BONE CEMENT AND CLINICAL APPLICATION IN SPINAL SURGERY

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Acrylic cement has been used in orthopaedics since its introduction by Sir John Charnley in 1958. In 1959 Knight reported using self-curing MMA to stabilize the spine, and it has remained an important tool for fixation of bone implants.

The basic MMA polymer formula is $C - CH^2 - C(CH^3).COO(CH^3)$ which consists of seperately liquid monomer and sterile polymer power. The power of PMMA is composed of two forms of PMMA, one consisting of tiny spherical beads and the other of finely ground amorphous PMMA. Polymerized cement has a biphasic structure, consisting of aggregates of small spheres or granules of the powder polymer together by liquid monomer. The balls of polymer 10-80 um in diameter are responsible for the semicircular impression on the surface of endosteal bone.

CEMENT-BONE INTERFACE

PMMA is a cement and not a glue. The bonding between PMMA and bone is not one of adhesion but is based on the interdigitation of cement particles and bone trabeculae with the two being separated by a thin layer of fibrous tissue. Generally, PMMA is used as a space filling for transfering load and decrease stress concentration area for the implants.

MECHANICAL AND PHYSICAL PROPERTIES

PMMA has compressive strength 15,000 psi (50% cortical bone) Tensile strength 10,000 psi (25% cortical bone) and Modulus of elasticity 0.3×10^6psi (15% cortical bone). Because of the viscoelastic properties of PMMA, it becomes stiffer and stronger at a higher strain rate than at a low strain rate.

FACTORS AFFECTING MECHANICAL PROPERTIES OF BONE CEMENT

1. Porosity of Cement

It has been estimated that the method of cement preparation affects shrinkage, density and porosity of cement. Cement porosity is caused by the presence of air spaces between poly beads and formation of bubbles during cement mixing, voids may result from evaporation of monomer and thermal expansion of bubbles. A low viscosity cement contains fewer macropores since such cement allows large bubbles to escape. Porosity plays a major role in determining the tensile and fatigue strengths of PMMA.

Porosity of cement can be reduced by centrifugation, under partial vacuum, ultrasonic vibration and pressureization etc. Centrifugation is effective in low viscosity cement such as Simplex P, centrifugation can reduce the porosity from 10% to 5%. A partial vacuum between 400-730 mm Hg below atmospheric pressure reduces the porosity to 1%.

A partial vacuum at 500-550 mm Hg at slow speed (2Hz) is most effective in eliminating most porosity in most cements tested.

2. Cement Thickness

Because of the relative weakness of cement in shear and tension, it is used in bulk and in thickness sufficient to withstand applied forces. A thick layer also generates a greater exothermic reaction, and greater cytotoxicity.

3. Contamination by Blood, Fat and Debries

Contaminants can also increase stress after polymerization. In one study, they reduced the ultimate compressive stress between 8-16% and reduces tensile and shear strength by as much as 77% and 69%.

4. Mixing Technique

Rapid beating of cement before polymerization increases porosity, thus lowering its strength.

5. **Layering of Cement**

It occurs during the late stages of polymerization, which influence by lacking of pressure on the cement.

6. **Environoment Effects**

High temperature and high moisture can reduce the cement strength.

7. **Additives**

Their effect is based on the ratio of additives to the quantity of cement used. Radiopaque materials 2.5 gm/40gm powder or antibiotics 1-2 gm/20 gm powder can be mixed with cement without any serious effect.

8. **Load Bearing Capacity**

Poor prosthesis design with the sharp corners will cause the high stress to the cement to fail.

9. **Viscosity of Cement**

The low viscosity cement has less porosities during preparation.

10. **Aging and Fatique**

It has been found that the strength increased in the first week and then gradual reduction in strength, over10 years was approximately 10%.

11. **Bone Strength and Fixation Strength**

The loosely attached and fragile trabeculae can not withstand the stresses that affect a heavily load. Proper cleansing and removal of soft cancellous bone enhance fixation.

12. **Cement Bone Interface**

Low viscosity cement and pressurization increase the strength of the interface.

SYSTEMIC AND LOCAL SIDE EFFECTS

1. Intraoperative hypotension and cardiac arrest

By study of Berman, Concludes that the monomer influenced arterial blood pressure and cardiac out put as well as peripheral resistance.The monomer produced vasodilatation of the small blood vessels.

Mc Master found that peripheral vasodilatation with myocardial depression is the main mechanism and inadequate blood replacement was a predisposing factor in the severe blood pressure lowering effect.

However, controversy still exists as to the cause of death. Many intraoperative deaths are reported related to the insertion of acrylic cement, which usually immediately, about 30-75 seconds follows application of the cement into the medullary cavity of the femur, always precedes the appearance of monomer in the serum. By autopsy, almost of these cases found fat and narrow emboli. Kallas found that insertion of cement into the femoral shaft resulted in medullary pressure up to 900 mm Hg with the appearance of medullary contents in the lung within 10-120 seconds. Thus, is seems that cardiovascular changes result from embolization of fat and narrow contents, which initiate aggregation of platelets and fibrin in the pulmonary circulation.

To prevent this phenomenon, Kallos suggest drilling the shaft (distal venting) to release the pressure. Charnley prefer to have the anesthetic agents discontinued 2-3 minutes and maintained on pure oxygen at the time of cement insertion and keep the patient normotensive and normovolemia before insert cement, with this technique 12,000 low friction hip arthroplasty have no significant hypotension or cardiac arrest.

2. Anaphylaxin Release

Anaphylaxin (C3A & C5A) have been found in the plasma in which acrylic cement is used.

3. Intra Articular Lodgement

PMMA can lodge between the articular surfaces, resulting

in an accelerated wear rate.

4. Effects of Chemotaxis on PMN Leukocytes

Using PMMA made patients more susceptible to infection, by depression of chemotaxis.

5. Liver Dysfunction

Rising of SGGT correlated with the amount of cement used.

By the bonding between PMMA and bone is based on the interdigitation of cement particles and bone trabeculae. PMMA is less effective in resisting tensile loading than it is in withstanding compression. With PMMA in spinal surgical construct, it may be employed as a spacer, an internal splint or a fixation device.

The Principles in the use of PMMA in spine surgery

1. Consider the use of bone before bone cement.
2. Determine immediate and long need of stability.
3. Develop technical knowledge and ability to design a construct.
4. Use wiremesh to maintain to dura.
5. Reinforce cement with mesh wire or pins.
6. Provide vertebra with holes, pins, screws and wires for interdigitation of bone and cement.
7. Bone grafting of survival more than 12 months.