HIP ARTHROPLASTY: AVOIDING AND MANAGING PROBLEMS

The modern, hybrid total hip arthroplasty for primary osteoarthritis at the Hospital for Special Surgery

A. González Della Valle, N. Sharrock, M. Barlow, L. Caceres, G. Go, E. A. Salvati

From The Hospital for Special Surgery, New York, United States

We describe our technique and rationale using hybrid fixation for primary total hip arthroplasty (THA) at the Hospital for Special Surgery. Modern uncemented acetabular components have few screw holes, or no holes, polished inner surfaces, improved locking mechanisms, and maximised thickness and shell-liner conformity. Uncemented sockets can be combined with highly cross-linked polyethylene liners, which have demonstrated very low wear and osteolysis rates after ten to 15 years of implantation. The results of cement fixation with a smooth or polished surface finished stem have been excellent, virtually eliminating complications seen with cementless fixation like peri-operative femoral fractures and thigh pain. Although mid-term results of modern cementless stems are encouraging, the long-term data do not show reduced revision rates for cementless stems compared with cemented smooth stems. In this paper we review the conduct of a hybrid THA, with emphasis on pre-operative planning, surgical technique, hypotensive epidural anaesthesia, and intra-operative physiology.

Cite this article: Bone Joint J 2016;98-B(1 Suppl A):54–9.

History and scientific background behind hybrid fixation for total hip arthroplasty

Long-term results of cemented total hip arthroplasty (THA) have revealed a progressive deterioration of acetabular fixation after the first decade in vivo.1,2 While acetabular revision rates for aseptic loosening increase, the radiographic fixation and clinical survivorship of cemented femoral stems has remained excellent at a follow-up of three to four decades.1,3 Coupled with advances in cementless acetabular fixation, these observations have resulted in an increased use of hybrid fixation.4 Long-term survivorship and a low incidence of complications reported in national registries support the use of hybrid fixation.4,5 Accordingly hybrid fixation continues to be our preferred method for primary THA.

First generation cementless acetabular components exhibited low rates of loosening,6 but were affected by complications related to deficient design, implantation technique and manufacturing processes. Suboptimal locking mechanisms permitted micromotion between the liner and the shell, with the subsequent generation of backside wear.7 The lack of conformity between the liner and the shell, and the roughness of the inner surface of the shell, compounded this problem.7 In some of the early acetabular component designs, fatigue failure of the locking mechanism and displacement of the insert have been reported.9 The presence of screw holes permitted debris to access the pelvic interface, which accompanied by the hydrodynamic pumping action of repeated hip loading, resulted in retro-acetabular osteolysis.9 Lastly, suboptimal sintering of the ingrowth surface enabled shedding of this material and third-body wear to ensue.10,11 Understanding these modes of late failure, coupled with advancements in the manufacturing process, resulted in modern uncemented shells with fewer or no screw holes, polished inner surfaces, improved locking mechanisms, and maximised thickness and shell-liner conformity.12 Contemporary cementless acetabular shells combined with highly cross-linked polyethylene liners have provided encouraging results with low wear and rates of osteolysis.13,14 In a review of 60 patients who underwent primary, hybrid THA with conventional (gamma irradiated in nitrogen) or highly cross-linked polyethylene, at a mean follow-up of 11 years (7 to 15) the latter group exhibited significantly lower annual wear rates (0.17 mm/year and 0.02 mm/year respectively, p < 0.001) and osteolysis (97% and 10% respectively, p < 0.001).14 The satisfactory long-term results of cemented femoral stems support the use of cement for stem...
THE MODERN, HYBRID TOTAL HIP ARTHROPLASTY FOR PRIMARY OSTEOARTHRITIS AT THE HOSPITAL FOR SPECIAL SURGERY

Vol. 98-B, No. 1, January 2016

Fixation. The constituents of acrylic cement remained virtually unchanged since the 1960s and advancements in the understanding of cement fixation, mixing techniques, application, pressurisation, stem materials and design resulted in predictable long-term fixation and clinical results. The improvements in cementing technique include: femoral preparation to diminish interface bleeding, pulsatile lavage, reduced cement porosity by vacuum mixing, the use of a cement restrictor, pre-heating the stem and polymer, retrograde canal filling and pressurisation with a cement gun, stem centralisation and stem geometries that increase the intramedullary pressure, and intrusion of the cement into the bone. In contrast, certain changes in cement fixation and the polymer itself were detrimental and were abandoned.

In recent years there has been a tendency towards an increased use of cementless femoral fixation. Survivorship has not been surpassed by uncemented femoral fixation and it continues to be our preferred form of fixation.

Pre-operative templating

A standardised radiographic evaluation of the hip, includes an anteroposterior (AP) view of the pelvis centred over the pubic symphysis, and a flog-leg lateral view of the affected hip. The AP view is obtained with the hips in 10° to 15° of internal rotation to ensure a true AP view of the femoral neck.

Assuming that the x-ray tube is at a distance of 1 metre from the tabletop, and the film is placed in a tray 5 cm below the table, the radiographic magnification will approximate 20%. The magnification will increase in obese patients and diminish in thin patients. If digital radiography is used or if absolute measurements are required, a magnification marker is placed at the level of the hip.

Our templating protocol has been developed by the senior author (EAS) and has been in use for the last three decades. It begins with drawing the inter-teardrop line as a horizontal reference for acetabular inclination and leg length. The acetabular template is placed at 40° to 45° of inclination with the inferomedial silhouette of the component approximating to the base of the teardrop and the medial border approximating to the ilioischial line. The intended acetabular component should be sized to achieve maximum acetabular coverage with minimal removal of subchondral bone (Fig. 1). The implant size, the new centre of rotation, and the relative amount of uncoverage (if any) are recorded in the plan.

The goals of femoral templating are to achieve an implant with adequate alignment and fixation, restore femoral offset, and equalise leg length. The stem size should be the one that allows for a 2 mm circumferential cement mantle, which usually is marked on the template. The position of the stem in the femoral canal should allow equalisation of limb length and restoration of offset (Fig. 1). The surgeon should aim to use the mid-range of neck lengths in order to allow adjustment to a shorter or longer modular head during surgery. Once the position and offset of the stem are planned, the new centre of rotation of the prosthetic head, and the level of the femoral neck osteotomy are marked. The distance from the proximal corner of the lesser trochanter to the centre of rotation of the prosthetic head, and the distance from the proximal corner of the lesser trochanter to the neck cut are then both measured. Measuring the distance from the calcar medial to the medial border of the templated stem at the neck cut helps the surgeon assess the alignment of the stem in the frontal plane (varus–valgus) intra-operatively (Fig. 2). The diameter of the distal centraliser, the plug size and depth of insertion are also recorded in the plan.

With careful templating, acetabular and femoral components for hybrid THA can be predicted to within one size in 99.2% of cases. The predictability in component sizing...
allows pre-heating of the intended stem (± 1 size) and having the remaining implants available in the operating theatre to expedite surgery.

Intra-operative and anaesthetic factors

There are three important intra-operative factors to consider: Firstly, the use of regional anaesthesia; secondly, intra-operative hypotensive anaesthesia; and thirdly, use of multimodal thromboprophylaxis.

Improved outcome has been shown when spinal or epidural anaesthesia is used rather than general anaesthesia. Advantages include fewer respiratory complications, less blood loss/transfusion, lower risk of thromboembolism and a lower rate of post-operative mortality.

Intra-operative hypotensive anaesthesia results in improved interdigitation of cement into cancellous bone. Secondly, a dry surgical field improves surgical exposure and finally, reduced blood loss results in less fluid administration and transfusion requirements.

Multimodal thromboprophylaxis developed at the Hospital for Special Surgery, encompasses several strategies based on the peri-operative physiology which contributes to thrombogenesis. Firstly, femoral venous occlusion occurs during surgery on the femur when the femoral vein is kinked because of flexion and internal rotation of the femur. In the mid-1990s, using rapid markers of thrombosis, it was determined that this is the moment when thrombogenesis begins. Therefore, the period of potential femoral venous occlusion should be as brief as possible. We administer intravenous (IV) heparin (15 units/kg) before surgery on the femur. Administering a low intra-operative dose of IV unfractionated heparin demonstrated that thrombogenesis during surgery is avoided. Lower extremity blood flow is augmented with low dose IV epinephrine (1 mcg/min to 3 mcg/min), and post-operatively by foot flexion/extension exercises, pneumatic compression devices and early ambulation. This multimodal approach to thromboprophylaxis enables aspirin to be used, which is both a safe and effective chemoprophylaxis agent in this setting. This results in a lower risk of bleeding than found with powerful anticoagulants and is associated with an overall lower rate of post-operative mortality.

General principles of surgical technique

The long-term success of THA is contingent upon the precision and accuracy with which the components are implanted. Adequate exposure to allow accurate bony preparation and component implantation is encouraged. We favour the posterolateral approach because of its anatomical dissection and its extensile nature.

Acetabular preparation

After acetabular exposure, the labrum must be completely resected. Often a medial acetabular osteophyte is present which must be reamed until the true medial wall is encountered. Once the medial wall is reached, the reamer angle is changed to proceed in 40° of abduction and 20° to 25° of anteversion. Reaming to size is reached when subchondral bone is exposed and healthy bleeding bone is visualised. The acetabular bed should be inspected for subchondral cysts which are curetted and packed with autologous graft. Under-reaming by 2 mm has been promoted as a way of enhancing initial component stability. A trial component can be used to assure adequate contact and stability. We currently use a porous shell with limited screw holes or no holes. If socket
stability is questionable, supplementary screw fixation can be used. If the acetabular component insertion is being obstructed by a dense sclerotic acetabular rim, expansion with the reamer 1 mm smaller than the component size is required. Any peripheral osteophytes are removed and the highly cross-linked polyethylene liner is inserted.

Complications related to press-fit sockets are rare but can arise owing to technical errors during preparation and insertion. Sharkey et al have reported acetabular fracture during cementless socket insertion. The fractures can be the result of undersized reaming. Care should be taken to avoid over-zealous shell impaction in osteoporotic bone. While the routine use of supplementary screws for fixation in primary THA is becoming less common, neurovascular complications related to screw placement are best managed by avoidance of the danger zones, described by Wasielewski et al.

**Femoral preparation**

**Stem and cement pre-heating.** The pre-operative plan allows pre-heating the selected femoral stem and the next size smaller and larger to approximately 40 °C to 44 °C in an oven close to the operating theatre. Pre-heating the stem and the cement reduces cement porosity, particularly at the cement metal interface and polymerisation time by approximately six minutes, without affecting its mechanical properties. The surgical time is shortened at a critical time when the thrombogenesis is maximally activated and while the leg is maintained in an extreme position, with the femoral vein kinked and occluded, causing venous stasis, and potential endothelial injury. Reducing the time for polymerisation also decreases the risk of an inadvertent displacement of the stem while the cement is curing.

Pre-heating of the stem and cement should be implemented cautiously only once an efficient surgical team is working together, as a delay could result in premature polymerisation.

**Surgical technique for cemented femoral fixation.** Surgical exposure should allow a clear view of the proximal femoral opening and the proximal corner of the lesser trochanter, while protecting the soft-tissues around the proximal femur (Fig. 3). The surgeon should avoid muscular damage, particularly in the presence of hypotensive anaesthesia. The surgical time is shortened at a critical time when the thrombogenesis is maximally activated and while the leg is maintained in an extreme position, with the femoral vein kinked and occluded, causing venous stasis, and potential endothelial injury. Reducing the time for polymerisation also decreases the risk of an inadvertent displacement of the stem while the cement is curing.

Vacuum mixed, pre-heated cement is then injected and pressurised in the canal. The authors prefer to occlude the proximal femur with their thumb rather than with a rubber seal as it affords greater control over the pressure in the canal during cement pressurisation. The surgeon should create a high and constant intramedullary pressure that allows the viscous cement to interdigitate in the cancellous bone.

The stem is inserted at a slow pace, without changes in rotation or alignment while the surgeon continues to occlude the proximal femoral opening with the thumb. It is during stem insertion that the highest intramedullary pressures are achieved. We have shown that rarely, post-operative radiographs demonstrate cement filling the prox-
imal femoral veins indicating high pressurisation has been obtained.\textsuperscript{44} This radiographic finding is clinically benign and should not be misinterpreted as a femoral fracture. Tapered stems generate higher intramedullary pressures during insertion than cylindrical stems, as the former reduce the proximal space for the cement throughout stem insertion.\textsuperscript{19,20}

Once fully seated, gentle pressure should be applied without changes in alignment or rotation until the cement is polymerised. The modular femoral head should be impacted onto a clean dry taper. A Morse taper contaminated with blood or irrigation fluids can favour corrosion.

**Preference for satin or highly polished cemented femoral stems**

Cement is not an adhesive and the fixation is achieved by interdigitation. The cemented femoral stem acts as a composite structure, transmitting body weight through three layers (metal, cement and bone) and through the two interfaces between them (metal-cement and cement-bone).\textsuperscript{45} This load transfer is determined by the cement-metal surface interaction, the cement-bone interface, the stem geometry, the structural properties of the implant, and by the patient weight and activity level.\textsuperscript{46} Surgeons implant femoral stems with a wide variety of surface finishes and textures which are supported by contrasting philosophies of fixation.

In polished stems, bone cement acts as a structural grout material. Load transfer occurs through compression with micromotion at the cement-metal interface in view of the non-adherent, smooth and polished interface.\textsuperscript{21,46} This micromotion may be protective of the bone-cement interface. Conversely, with the firm mechanical adhesion of cement to the femoral stem with rough surfaces, the load transfer occurs through tension, shear and compression directly to the cement-metal interface. The lack of micromotion at this interface transfers all the loads to the bone cement interface.

Our experience with a rough, proximally textured, modern cemented femoral stem has been disappointing. A series of 64 THAs with a rough Versys stem (Zimmer, Warsaw, Indiana) (μRa: 80 to 100 microinches) and 138 THAs with a satin Versys stem (μRa: 20 microinches) was followed clinically and radiographically for four to seven years. All operations were performed by the senior author (EAS) with the same surgical technique, acetabular component, cement type and cementing technique. In the rough group, seven hips and none in the satin group developed aseptic loosening (p < 0.001).\textsuperscript{22}

Smooth stems tolerate micromotion at the cement-prosthesis interface without damaging the fixation. Conversely, when a tight mechanical or chemical cement-prosthesis bond is achieved with a rough or pre-coated stem, the torsional and axial forces transmitted to the bone-cement interface are higher and micromotion may initiate macro-motion with loosening at the bone-cement interface. The literature supports the use of smooth or polished surface finish for cemented femoral components.\textsuperscript{21,45}

**Wound closure and rehabilitation**

We strongly advocate the use of an enhanced soft-tissue repair that includes capsule, short external rotators and quadratus femoris muscle. Finally, 3 g of tranexamic acid is applied topically before would closure to avoid the use of drains.

Patients are mobilised promptly after surgery, bearing weight as tolerated with assistive devices as required. Exercises will avoid flexion greater than 90° and internal rotation for the initial five to six weeks following surgery.

The multimodal thromboprophylaxis is used for the first six post-operative weeks.\textsuperscript{28,34,35}

**Author contributions:**

N. Sharrow: Generated a structured draft, edited the draft, reviewed current literature.

E. A. Salvati: Generated a structured draft, edited the draft, reviewed current literature, generated illustrations.

A. González Della Valle: Generated a structured draft, edited the draft, reviewed current literature.

M. Barlow: Generated a structured draft, reviewed current literature, generated illustrations.

L. Caceres: Generated a structured draft, reviewed current literature, generated illustrations.

G. Go: Generated a structured draft, edited the draft, reviewed current literature.

No benefits in any form have been received or will be received from a commer- cial party related directly or indirectly to the subject of this article.

This study was partially funded by the generous donation of Mr. G. Bergenfield, the Sidney Milton and Leoma Simon Foundation and by Mrs. M. Bayroff.

This article was primary edited by G. Scott.

This paper is based on a study which was presented at the 2014 Current Concepts in Joint Replacement© - The Journey Continues meeting held in Iguassu Falls, Brazil, 17th-20th September.

**References**


