MECHANICAL CHARACTERISTICS OF THE BONE-GRAFT-CEMENT INTERFACE AFTER IMPACTION ALLOGRAFTING

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Introduction
Impaction allografting is an attractive procedure for the treatment of failed total hip replacements (THR). However, high prevalence of stem subsidence (>10 mm) have been associated with this procedure. From a mechanical perspective, stem subsidence can occur through failure of any material between the stem and the cortex or any of the interfaces between materials. Although important for the success of any THR, the interface between the host cortex and the graft material has not been addressed for the impaction allografting technique. The interface morphology at the endosteal surface after impaction allografting was determined recently by histological analysis of cadaveric femurs. In addition to the impacted allograft-host bone interface, an impacted allograft-cement composite-host bone interface was identified. Given these variations of interface morphology, we hypothesized that the mechanical characteristics of the impacted allograft-host bone interface would exhibit substantial differences along the length of the stem and that the degree of cement penetration of the endosteal cortex would explain a significant percentage of the variation.

Methods
The femoral necks from six fresh frozen human cadaveric femora were osteotomized. Using a high-speed burr the cancellous bone was removed from the proximal femoral metaphysis and local diaphyseal lytic defects were created. The endosteal surface roughness achieved was similar to that of a femur in a revision total hip arthroplasty as judged by two experienced surgeons. Three surgeons performed the impaction allografting procedure, each on two cadaveric femora using the Zimmer Change revision system (Howmedica Inc, Rutherford, NJ, USA). After impaction of the morsellized allograft bone, two packages of low viscosity Simplex cement (Howmedica Inc, Rutherford, NJ, USA) were mixed and injected into the neo-medullary canal. After the canal had been filled in a retrograde manner, a proximal femoral seal was applied and the cement pressurised with a cement gun. The pressure was maintained until the viscosity of the cement was appropriate for the insertion of the double tapered polished collarless Exeter stem (Howmedica Inc, Rutherford, NJ, USA). The femurs were cut in 6mm thick transverse sections with a diamond saw. Anatomical landmarks and the tip of the stem were used to match every other section to seven levels (Figure 2). Push-out tests were performed on these sections to mechanically characterise the impacted allograft/composite-host bone interface. From the recorded load-displacement curves, the failure load was defined as the point where a zero slope was reached the first time.

Results
The apparent shear strength was significantly different among the levels with the highest shear strength at level 3 and lowest at levels 6 and 7 (p<0.02) (Figure 2). 69% of the sections exhibited a pure interface failure (Type I) without composite or graft layer failure. Local cement failure (Type II) was found in 19% of the sections and 12% of the sections showed local graft failure (Type III). Sections with Type II failures were significantly stronger compared with Type I and Type III failures. The apparent interface shear strength was significantly correlated with the percentage cement contact (%c), with the relationship explaining 52% of the variance.

Discussion
The impacted allograft-host bone interface and/or the impacted allograft-cement composite-host bone interface is a potential site of subsidence for this revision hip reconstruction. The correlation between the interface shear strength and percentage cement contact (%c) showed that cement penetration up to the endosteal surface increases the strength of the interface. In the sections of the Type II failures, the cement was able to interdigitate with local remnants of trabecular bone or the rough, porous cortex resulting in local failure of the cement with significantly increased apparent interface strength. This investigation showed that mechanical interface properties vary significantly along the femur due largely to different interface morphologies. Although, cement-endosteal surface contact enhanced the allograft-cement composite-bone interface strength, it was significantly weaker compared to a primary THR. However, bone ingrowth would be expected to enhance the interface properties which might be the key to the success of the impaction allografting technique.

Reference
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