Mechanism for Rotational Stability in Cemented Implants

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Introduction

The removal of well-fixed cement is a difficult and time consuming aspect of femoral component revision. Various surgical techniques and instruments have been developed to facilitate cement removal: extended trochanteric osteotomy, cortical windows[1], cement removal osteotomes/gauges/reamers, and ultrasound probes. Latrogenic femoral host bone loss, inadvertent perforation, and femoral fracture are the main risks associated with the removal of cement.

The use of cortical windows, as initially described by Nelson[1], reduces the risk of perforation while allowing for full weight bearing in the early postoperative period. The window is typically made near the tip of the implant to facilitate distal cement removal. After removing the cement, the femur is prepared to receive the revision implant. The cortical lid, which was removed creating the window, is replaced and secured using a circlage wire. The femoral prosthesis can then be inserted using standard techniques. Although the risk of perforation is less with the use of a cortical window, the risk of periprosthetic fracture remains.

The risk of fracture is related to the size of the window[2]. Concerns about periprosthetic fractures have led to the recommendation that the cortical window be bypassed by two cortical diameters by the femoral prosthesis[2-4]. The rule of two cortical diameters is based on a finite element model by Dennis[3] published in 1987. There is very little biomechanical data to support this practice which raised the question of how large the window can be before risk of fracture is related to the size of the window[2].

A biomechanical porcine cadaveric study was designed to determine and compare the risk of periprosthetic fracture for bypassed and non-bypassed anterior cortical windows.

Materials and Methods

Two separate biomechanical studies on porcine femurs were conducted in order to thoroughly evaluate periprosthetic femoral fracture risk: three point bending load to failure; and torsional load to failure. Fifty-two (twenty-six pairs) fresh porcine femurs underwent biomechanical testing. A custom made cutting jig was designed to consistently create a 10 mm by 25 mm cortical window. The size of the cortical window was based on the typical size used clinically by the senior author (RWC). The four corners of the window were predrilled using a 2 mm drill to minimize stress risers. Four bony cuts were then made, connecting the drill holes, with an oscillating saw guided by the cutting jig. The femur was then prepared as per clinical practice for a cemented implant (Figure 1). A steel rod implant was then cemented with the distal extent of the implant ended at the midpoint of the cortical window for the no bypass group and 15 mm beyond the distal extent of the cortical window for the bypass group. A bypass distance of two cortical diameters was not used because of the prohibitive geometry of the porcine femurs. The cortical window was replaced and secured with a cerclage wire. Femurs were stored in pairs at minus 20°C. The femurs were removed from the freezer 24 hours prior to biomechanical testing.

Forty (twenty pairs) fresh porcine femurs were used for three point bending biomechanical testing. The contralateral femur was left intact to act as the control and to allow normalization of the applied loads. All specimens were tested in a 3 point bending setup with each of the three points separated by 40 mm (Figure 2). The femur was positioned with the antero-lateral aspect facing down, with load applied opposite to distal window edge with a strain rate of 4 mm/minute. The maximum loads to failure were measured for all femurs which was then divided by the recorded load for the corresponding contralateral intact femur.

Torsional Analysis

Matched paired femurs (right and left) were tested to compare no bypass versus 15 mm bypass implantation. Each pair of femurs was distally and proximally potted to a depth of approximately 40 mm using fixative screws and bone cement. Each specimen was loaded into an Instron 8874 machine with torque applied at a rate of 5 Nm/s until failure.

Results

Three Point Bending Analysis

There was no statistically significant difference found when comparing the maximum load to failure ratios for the no bypass and bypass groups specimens undergoing 3-point bending testing (p=0.177). There was, however, a trend towards higher maximum load to failure ratios for the no bypass group (average 0.81) compared to the bypass group (average 0.70).

Torsional Analysis

There was no statistically significant difference found when comparing the maximum torque to failure for the no bypass and bypass groups specimens (Table 2; p=0.955).

Discussion

The results of this study suggest that bypassing an anterior cortical bone window with a long stem component during revision femoral hip replacement does not decrease the risk of postoperative periprosthetic femur fracture. This finding contradicts the conclusion drawn by Larson and associates[2] who performed a similar biomechanical study. The variation in the results is likely related to the size of the cortical window used by the studies. The window by Larson and associates used a 50% cortical window, significantly larger than the 10 mm by 25 mm window used in this study. The 10 mm by 25 mm window was deemed to be large enough to allow easy and safe removal of well fixed cement.

Although the results of this study contradict several published clinical studies[3-5], it is in keeping with the conclusions from a recently published clinical paper by Zweymuller and associates[6]. The avoidance of a long stemmed component has several advantages including cost, ease of future revision surgery, and avoiding violation of virgin bone which may be needed in future procedures.

A limitation of this study is the use of porcine rather than human femurs. Porcine and human cortical bone has been shown to have comparable mechanical properties, but the difference in bone morphology could influence the results.

This study raises questions about the standard practice of bypassing cortical windows with long stemmed femoral components during revision femoral replacement. Further human cadaveric studies as well as ongoing clinical evaluation are required to determine if this technique is still warranted.

References


Figure 1 Femur prepared for implantation.
Figure 2 Instron 5567 Machine with femur load for three-point bending.