Relevance to Musculoskeletal Conditions: Understanding of the attachment between bone and implanted materials might lead to better joint replacements.

Introduction: The interfacial attachment of an implant material relates to surface roughness and surface chemistry. To determine the contribution of chemical mechanisms in bioactive bone cements, the contribution of microinterlock needs to be known first. To solve problems associated with polymethylmethacrylate cement, so-called bioactive bone cements have been developed by adding a bioactive powder or hydroxyapatite to bone cement. It is thought that a higher interfacial strength resulting from chemical bonding to the hydroxyapatite might prevent aseptic loosening. The magnitude of such a chemical bond is hard to establish. Studies involving only the bioactive material itself revealed comparatively low interfacial tensile strengths such as 0.15 MPa to 1.5 MPa for bone bonded to hydroxyapatite. If a bioactive material can be expected to yield only a moderate tensile strength, this becomes less important if microinterlock of bone cement is just as strong. This study describes the tensile strength between newly formed bone and an unpolished methacrylate surface.

Materials and Methods: The pull-away plate consists of a flat circular cp. titanium cylinder held against the bone by a holder. For the present study it has been modified to hold the cement like a fill in a tooth. The holder surrounds the pull-away plate so that it could have contact with the tissue only at its flat cement surface (Figure 1). Palacos® R bone cement was chilled to 6°C prior to mixing. The vacuum mixed (15 kPa) bone cement was 'finger packed' into the hollow pull-away plates under sterile conditions and then either polished or left untreated after curing within the plates. The plates were inserted after the cement had cured. The surface roughness of the polished specimens was Ra, 0.05µm and a Rmax 3 µm. The unpolished specimens had a surface roughness of Ra, 5 µm and Rmax, 28 µm. 20 Sprague-Dawley rats were operated on at the proximal tibia. A depression in the tibial cortex was milled out corresponding to the contact area of the pull-away plate, and the construction was implanted. Thus new bone would form and make contact with the cement surface. After 4 weeks the animals were sacrificed and the top screw and the hood were removed from the holder, so that a wire loop on the pull-away plate could be reached. Traction was applied to the implanted plate through a metal hook attached to the loop. The detaching load was then measured as the peak force when the plate loosened from bone.

Histological sections were produced at a right angle to the test surface, through the middle of the circular surface.

Figure 1: Pull-away plate with cement fill in holder during implantation time and detachment load measurement.

Results: The detaching loads of the unpolished samples had a median of 0.28 MPa whereas the polished samples had a median of 0.01 MPa (Mann-Whitney U-test; p=0.0001, Table 1). Histologically the polished samples usually had a smooth cortical bone lamella at the interface, in some areas with fibrous tissue attached, whereas in the unpolished specimens the shape of the interface was more irregular with suspected fractures, digit-like bone formation and less fibrous tissue.

Discussion: The interfacial attachment strength of PMMA bone cement appears to depend on its interdigitation with bone on a macroscopic and microscopic level. The use of bone cement has already been shown to result in direct bony contact at both levels. Our study demonstrated only the mechanical attachment strength of the microscopic interlock since the plate surface was macroscopically flat. The difference between a rough and a polished surface reflects the tensile strength of the interlock. Recently bioactive bone cements have been developed. Glass or glass ceramic powder has been added to PMMA bone cement. Other types of cements are based on calcium phosphate materials. Few studies have investigated relationships between interfacial tensile properties and surface roughness of the implanted material. Edwards et al. found mean interfacial strengths of only 0.2±0.1 MPa at 55 days for dense hydroxyapatite disks with a surface roughness of 0.32 µm (Ra) implanted in rabbit tibia. Tamura et al. reported mean interfacial strengths from 0.5 to 0.7 MPa for different bioactive bone cements with a surface roughness around 0.3 µm (Ra) 10 weeks after implantation in rabbit tibias. Gross et al. suggested a direct relationship between roughness and bone-implant interfacial tensile strength for bioactive ceramics. When measuring tensile attachment strength for biological tissue to bioactive glass-ceramic, mean tensile strength values increased from 0.8 to 1.1 MPa as the roughness value Ra increased from 0.06 to 52µm. The overall pattern of the data agrees with the hypothesis that material roughness has a direct and considerable effect on pull-off strength values.

Conclusion: The cement-bone interfacial tensile strength is of the same magnitude as the attachment strength of bioactive materials with similar surface characteristics. Therefore the relative contribution of chemical mechanisms in bioactive bone cements remains to be elucidated.

References:
4. Mirichi et al., Calcium phosphate cements: Biomaterials 1989; 10; 475
6. Supported by the Swedish Medical Research Council (2034)

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