THE "FRENCH PARADOX" EXPOSED: A FINITE ELEMENT ANALYSIS OF CEMENT PHILOSOPHY ON IMPLANT STABILITY AND CRACK FORMATION IN THE CEMENT MANTLE

*Janssen, D; *van Aken, J; **Scheerlinck, T; +*Verdonschot, N
+*Orthopaedic Research Laboratory, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands
n.verdonschot@orthop.umcn.nl

INTRODUCTION

A thin cement mantle and cement mantle defects have been associated with early failure of total hip arthroplasty (THA) [1]. This led to the generally accepted rule to select a nominal stem size that results in a cement mantle with a thickness of at least 2 mm (undersized stem).

In France, however, in the early seventies, a surgical technique was developed that is in complete contradiction with this philosophy. A canal-filling stem is implanted line-to-line with the goal to achieve direct load transfer from the stem to the bone. This, however, results in a thin cement mantle with multiple cement mantle defects. Surprisingly, excellent survival rates have been reported for THA’s implanted with this technique [2]. This phenomenon of excellent clinical results obtained with two seemingly contrasting techniques has previously been referred to as the “French Paradox” [3].

In the current study, using finite element analysis (FEA), the underlying mechanism responsible for the “French Paradox” was investigated. For this purpose, the femoral implant size and the resulting load transfer from the stem to the bone. This, however, results in a thin cement mantle with multiple cement mantle defects. Surprisingly, excellent survival rates have been reported for THA’s implanted with this technique [2].

RESULTS

Due to the torque load applied to the models, the implants rotated inside the cement mantle, creating gaps at the implant-cement interface (Fig. 2). Stress concentrations led in some cases to the formation of full-thickness cracks. The models with the severely undersized stem (thick mantle) crack formation progressed much faster (Fig. 2a) than in the models with a maximal canal-filling stem (thin cement mantle) (Fig. 2b).

In general, the total number of cracks formed in the cement increased with decreasing implant size, and full thickness cracks occurred after fewer loading cycles when the cement mantle was supported by trabecular bone only.

Irrespective of the type of bone support to the cement mantle, full thickness cracks were found in all models with the undersized and severely undersized femoral hip implant (Fig. 3). Overall, the maximal canal-filling stem outperformed or equaled all undersized stem models regardless of the type of bone support.

Crack formation increased rotational instability and progressive rotation of the stem. Models with canal-filling implants displayed a superior stability compared to the models based on undersized stems. Increasing the amount of cortical bone supporting the cement mantle generally increased the rotational stability of the model.

DISCUSSION

The results of this study indicate that the so-called “French Paradox” may not be so paradoxical after all. It can, at least partly, be explained by mechanical analysis of the different bone-cement-stem composites obtained using various implantation techniques. The fact that canal filling stems perform clinically so well is probably attributable to the relatively low cement stresses and an increased stability of the larger implants. On the other hand, undersized stems perform well in clinical practice because, using a third generation cementing technique, cement can be pressurized throughout the cancellous bone, up to the cortex. As such the cement mantle finds mechanical support and is protected against cement failure and subsequent destabilization. Perhaps the most important finding of this study is the demonstration of a clearly inferior mechanical reconstruction if a stem is undersized and the cement is not adequately pressurized. In these cases, the stem creates high cement stresses that promote full thickness cement cracking.

In conclusion, this study provides an explanation for the French Paradox and clarifies several critical aspects of cemented femoral reconstruction. Moreover, it illustrates that there may be more than one option available to reach a clinically optimal result for the total hip replacement patients.

REFERENCES


AFFILIATED INSTITUTIONS FOR CO-AUTHORS

** Department of Orthopaedic Surgery and Traumatology, Academic Hospital of the Vrije Universiteit Brussel (AZ-VUB), Brussels, Belgium

53rd Annual Meeting of the Orthopaedic Research Society
Paper No: 0280