The Tri-Lock® Femoral Stem (DePuy Orthopaedics, Warsaw, Ind.) has been used for nearly 30 years as a cementless stem in total hip arthroplasty, and it is characterized by excellent clinical results.1-6, 10 The Tri-Lock cementless design is based upon the cemented, straight, collarless, cobalt-chromium tapered Müller stem, which was popular in the 1980s and 1990s and enjoyed a strong clinical performance.7-9 In 1981, the original Tri-Lock Stem was introduced in cobalt-chromium for cementless application, and it featured a mono block fixed head/neck segment and a 5/8 proximal porous coating (Porocote Coating). With progressive sizes which increased from a constant medial border and a constant 6 degree mediolateral wedge in the frontal plane, the stem featured excellent rotational stability owing to a geometrically constrained fit based on its flat and thin parallel-sided lateral profile. In the mid-1980s, modularity was introduced for head/neck length flexibility, standard and lateralized (+8mm) offsets were offered, the modular titanium Tri-Lock Femoral Stem was introduced in 1998.10,11

In 2008, the Tri-Lock Femoral Stem was modified based on a goal of preserving proximal femoral bone stock, facilitating implantation from any surgical approach, and minimizing disruption of the abductor musculature. None of the design features judged to be critical to the success of the Tri-Lock Stem were changed. The Tri-Lock Bone Preservation Stem (BPS) remains a broach-only femoral stem system. Its design is based on a 6 degree frontal plane mediolateral taper, and a flat parallel sided lateral profile. Rotational stability is achieved with a geometrical fit within the medial-lateral cortical dimension of the proximal femur. Tri-Lock BPS is made of titanium, it has a modular femoral neck, and it offers a standard and lateralized offset. The length of the porous-coated surface relative to the length of the stem is unchanged from the original Tri-Lock cementless design. The new Tri-Lock BPS has an enhanced roughness ingrowth surface (Gription™ Coating) that promotes immediate stability through an optimal interference fit. The Tri-Lock BPS stem has been shortened based on a decrease in the length of its smooth distal portion, which has also been undersized relative to the broach to ensure proximal fit with no distal stem potting in type A femora. The lateral profile of the distal stem has been cut away to facilitate implantation without need for surgical access through the bed of the greater trochanter thereby limiting disruption of the abductor musculature. The Tri-Lock BPS Femoral Stem is predicated on nearly three decades of successful application of the fundamentals of a straight flat tapered femoral stem design. It preserves all of the features integral to the success of the original ingrowth stem while incorporating design modifications to facilitate surgical implantation and achievement of immediate stem stability. Technical tips for implantation of the Tri-Lock BPS Femoral stem are based on the design features of the stem. The importance of proper surgical technique is paramount to achieving predictable and reproducible outcomes with all broach-only femoral implants. Irrespective of surgical approach, the fundamental elements of planning and performing a total hip arthroplasty with the Tri-Lock BPS should be purposeful and consistently applied across all patients. What follows are surgical tips and pearls for broach-only cementless stems with specific emphasis on the Tri-Lock Bone Preservation Stem.
I. Preoperative Templating

Calculations are made on a standardized anteroposterior radiograph of the pelvis, centered at the hips or pubic symphysis, taken with both feet rotated upwards towards the ceiling. This provides a view of the complete acetabulum as well as the upper femur in neutral rotation that is suitable for templating.

The principal objectives to be accomplished by preoperative templating include:

**Determination of leg lengths and level of femoral neck cut:**
In order to afford the greatest flexibility in restoration of equal limb lengths, templating for the level of femoral neck osteotomy is typically performed using the +5 head/neck segment. This allows the option of intraoperative adjustment of neck length one size up or down while avoiding the need for a skirted femoral head. Assuming normal and symmetrical location of the acetabulae, the +5 head center on the template is placed over the (normal) nonoperative hip on the pelvic radiograph. With the medial border of the femoral component on the template aligned along the medial endosteal border of the femur on the radiograph, the level of femoral neck osteotomy is marked on the (normal) nonoperative hip. The distance of this mark from the lesser trochanter is recorded, transposed to the operative side, and the planned level of osteotomy is marked on the diseased hip.

**Determination of femoral component offset:**
Femoral offset is determined on the operative side by overlaying the +5 femoral head template center on the native femoral head and aligning the medial prosthesis border parallel with the medial endosteal border of the femur. If the medial line of the prosthesis on the template lies outside the cortical thickness of the medial femur, a more lateralized (high offset) stem is indicated. Alternatively, the medial borders of the template femoral component and the endosteal surface of the femur are superimposed; if the +5 head center on the template is 8mm or more lateral to the femoral head center on the radiograph, a lateralized (high offset) stem is indicated.

**Estimation of femoral component size:**
It is important to realize that this is the least important measurement obtained from the templating exercise; ultimately, in the hands of an experienced surgeon, component size is determined intraoperatively by broach sizing and rotational stability. With the calcar of the component template at the level of the femoral neck osteotomy, the medial border of the template is aligned with the medial endosteal surface of the femur. From this point, the size is selected that fits within the lateral endosteal surface of the femur. The actual implant size should be within one size up or down from the templated size.

II. Operative Approach

The choice of surgical approach remains the preference of the surgeon. Regardless of the approach selected, unobstructed access to the femoral canal is of paramount importance for correct positioning of the stem. Minimally invasive approaches that pass anterior or posterior to the abductor musculature are prone to providing a distorted view of the proximal canal with an off-line access that risks eccentric broaching and stem placement in flexion or extension, as well as undersizing. Regardless of the operative approach selected, it is imperative that sufficient mobilization of the upper femur and proper positioning of the leg are achieved in order to facilitate proper broach and stem placement. Release of the capsule, short external rotators, and even part of the gluteus minimus tendon may be required to achieve sufficient and unobstructed access to the proximal femur.

III. The Femoral Stem

Appropriate preparation of the femur to accommodate a proximally tapered femoral stem is critical to achieving immediate stability of the stem and subsequent tissue ingrowth.

**Neck cut:**
The level of the femoral neck osteotomy is determined by preoperative templating and, ideally, is made at a distance above the lesser trochanter that will equalize leg lengths after placement of the stem. However, the actual position of the femoral stem relative to the lesser trochanter, and not the neck cut, is the ultimate determining factor as to leg length. The stability of the Tri-Lock BPS collarless tapered femoral stem is due to endosteal contact within the proximal femur rather than by contact with the calcar, so it is not essential that the femoral stem sit at exactly the same level as the femoral neck cut. In contrast to surgical technique for a collared stem, the ideal position of the tapered collarless stem and the femoral neck cut are not necessarily the same.
Indeed, it is preferable that the stem remain 1-2 mm proud of the neck cut in order to be confident that it is seated at a stable position, will not subside with additional impaction blows or weight-bearing, and it is rotationally stable when tested with torque. Therefore, the neck osteotomy should ideally be made at the templated position relative to the lesser trochanter or 1-2 mm lower than the templated position. Also, the implanted stem should come to rest at the level of the neck resection, or 1-2 mm proud of the neck cut, corresponding to the precise templated position relative to the lesser trochanter. Two related points should be made at this juncture: 1) because a tapered collarless stem does not rest on the calcar, the use of the calcar planer is unnecessary, and 2) seating of the stem below the level of the femoral neck cut is undesirable, because it is difficult to determine the ultimate stable position of the stem when it sinks below the visible edge of the femoral neck osteotomy.

**Accessing the femoral canal:**
Entry to the femoral canal can be achieved with a box (“cookie-cutter”) chisel, an intramedullary canal seeker, or a starter broach. Since femoral component version is dictated by the orientation of the slot created by the box chisel, its position should be precisely determined. It is important that the slot for the stem sit at the center of, or slightly posterior to, an imaginary line bisecting the mediolateral dimension of the femoral neck (Figure 1). The medial border of the femoral stem should always rest along the center of the concavity of the oval of the medial femoral neck; therefore, a slight increase in stem anteversion is accomplished by orienting the stem slot slightly posterior to the center-line in its lateral aspect. The medial aspect of the slot, and hence the femoral stem, deviates minimally, if at all, from the medial center position within the cortical tube of the femoral neck.

**Broaching the femur:**
The Tri-Lock BPS Femoral Stem is a broach-only system. The canal is entered along the medial cortex of the neck with the short blunt starter broach (“canal finder”), which is fully inserted along the axis of the slot created by the box chisel. The starter broach is then removed and loosely reinserted into the slot of the canal. It is now used as a hand rasp with a “to-and-fro” motion to lateralize the slot into the bed of the greater trochanter. This maneuver ensures that the stem sits in a neutral or valgus position, and is not left in varus. Formal broaching begins with the smallest broach. Progressive enlargement of the envelope within the femoral canal is accomplished by use of increasingly larger sized broaches. Alternatively, after use of the canal finder, formal broaching may begin at two or three sizes smaller than the templated stem size. This shortcut should only be pursued after a reliable correlation with the templated stem and the final implanted stem is achieved by the experienced surgeon. The advantage of such an approach is to minimize the number of times that a broach is passed in and out of the femur. Care should be taken not to twist the broach to assist in its removal from the canal. The broach should be carefully removed only by reverse blows to the handle in line with the axis of the femoral canal so as to preserve the slotted configuration of the femoral envelope. Similarly, use of a reamer to prepare the femoral canal also risks disruption of the slotted envelope for the femoral stem and is strongly discouraged.

**Sizing the broach and stem:**
Insertion of the broach past the neck cut, which acts as the surrogate for stem position to equalize leg lengths, is the indication to progress to the next size broach. Application of consistent, brisk blows to the strike plate of the broach handle is the most effective technique as it provides a steady impaction force. The broach is a sharp cutting instrument and should be used aggressively, but with controlled force. When the appropriate size is reached to fill the mediolateral canal and the broach is resting on the medial endosteal cortex, the broach will neither advance deeper into the canal nor move with a firm twisting motion on the handle. Occasionally, an apparently tight broach will not appear to be advancing beyond the neck cut into the canal but application of torque to the handle will move the broach. In this instance, additional blows to the strike plate will advance the broach to a point where it becomes stable to ro-

![Figure 1: Creating the stem envelope with appropriate anteversion within the femoral neck](image-url)
tional torque or it passes the neck cut and the next larger size is inserted. When a stable position of the final broach is attained, the medial border of the broach will be resting on endosteal cortical bone without any intervening cancellous bone. Occasionally, the medial border of the broach may even slightly scallop the endosteal cortex. It should be noted that both axial and rotational stability are necessary to declare the endpoint in sizing of the broach, which should come to rest at a point flush with, or within 1-2 mm above, the neck cut determined to equalize leg lengths. When a surgeon begins using this broach only technique for a tapered femoral stem, flouroscopy can be used to check the position of the broach in the proximal femur in both the A/P and lateral planes.

**Trial reduction and stem offset:**
Assembly of the femoral head/neck segment onto the broach is performed primarily to verify the appropriate lateral offset of the final stem and secondarily to confirm equalization of leg lengths. Accuracy of the latter is less demanding, since the head/neck length may be ultimately adjusted after selection and implantation of the final stem in order to fine-tune leg lengths. Lateral offset of the stem is determined after assessment of stability of the hip based upon cup position, soft tissue tension, and the presence of bony impingement between the femur and pelvis. Impingement may occur between the greater trochanter and the posterolateral wall of the acetabulum in extension-external rotation or the anterior-inferior iliac spine in flexion-internal rotation, and the lesser trochanter and the ischiur in adduction-external rotation. Increasing lateral offset of the femoral stem is generally desirable because it minimizes bony impingement of the femur on the pelvis, increases tension in the soft tissue envelope, and advantages the abductors by lengthening their intrinsic lever arm. However, if the lateral offset of the stem is excessive, the iliotibial band will snap over the greater trochanter with rotation of the hip in an adducted position. A lower offset stem should be selected in this situation so as to avoid development of a bothersome greater trochanteric bursitis. In general, a hip that is templated to a lateralized stem will reliably accept a high offset stem at the time of operation. Conversely, a hip that templates to a standard offset will accept a high offset stem in approximately half of the cases. This is explained by the fact that removal of the typical medial acetabular osteophyte deepens the position of the socket and decompresses the abductor soft tissue sleeve in the osteoarthritic hip. Deeper positioning of the acetabular component adjacent to the floor of the cotyloid notch therefore commonly allows use of a high offset femoral stem, with all of its attendant biomechanical advantages, without snapping of the overlying iliotibial band.

**Insertion of the femoral stem:**
After determination of the appropriate femoral stem offset and removal of the broach, the final stem is inserted. The medial border of the stem is started along the medial endosteal surface of the femoral neck, in a neutral axis down the centerline of the broached envelope within the femoral canal. Unlike using a cylindrical stem, it is critical to recognize that the deeper a tapered stem is inserted, the tighter it will get owing to its larger proximal dimension. The stem is inserted by hand until resistance is met; this usually brings the stem to within 2 cm of its final insertion point. At this juncture, a non-threaded insertion driver with a pointed tip is used to seat the stem. A threaded device is useful if extraction of the stem is ever necessary, but an insertion device that is not united to the stem is preferable. This device allows the implant to follow the broached envelope in the femur, thereby minimizing the risk of malrotation of the stem during insertion which may lead to femoral fracture. Initial blows to the insertion driver are oriented slightly laterally in order to align the stem into a valgus attitude. Thereafter, coaxial blows in line with the shaft of the femur advance the stem to its final position at, or within 1-2 mm proud of, the final broach.

It should be cautioned that, unlike the broach, the surface of the stem does not present a cutting surface. The femoral stem is a tapered wedge which is effectively a wood-splitting device and it should be inserted with care and respect. The blows used to insert the stem are shorter and more brisk than those used to advance the broach. Typically at least 50, and often up to 100, of these “staccato” blows are necessary to confidently seat the stem to its final position. The rough Gripton porous coating provides some rotational stability to the stem, but it is also associated with friction during stem insertion. Accordingly, a greater number of blows may be required to seat the Tri-Lock BPS stem, which advances more gradually than other tapered stems with smoother surface coatings. Patience and a series of consistent blows to the inserter/driver will reliably advance the stem to within 1-2 mm of the position of the last broach. At this point, 10-20 additional blows are delivered to ensure that the stem is secure and will not advance further into the canal. The stem should not advance past the last position of the final broach. If this occurs, either the stem is undersized by virtue of inadequate broaching and the femoral neck is trimmed to
allow deeper insertion of the stem, or a femoral fracture has occurred and the stem must be withdrawn to cerclage and stabilize the femur.

After achieving a stable stem, the head is trialed as necessary and followed by application of the final femoral head to a clean dry taper. Any residual gaps around the margin of the upper stem, which occur infrequently, are grouted with cancellous bone from the box chisel in order to prevent access of particulate wear debris to the effective joint space and perhaps reduce post-operative blood loss.

IV. Post-Operative Protocol
An important factor in achieving reliable patient outcomes is a thoughtful post-operative protocol that respects the implanted components and protects the bone-prosthesis interface from undue stress that can compromise both fixation and long term performance. Notwithstanding the clinical data that endorse immediate weight bearing to tolerance as an acceptable rehabilitation protocol for many patients, the biology of bone healing and fracture repair dictates that 6 weeks are required for the femur to reliably establish a primitive osseous attachment to the implant. Engaging in vigorous physical activity within days of hip replacement is an unnecessary risk and it allows for adverse consequences in some patients. Despite social and marketing pressure to promote early return to activities of daily living, irrespective of advances in implant technology and surgical approaches, human biology must be respected, and a prudent approach to rehabilitation should be adopted.

My preferred post-operative protocol for patients without medical conditions that compromise immune function or impair wound healing consists of protected partial weight bearing (up to 50% of body weight), with two crutches or a walker, for the first 6 weeks postoperatively. This can be called “foot flat partial weight bearing”. Up to half of patients will return for their 6 week visit having spontaneously advanced to a single crutch or cane. After radiographic confirmation of a stable femoral implant, the remaining patients are promoted to weight bearing as tolerated with a cane in the opposite hand. Full weight bearing is gradually resumed between 6 to 12 weeks after operation as the patient is weaned from cane or crutch. Standing gluteal abductor strengthening with up to 10 lbs for 20 repetitions daily followed by side-lying abductor strengthening without weights is recommended to hasten the return of normal ambulatory function. By two to three months after operation, the typical patient has returned to usual activities of daily living independent of assistive devices and free of pain. Strength and endurance of ambulation continue to improve for 6 months after operation. This structured approach to rehabilitation after cementless total hip arthroplasty in my experience has provided patients with a return to an active lifestyle with the Tri-Lock BPS tapered stem.
Total Hip Prostheses, Self-Centering™ Hip Prostheses and Hemi-Hip Prostheses

IMPORTANT This Essential Product Information sheet does not include all of the information necessary for selection and use of a device. Please see full labeling for all necessary information.

INTENDED USE/INDICATIONS Total Hip Arthroplasty (THA) is intended to provide increased patient mobility and reduce pain by replacing the damaged hip joint articulation in patients where there is evidence of sufficient hip sound bone to seat and support the components.

THA IS INDICATED for a severely painful and/or disabled joint from osteoarthritis, traumatic arthritis, rheumatoid arthritis or congenital hip dysplasia; avascular necrosis of the femoral head; acute traumatic fracture of the femoral head or neck; failed previous hip surgery; and certain cases of ankylosis.

Self-Centering Hip Prostheses and Hemi-Hip Prostheses are intended to be used for hemi-hip arthroplasty where there is evidence of a satisfactory natural acetabulum and sufficient femoral bone to seat and support the femoral stem.

HEMI-hip ARTHROPLASTY IS INDICATED in the following conditions: Acute fracture of the femoral head or neck that cannot be reduced and treated with internal fixation; fracture dislocation of the hip that cannot be appropriately reduced and treated with internal fixation; avascular necrosis of the femoral head; non-union of femoral neck fractures; certain high subcapital and femoral neck fractures in the elderly; degenerative arthritis involving only the femoral head in which the acetabulum does not require replacement; and pathology involving only the femoral head/neck and/or proximal femur that can be adequately treated by hemi-hip arthroplasty.

CONTRAINdications

THA AND HEMI-hip ARTHROPLASTY ARE CONTRAINDICATED IN CASES OF: active local or systemic infection; loss of muscle tone, neuromuscular compromise or vascular deficiency in the affected limb, rendering the procedure unjustifiable; poor bone quality; Charcot’s or Paget’s disease; for hemi-hip arthroplasty – pathological conditions of the acetabulum that preclude the use of the natural acetabulum as an appropriate articular surface. Ceramic heads are contraindicated in revision surgery when the femoral stem is not being replaced or for use with any other than a polyethylene or metal-backed polyethylene cup. In the USA and Canada, ceramic heads are not approved for use with metal inserts.

WARNINGS AND PRECAUTIONS Ceramic coated femoral stem prostheses are indicated for uncemented press fit fixation.

CAUTION: DO NOT USE BONE CEMENT FOR FIXATION OF A CERAMIC COATED PROSTHESIS.

Components labeled for “Cemented Use Only” are to be implanted only with bone cement. The following conditions tend to adversely affect hip replacement implants: excessive patient weight, high levels of patient activity, likelihood of falls, poor bone stock, metabolic disorders, history of infections, severe deformities leading to impaired fixation or improper positioning, tumors of the supporting bone structures, allergic reactions to materials, tissue reactions, and disabilities of other joints.

ADVERSE EVENTS The following are the most frequent adverse events after hip arthroplasty:

- change in position of the components, loosening of components, wear or fracture of components, dislocation, infection, peripheral neuropathies, tissue reaction.

References


7. Havinga, M. Results with the M. E. Müller cemented, straight-stem total hip prosthesis. The Journal of Arthroplasty, Volume 16, Issue 1, Pages 33-36


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DePuy Orthopaedics, Inc.
700 Orthopaedic Drive
Warsaw, IN 46581-0888
USA
Tel: +1 (800) 366 8143
Fax: +1 (317) 371 4865

DePuy International Ltd
St Anthony’s Road
Leeds LS11 8DT
England
Tel: +44 (113) 387 7800
Fax: +44 (113) 387 7890

Vincent D. Pellegrini, Jr., M.D.
James L. Kernan Professor and Chair
Department of Orthopaedics
University of Maryland School of Medicine

Printed in USA.
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