The effect of the addition of hydroxyapatite to morcellised bone graft upon femur cortical strain and implant stability

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In vitro biomechanical studies using tube and taper, synthetic femoral and acetabular models have demonstrated that the addition of bone graft substitutes, such as hydroxyapatite (HA), to bone graft leads to either a decrease in femoral prosthesis subsidence or increased stability of an acetabular cup.

While the decrease in subsidence with the addition of bone graft substitutes looks encouraging, one rather worrying report raised the possibility of an increased risk of femoral fracture in a cadaveric femur during the impaction of a bone graft:hydroxyapatite mixture.1 This was hypothesized to be due to a greater transmission of force to the femoral cortex via the HA and may lead to an increased fracture risk.

The aim was to compare a 1:2 mixture of bone:HA with pure bone algolraft in a revision hip arthroplasty model. This was undertaken to investigate if difference exist in cortical hoop strain between the different bone:hydroxyapatite mixes that might account for the reported increased risk of femoral fracture and if the addition of bioceramic can lead to less subsidence than bone while using a lower impaction force.

Materials and methods

The femoral models used were large left generation composite femurs, Sawbones, Sweden). These have been shown to have mechanical properties similar to that of human femora. They were prepared to represent a femur with bone loss similar to that seen at revision surgery. The femoral head was removed with a power saw with the position of the neck cut being standardised by a template before mounting on an intramedullary post. All of the interstitial foam was then removed from the shaft of the femur by a combination of power and hand tools. A total of 12 uniaxial strain gauges were attached at set points to each femur using cyanoacrylate adhesive and positioned at 0, 90, 180 and 270 degrees around the shaft of the femoral model. The strain gauges were aligned to measure the strains perpendicular to the medullary axis of the femur (hoop strain).

The mounting devices of the Instron serohydraulic machine were modified to accept the X-Change 2 instruments (Stryker Howmedica Osteonics). Graft material was introduced in small quantities and impaction was performed using distal and proximal impaction, 2 distal impaction cycles and 4 proximal impactions for 60 impactions each.

Study groups

The study consisted of four experimental groups. The first two tests used 100% bone graft. The first group was impacted using a force of 1.98 kN (equivalent to the physiological stress in the acetabulum during walking for a 80 Kg person); the second was impacted at 3.63kN. Test 3 and 4 used a 1:2 mixture of bone:HA, of either porous HA (pHA) (1B:2pHA, test3) or non porous HA (npHA) (1B:2npHA). These mixes were chosen to correspond to the largest proportion of HA:bone used clinically. 6 samples of each group were performed.

Endurance testing

The potted femur was loaded in a manner to represent the physiological walking cycle (1.98kN). The displacement of the femoral head during loading was measured by two displacement transducers (LVDT) were mounted on aluminum brackets to measure vertical displacement and rotation. The loading protocol designed by Westphal et al was applied to simulate the forces during heel strike up to a force of 1.98 kN at 1Hz for 50 000 cycles.

Data analysis

The data from the LVDTs were analyzed by use of Labview 8.6 (National instruments).

Statistical analysis

Statistical analysis was performed using a Mann – Whitney U test for total subsidence and prosthesis cyclical movement at 6 hours following the start of the endurance testing between the control bone 1.98 and the other experimental groups. Subsequent analysis compared Apapore and HA to bone 3.65kN. Level of significance was taken at p<0.05.

Results

Strain

The hoop strain in the control group was generally smaller for the control group than for any of the experimental groups.

Distal strain gauges

The mean distal hoops strain increased in all groups during distal impaction. The bone 1.98 kN group exhibited the lowest distal hoop strain and the bone 3.65 kN exhibited the greatest distal hoop strain. All of the experimental groups demonstrated a significantly greater distal hoop strain than the control group (bone 1.98 kN).

Middle strain gauges

The mean peak middle hoops strains increased with each consecutive set of impactions in all groups. There were no significant differences between the HA groups and the control group. There were significant differences between the control bone 1.98 group and the bone 3.65.

Top strain gauges

There was no significant difference between the control group or any of the experimental groups.

Discussion

This study suggests that addition of HA to bone graft decreases subsidence and decreased movement during cyclical loading. There were significantly greater hoop strains in the distal and midshaft strain gauges with impaction at greater forces and while using HA. Endurance testing demonstrated a significant decrease in cyclical motion and cyclical rotational stability of the prosthesis with a trend to a decrease in total subsidence during endurance testing. The addition of HA might have longer term benefits in terms of prosthesis stability and subsequent graft healing but caution is needed during impaction.