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Femoral cement pressurisation for hip arthroplasty in previously fixated hips: An experimental study

S.E. McMahon, F. Alvi, J.G. Lemon, M.E. Lovell *

Department of Orthopaedic Surgery, Wythenshawe Hospital, Southmoor Road, Manchester M23 9LT, United Kingdom

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ABSTRACT

Introduction: It is common to use a cemented total hip replacement following failed hip screw fixation of a fractured femoral neck; this solution, however, is complicated by the presence of the holes that are left in the femur when the screws are removed. These holes can allow cement to leak out while being pressurised. The aim of this study was to look at the cement femoral pressures proximally and distally in a sawbone model with pre-drilled holes to assess if the commonest surgical technique of occluding the holes with fingers could maintain the cement pressure high enough.
Materials and methods: We used eight synthetic proximal femurs, four with dynamic hip screw holes drilled in them on the lateral surface (“drilled femurs”) and four with no holes (“undrilled femurs”). We used pressure sensors positioned in holes drilled in the proximal and distal parts of the medial surface to measure the pressure in the cement as it was being delivered and pressurised into the femur canal. The tests were conducted while the femur was clamped at its distal end and, in the case of the drilled femurs, while the screw holes were occluded manually.
Results: We found that on the proximal side, the peak cement pressure in undrilled femurs was significantly greater than in drilled femurs ($p = 0.006$). On the distal side, the difference in peak cement pressure between the two study groups was not significant ($p = 0.22$). At both the proximal and distal positions, the time over which the cement pressure exceeded both 5 and 100 kPa was significantly longer in undrilled femurs than in drilled femurs ($p < 0.05$).
Conclusion: Our results show that it is difficult to fully occlude the drill holes completely with finger tips, especially when using pressurised cement. There are significant differences in the peak cement pressures between drilled and undrilled femurs with possible consequences for patients undergoing total hip replacement.

Introduction

Failure of dynamic hip screws (DHSs), due to screw cut, avascular necrosis, and/or lack of wound healing, is a challenging problem in orthopaedics. A common solution to this problem is to convert to hip arthroplasty or hemiarthroplasty.[6] When this is done, the screw holes left on the lateral side of the femur after the removal of the DHS need to be occluded. From our own personal experience, a review of our own radiographs shows that, almost invariably, the holes on the medial side are plugged by tissue. During a cemented hip arthroplasty, it is important to ensure that sufficient pressure is maintained in the acrylic bone cement as it is being delivered into the femoral canal. It has been shown that excellent femoral fixation is obtained when cement pressures of 346 kPa over a time of application of 226 s are used[5]; and a cement pressure of at least 103 kPa improves interdigitation of the cement into the trabecular bone,[4,10,11] which, in turn, may contribute to the longevity of the implant.[12] It is known that a cement pressure of at least 300 kPa is required for a cement intrusion of 3–5 mm into the trabecular bone.[8] However, studies have shown that a minimum peak pressure of 100 kPa is required for a successful outcome.[10,12] One of the challenges in cemented hip arthroplasty is back bleeding, a term which refers to bleeding at capillary/arteriolar pressure from the trabecular bone. If the cement is not pressurised to above the capillary pressure then this may result in a phenomenon that leads to displacement of the cement dough from the bone which may be implicated in early aseptic loosening of the implant.[2] It is thought that a cement pressure of at least 5 kPa is required in order to prevent back bleeding.[7]

Little is known about the possible cement pressures that are maintained when converting a failed DHS to a cemented total hip replacement. In particular, it is important to know if the cement

* Corresponding author. Tel.: +44 161 291 6150; fax: +44 161 291 6153.
E-mail address: Martin.Lovell@uhsm.nhs.uk (M.E. Lovell).

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pressure is high enough when cementing a femur with screw holes that are already present. Obviously, the screw holes will allow cement to escape when pressurised and one common technique used by many surgeons is to occlude the holes with their finger tips. This does not provide an ideal way to ensure cement pressurisation is maintained during the fixation of the femoral component. Some of the cement will still escape through the screw holes even when using this technique. The maintenance of a high cement pressurisation is mandatory to ensure good fixation of the component and also to reduce the risk of aseptic loosening which can result if the pressure is too low. The purpose of this study was to look at the cement pressures that occur in a normal femur during cementation and compare this to a femur with screw holes pre-drilled to simulate a failed DHS being converted to a cemented total hip replacement. Our objective was to show that a surgeon using only their finger tips cannot occlude the screw holes completely to allow a high enough peak cement pressure to be sustained.

Materials and methods

A verbal orthopaedic consultant survey was conducted at a North West Hip Interest Group in the UK. Surgeons were asked their preferred method of occluding the holes left by neck of femur fracture fixation when converting to an arthroplasty from a DHS. Twenty-six surgeons were questioned. Seventeen occluded the holes with fingers, four used a cementless prosthesis, three impacted bone around the holes and two clamped a longitudinally split syringe over the holes.

We evaluated cement pressurisation in eight synthetic proximal femurs (Sawbones Europe AB, Malmo, Sweden). The bones had a pre-broached proximal cavity and a resected neck. This allowed us to drill, in an accurate and reproducible fashion, the holes that would be present after DHSs are removed. One large circular hole (12 mm diameter) and four small circular holes (each 3.2 mm diameter) were drilled in the proximal and the distal positions on the lateral surface of the femur, respectively. Each of these holes penetrated into the canal. Two circular holes (each 4 mm diameter) were drilled on the medial side of the femur for the placement of the pressure sensors (Model number PFP350, Futek Advanced Sensor Technologies Inc., Irvine, CA, USA) (Fig. 1). On the femurs in which no screw holes were drilled, the pressure sensors were placed in the two holes at the medial position. The sensors were calibrated using the data acquisition software required to collect the pressure readings (WINDAQ software by DATAQ Instruments, Akron, OH, USA). During the drilling of the holes, the femur was fully clamped at its distal end. We tested four femurs that contained holes ("drilled femurs") and four that did not ("undrilled femurs").

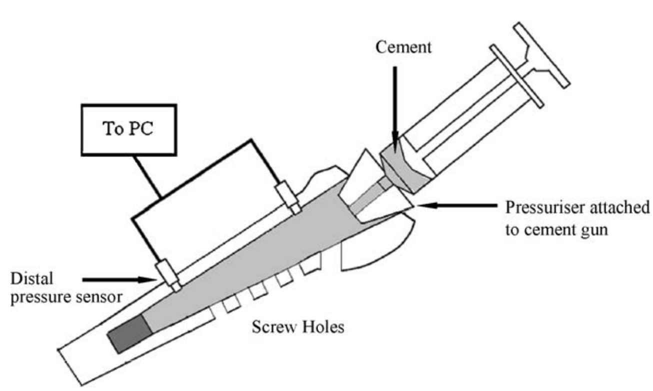

Fig. 1. Schematic showing experimental setup including position of pressure sensors in drilled femur.

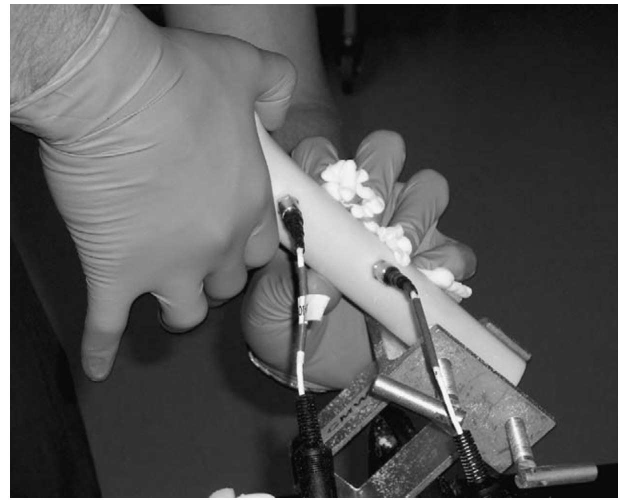

Fig. 2. Visualised cement escape in a pre-drilled femur, the two drilled sensors are seen.

The cement (CMW1; CMW International, Blackpool, UK) was mixed at room temperature using the Cemvac vacuum mixing system. The cement dough was delivered into the canal using a standard hand held cement gun with a pressuriser attached at the end with retrograde filling of cement in the femur. The pressuriser prevents any cement escape from the top of the femoral canal during pressurisation and provides a seal between the cement gun and the proximal femur. Filling commenced at 90 ± 1 s and mixing was maintained for 210 ± 5 s. During cement insertion and pressurisation, an assistant covered all the holes on the lateral side with his fingers. Cement pressures at the distal and proximal positions were measured from first filling until the end of pressurisation using the sensors (Fig. 2). These results were statistically analysed using the Mann–Whitney *U*-test (Stats Direct software, Stats Direct Ltd., Altrincham, Cheshire, UK). Significance was denoted at $p = 0.05$.

Results

At the proximal position, the peak cement pressure in undrilled femurs (370.8 ± 40.4 kPa) was significantly greater than in drilled femurs (194.4 ± 26.9 kPa) ($p = 0.006$). At the distal position, however, the peak cement pressure in the undrilled femurs (672.0 ± 43.4 kPa) was greater than in the drilled femurs (511.5 ± 207.6 kPa) but the difference was not significant ($p = 0.22$) (Figs. 3 and 4).

At the proximal position, time during which the cement pressure was >5 kPa was significantly longer in the undrilled femurs (198.8 ± 0.96 s) than in the drilled femurs (178.5 ± 11.5 s) ($p = 0.0381$). This trend was also seen at the distal position, with the respective times being 204.0 ± 3.6 and 173.8 ± 14.5 s, respectively ($p = 0.022$). At the proximal position, the time during which the cement pressure was >100 kPa was significantly longer in the undrilled femurs (179.8 ± 4.8 s) than in the drilled femurs (49.3 ± 47.2 s) ($p = 0.001$). This trend was also seen at the distal position, with the respective times being 190.0 ± 2.9 and 157.3 ± 28.3 s, respectively ($p = 0.097$).

One aspect of the study was to visualise prevention of cement escaping during pressurisation. The larger proximal hole, where the sliding screw enters the bone, was a particular problem, as its greater diameter made it harder to effectively seal. This lead to an increased amount of cement leakage proximally.

Discussion

Our results show that the peak cement pressure proximally in the drilled femurs is significantly lower than those in the undrilled