce fatigue failure

- 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

Antibiotics & Bone Cement

- Aminoglycosides are drug of choice:
  - their action
  - stability in high temperatures
  - shelf life
  - vancomycin, gentamicin, meropenem, and tobramycin

- 0.5 g Ab/40 g cement affects mechanical properties

The Dangers

- hypotension
- cardiac arrest
- cerebrovascular accident
- pulmonary embolus
- hypersensitivity reactions

Thank You