EVALUATION OF AN OPTIMAL CEMENT THICKNESS AROUND THE GLENOID COMPONENT FOR UNCONSTRAINED TOTAL SHOULDER ARTHROPLASTY

[1]Alexandre Terrier, [1]Philippe Büchler and [2]Alain Farron
[1]Orthopaedic Research Laboratory, Swiss Federal Institute of Technology Lausanne, Switzerland
[2]Orthopaedic Hospital, University of Lausanne, Switzerland

INTRODUCTION

Although shoulder arthroplasty is an accepted treatment for osteoarthritis, loosening of the glenoid component, which mainly occurs at the bone-cement interface, remains a major concern. At the bone-cement interface, radiolucent lines have been observed in 30-95% of patients at follow-up [1]. Radiolucent lines are associated with fibrous tissue formation and glenoid loosening. In vitro tests have shown that thickness of the cement mantle is important for the primary stability of cemented glenoid components [2]; however there is still a lack of information concerning the optimal cement thickness. The aim of the study was to analyze the effect of this parameter on the glenoid stress transfer by means of a finite element model of the shoulder.

METHODS

The 3D geometry of the scapula was reconstructed from 1 mm CT slices of a cadaver shoulder. The glenoid component was all-polyethylene, keeled with a flat back. Cement thickness was gradually increased from 0.5 to 2.0 mm. Bone, cement and polyethylene were linear elastic. Non homogeneity of bone was derived from CT. At the bone-cement interface two extreme cases were considered: fully bonded and fully debonded. In the latter case, the friction coefficient was 0.6. A 400 N force was applied on the glenoid face, corresponding to the maximal glenohumeral force during abduction [3]. The distribution of this force over the surface was derived from the Hertz theory. Two force distributions were considered: concentric and (posterior) eccentric. Several mechanical quantities were calculated near the bone-cement interface: principal stress within the cement, von Mises stress within the underlying bone, stress and micromotion at the bone-cement interface.

RESULTS AND DISCUSSION

Within cement, the increase of cement thickness induced a continuous decrease of stress (Figure 1). Below 1 mm, the fatigue limit of the cement (~7 MPa) was exceeded, even in the concentric and bonded case. Within bone, and at the bone-cement interface, there was a stress increase from 1.0 to 0.5 and from 1.0 to 2.0, suggesting a minimum between 1.0 and 1.5 mm. Bone stress was below its failure strength, but interfacial stress was close to the failure limit (~3 MPa). The debonding of the interface, as well as the eccentric loading, induced an overall increase of stress. Peak stress was mainly located at the keel tip, but also along the back-keel edges as cement thickness decreased. Micromotion remained moderate (<30µm) and almost constant (vs. cement thickness) in the concentric case, but was excessive (>150µm) and increasing (vs. cement thickness) in the eccentric case. Peak micromotion was located at the keel faces in the concentric case, but under the back in the eccentric case (rocking-horse effect).

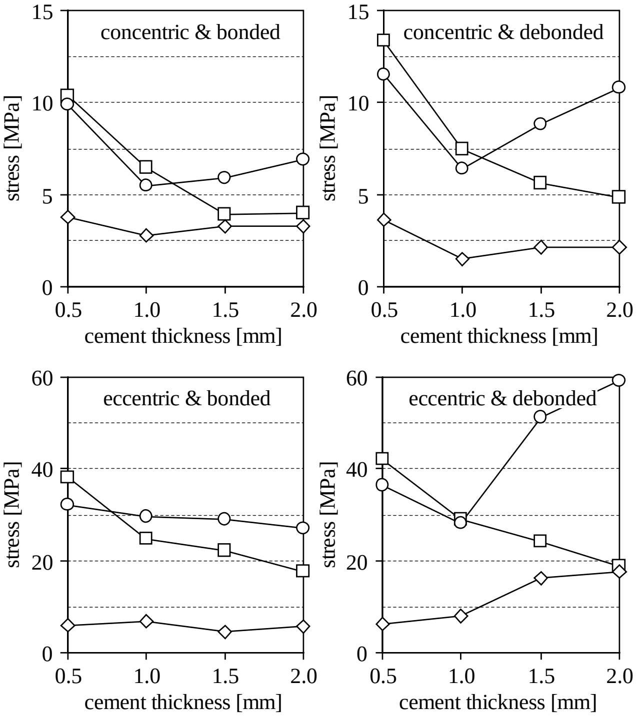

Figure 1: Peak value of cement maximum principal stress (square), bone Misses stress (circle), interfacial shear stress (diamond), for the four cases considered.

CONCLUSIONS

Results showed that cement thinning weakens the cement, but also the bone-cement interface along the back-keel edges. Conversely, cement thickening rigidifies the cemented implant, increasing consequently the overall interfacial stress and micromotion. To avoid both excessive cement fatigue and failure of the bone-cement interface, an optimal cement thickness has been identified between 1.0 and 1.5 mm.

Practically, to avoid the formation of large blocks of cement around the implant, we recommend to correct any bone defect of the glenoid by bone grafting and/or compaction. Moreover, future developments of new glenoid designs should include the ability to ensure a homogeneous cement mantel, with a minimum thickness of 1.0 mm.

REFERENCES

1. Wirth MA et al. *JBJS-A* **78**, 603-16.
2. Nyffeler RW et al. *JBJS-B* **85**, 748-52.
3. Van der Helm FC. *J Biomech* **27**, 527-550.1994.