REINFORCEMENT OF THE PROXIMAL FEMUR WITH CORTOSS BONE CEMENT: AN IN VITRO STUDY

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Introduction

Hip fractures represent an important public healthcare concern and are a major source of mortality and morbidity among the elderly. Continued growth in the elderly population will raise its incidence and their associated costs dramatically.

Infiltration of PMMA bone cement into osteoporotic vertebral bodies (vertebroplasty) has been shown to substantially increase the strength and stiffness of mechanically compromised trabecular bone. It is likely that a similar benefit can be realized in the proximal femur. However, given the large volume of the trabecular space in this region, the choice of augmentation material is critical to ensure adequate infiltration and to minimize the possible detrimental thermal consequences associated with polymerization. Furthermore, the use of conventional osteosynthesis techniques must not be precluded in the case of an eventual fracture of augmented femora.

The aim of the present study was (i) to investigate the rheological characteristics of Cortoss injection into the proximal femur (femoroplasty), (ii) to monitor the heat generation during polymerization, (iii) to study the effect of bone cement augmentation on the mechanical strength of the osteoporotic proximal femur and finally (iv) to evaluate the feasibility of conventional osteosynthesis techniques in cement-augmented femora.

Methods

Nine pairs of osteoporotic human cadaveric femurs were investigated. Any focal bone pathology was precluded using radiographs in two planes. Dual-energy X-ray absorptiometry scans were performed for each proximal femur, using a Hologic QDR-4500A densitometer (Hologic Inc., Waltham, MA, USA). From each pair, one femur was randomly assigned for augmentation, with the contralateral femur serving as a control.

A composite cement (tetrapolymer resin with glass-ceramic reinforcing particles, Cortoss, Orthovita®, Belgium) was injected by a 8G Biopsy needle (Manan™ Trapsystem™, MDTech Inc., Gainesville, FL, USA) and was terminated at a volume of 40 ml or earlier, if any leakage occurred. Cement injection pressure was measured using a specially-instrumented syringe holder. Additionally, the temperature at the femoral neck was recorded by two surface-mounted thermistors, mounted ventrally and dorsally, until twenty minutes after injection.

The fracture tests were conducted in a Zwick 1475 universal material testing machine (Zwick GmbH, Ulm, Germany) and the load-displacement behaviour was recorded. An impact loading, simulating a fall on the greater trochanter, was applied. The fracture load (maximum load) and the energy absorption (area under the curve to the point of maximum load) were calculated. For each specimen, fracture location was documented radiographically. The Wilcoxon signed rank test was used to test for differences in fracture load and energy absorption between the reinforced femurs and the native controls.

Following fracture, selected pairs were instrumented with a dynamic hip screw, proximal femoral nail or conventional screw fixation, then tested again to failure.

Essential Results

In all specimen 40 ml of cement could be injected (Figure 1). The maximum temperature elevation measured at the posterior surface of the femoral neck was 12.9°C on average (4.8 - 17.9°C), occurring 15 minutes after starting of the injection. The mean filling pressure at the piston of the syringe was 2004 kPa (1399-2539 kPa).

Discussion

The feasibility of reinforcement with Cortoss has been shown as well as its mechanical effectiveness. The temperature increase at the surface was moderate. In comparison with our previous studies using conventional PMMA bone cement, reinforcement with Cortoss was accomplished with reduced preparation time and less complicated equipment, a more homogeneous distribution of cement was observed, and the thermal loading was diminished.

Fixation with conventional osteosynthesis techniques in case of fracture is still possible after cement augmentation, with the following modifications to standard operative techniques: a higher drilling resistance is encountered through the cement, drill bit cooling is required, slightly increased drilling time is needed for stepwise drilling to clear cement debris, and pre-drilling is necessary for any guide wires. Before clinical application is considered, an animal study must show the effect of cement injection on the vitality of the femoral head, and to evaluate the risk of cement leakage to the vascular space due to the elevated injection pressures.

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Figure 1: Typical cement filling pattern.