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Innovations in Hip Arthroplasty

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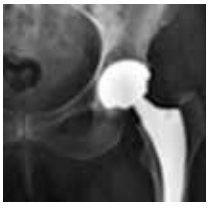

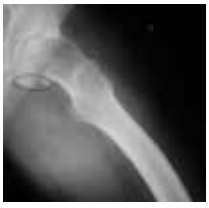

Clinical Results of a Modular Neck Hip System: Hitting the "Bull's-Eye" More Accurately

Paul J. Duwelius, MD, Mark A. Hartzband, MD, Robert Burkhart, PA, Clay Carnahan, PA, Scott Blair, BS, YingXing Wu, MD, and Gary L. Grunkemeier, PhD

Abstract

In this article, we present 2-year clinical results of a modular neck tapered hip stem, based on 634 patients from a 2-center study. Nearly half of the patients in this series required use of a head center location offered by the modular neck stem but not available in a nonmodular stem with an identical body. The modular neck enabled femoral-first preparation, which facilitates establishing the desired total version of the reconstruction. No fractures of a stem or modular neck occurred, and there were no dissociations of the head-neck junction. There were no complications or revisions related to the femoral implant.

Optimal leg length, femoral offset, and total version are goals in total hip arthroplasty. Neck modularity improves the ability to re-create the head center to achieve these goals and to hit the "bull's-eye" in total hip arthroplasty.

In this article, we report preliminary clinical results of a modular neck hip stem (Figure 1) used in primary total hip arthroplasty (THA). The modular neck total hip stem offers more options in improving head center. Joint stability and range of motion (ROM) are critical for long-term success in THA. Multiple studies have shown the importance of component position on the acetabular and femoral sides. Accurate component position is critical in avoiding impingement, which leads to dislocation and early liner wear. Re-creating the hip center or "bull's-eye" requires re-creating correct offset, version, and leg length (Figure 2). Neck modularity allows preoperative planning and intraoperative adjustment for offset, version, and leg length, independently of one another—a significant advantage in re-creating the head center. Most nonmodular stems have only 10 options; the modular neck stem has 60 options. Although there is not as much clinical experience with modular neck implants as with traditional implants, clinicians have advocated the benefits of modular neck implants: their ability to restore normal hip biomechanics and optimize joint stability.[1-5]

Rationale and Biomechanical Testing: Stem Design

The Zimmer® M/L Taper Hip Prosthesis with Kinectiv® Technology (Zimmer, Warsaw, Ind) was chosen because it is a broach-only stem that facilitates small-incision surgery and incorporates the design philosophy of a system with successful 20-year follow-up.[6] The stem and neck are manufactured from titanium alloy (Ti6Al4V). Thirteen

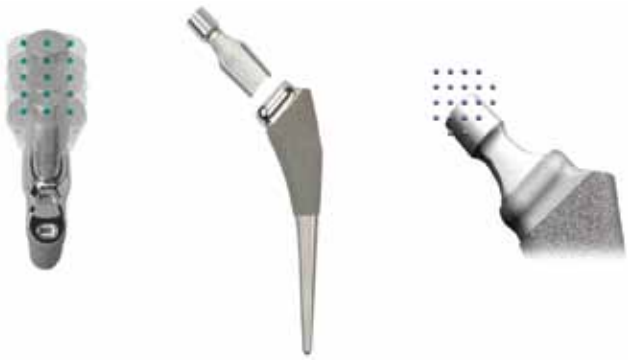

Figure 1. Modular stem with independent offset, version, and leg length using Kinectiv® (Zimmer, Warsaw, Ind) modular neck.

Figure 2. *Hitting the bull's-eye* refers to accurate re-creation of normal hip center of rotation, including 3-dimensional plane of version, offset, and leg length.

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Table I. Clinical Material

Age, mean years (range)	63 (21-97)
Body mass index, mean (range)	28 (16-52)
Sex, male/female	51% / 49%
Hip side, left/right	45% / 55%
Acetabular configuration, metal-on-polyethylene/metal-on-metal	57% / 43%
Stem configuration, standard/outlier	56% / 44%
Preoperative diagnosis	
Osteoarthritis	93%
Developmental hip dysplasia	3%
Avascular necrosis	3%
Inflammatory arthritis	1%

Table II. Complications

	Patients, n (revisions)	Events, n	Patients, %
General complications			
Death	5	5	0.8
Anemia	1	1	0.2
Congestive heart failure	1	1	0.2
Pulmonary embolism	1	1	0.2
Other	4	6	0.6
Hip-related complications			
Acetabular implant failure	15 (14)	15	2.4
Dislocation	4 (2)	6	0.6
Deep vein thrombosis	8	8	1.3
Fracture	4 (1)	4	0.6
Deep infection	2 (2)	2	0.3
Wound drainage	2 (1)	2	0.3
Other	2	2	0.3

stem sizes and 32 neck implants can accommodate a range of leg-length, femoral offset, and femoral version adjustments. The stem's modular female taper accepts the 32 different neck implants and therefore allows 60 different head center locations. As each neck is designed to mate only with a +0-mm (zero) femoral head, it can be designed for optimal ROM and strength. When another junction is introduced, strength and fretting/corrosion must be addressed. Research has shown strength performance and fretting/corrosion to be multifactorial in modular implants.[7,8] Investigators who tested fatigue, fretting/corrosion, and junction stability on this neck junction design considered load, orientation, temperature, pressure, and acidity (pH) of the environment.[9] As with all femoral implants, fatigue strength performance is influenced by amount of offset, amount of version, and, in the case of modular neck implants, taper design geometry. This design offers enough flexibility in these parameters to address a range of patient morphologies while meeting strength requirements that surpass ASTM (American Society for Testing and Materials) and ISO (International Organization for Standardization) standards.

Materials and Methods

We have preliminary results of using the modular neck THA Kinectiv hip stem in 634 patients. These patients underwent a minimally invasive primary THA through a posterior approach (described in multiple studies[10-14]) between April 1, 2007, and November 1, 2008, at Providence St. Vincent Medical Center in Portland, Oregon (n = 331) or Hackensack University Medical Center in Hackensack, New Jersey (n = 303). Both centers obtained institutional review board approval for this study.

Clinical Material

Mean patient age was 63 years (Table I). There was a near equal distribution of women (49%) and men (51%). Preoperative diagnoses were osteoarthritis (93%), inflammatory arthritis (1%), avascular necrosis (3%) and developmental hip dysplasia (3%). Mean body mass index was 28 (range, 16-52).

Outliers

The Kinectiv neck stem provides 60 different head center options allowing for independent offset, length, and ver-

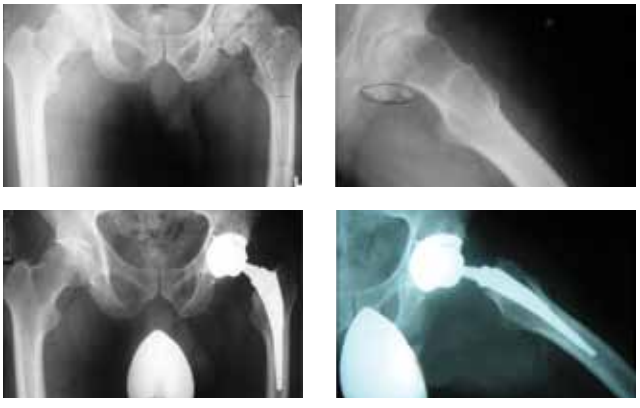

Figure 3. Case example: varus extra-extended dysplastic hip before surgery (top) and after surgery (bottom).

Table III. Quality-of-Life Measures, Preoperative and for Postoperative Matched Samples

Measure	N	Preoperative Mean	Preoperative SD	Postoperative Samples 1 Year Mean	1 Year SD	2 Years Mean	2 Years SD
Harris Hip Score	616	50	14				
SF-12 Physical Health	616	32	8				
SF-12 Mental Health	615	54	11				
Harris Hip Score	431	50	14	91	11		
SF-12 Physical Health	433	33	8	49	10		
SF-12 Mental Health	435	54	10	55	7		
Harris Hip Score	162	51	14	92	10	91	12
SF-12 Physical Health	160	33	8	50	9	50	10
SF-12 Mental Health	163	54	10	56	7	55	8

sion. Patients were presented as traditional hip patients or as outliers. Outliers were patients who required an anteverted or retroverted neck or an offset neck resulting in a head center not offered by a nonmodular stem with identical body. Figure 3 presents an example of an outlier in whom a typical stem would most likely result in leg-length discrepancy or inappropriate offset.

Statistical Methods

Continuous variables are presented as means (ranges), and categorical variables as percentages. Quality-of-life measures are summarized as means and standard deviations. Follow-up was calculated as time between surgery and most recent follow-up. Date of most recent follow-up was latest date of patient contact or examination or death date. Statistical analysis was performed with PASW Statistics 17 (SPSS, Chicago, Ill) and R 2.9 (http://www.R-project.org).

Clinical Results

Patients (n = 634) were observed for a total of 752 patient-years (mean, 1.2 years; maximum, 2.6 years); 457 patients (72%) were examined at 1 year, and 211 patients (33%) at 2 years. Six patients (1%) were reported as being lost to follow-up, and 7 patients (1%) withdrew from the study.

In this patient population, the distribution of outliers versus standard head center options by sex (Figure 4) shows significant variability in head center location with 29 of the 32 neck implants utilized. Aggregate distribution by investigator of standard and outlier head center location with differentiation of version and valgus/varus head centers is shown in Figure 5. The Portland neck distribution demonstrated 58% of the head centers in the outlier group—versus the 28% Hackensack distribution. A series of more than 25,000 consecutive cases based on implant manufacturer (Zimmer) sales data demonstrated a mix that falls in between these 2 cohorts: 52% outlier neck use (Figure 5).[15] The Portland series also had 100% use of metal-on-polyethylene cups, compared with 11% in the Hackensack series.

Complications were listed as either general or hip related (Table II). There were 5 deaths, all unrelated to THA. There were no complications related to the femoral implant, no fractures of a stem or modular neck, and no dissociations of the head-neck junction.

Twenty devices were revised because of hip-related complications, including 14 acetabular implant failures, all metal-on-metal cups. Six dislocations occurred in 4 patients; 2 of the patients were treated by revising the cup to a position of less anteversion. There were 4 periprosthetic fractures: 1 femoral shaft fracture, which required revision secondary to a postoperative fall, and 3 intraoperative calcar fractures treated at time of surgery with cerclage wiring but no other postoperative

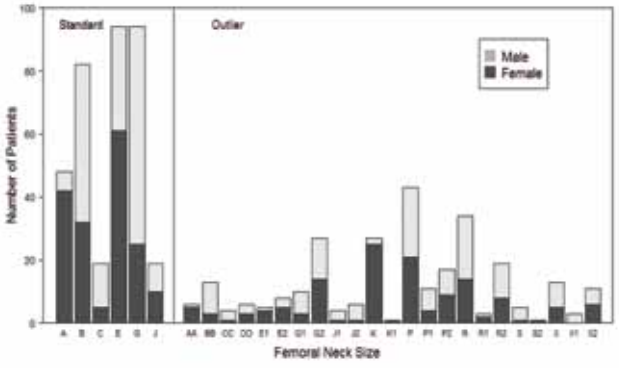

Figure 4. Distribution of neck sizes by sex.

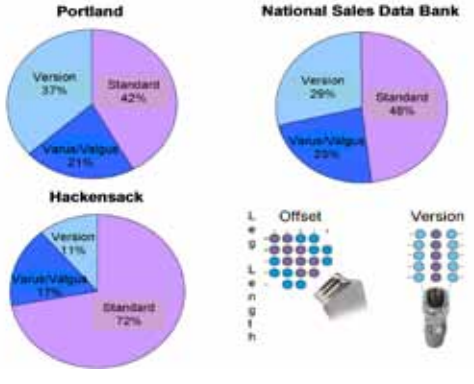

Figure 5. Distribution of outliers versus standard, by coinvestigators (left) and Zimmer sales data (right).

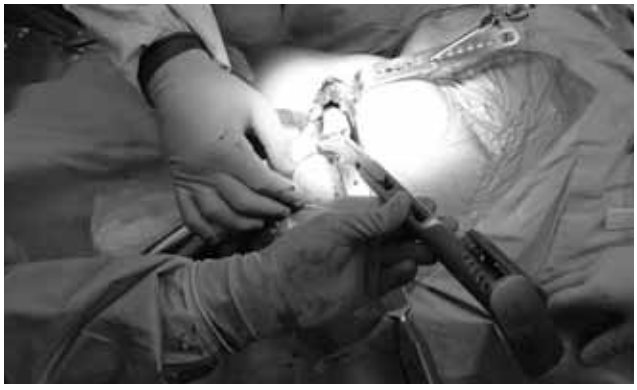

Figure 6. Insertion of modular femoral stem.

Figure 7. Insertion of modular neck and femoral head for trial reduction.

precautions. There were 2 deep infections. One occurred less than 6 weeks after surgery and was treated with exchange arthroplasty, and the other occurred more than 6 weeks after surgery and was treated with implant removal, with a temporary antibiotic spacer prosthesis implanted and a delayed exchange arthroplasty performed several months later. There were 2 wound drainage cases: a hematoma and a seroma. The hematoma was treated with irrigation and débridement and successful salvage of the implants. The seroma persisted and was treated with irrigation and débridement and then exchange arthroplasty. There was 1 case of a cellulitis, successfully treated with intravenous antibiotics.

Harris Hip Scores and Short Form 12 (SF-12) Physical Health scores increased dramatically from before surgery to 1 year after surgery and remained high 2 years after surgery (Table III).

Discussion

In this article, we present the early clinical results of a modular neck total hip stem. In nearly half the cases, the head center used would not be available in a nonmodular system. This series is comparable to other THA series with respect to improvement in hip scores and complication rates. Results have been reported for several series of THAs using the posterior approach.[10-14,16] There were no complications related to failure of the modular neck hip stem.

Mahfouz and colleagues[17] have reported sex differences, including differences in offset, version, and head center height. Dorr and colleagues[18] have reported on the importance of the total version, which is the combined femoral plus acetabular anteversion, and indicated that femoral anteversion is typically underestimated by the clinician. Multiple studies have demonstrated the importance of establishing accurate leg length for patient satisfaction.[19,20] Proper leg length and offset restoration improve THA function and minimize risk for dislocation and limp.[21,22]

The more accurately the head center is re-created in THA, the better the ROM and the lower the chance of impingement and dislocation.[23] Benefits of neck modularity in the Kinectiv design include ability to determine and adjust leg length, offset, and version independently. Exclusive use of +0-mm femoral heads eliminates skirted femoral heads to enhance ROM and makes the system inherently simple. The broad range of head center options addresses the disparate bone anatomy among patients. The broad head center opportunities allow preoperative planning to fit the stem in the femoral anatomy. This reduces the need to make significant adjustments to stem size to fit the patient to the implant. Preoperative planning for version is difficult, and femoral version is not fully appreciated until the femoral osteotomy is performed. The neck modularity in this uncemented tapered design allows for fitting the femoral anatomy without making significant adjustments to stem version, which have the potential to increase the risk for femoral fracture. Surgical techniques that have evolved with this stem include ability to prepare the femur first. Determination of femoral version allows for better determination of cup placement. Insertion of the stem first allows the stem to be inserted before preparation of the acetabulum, as there is no neck to interfere with cup insertion (Figure 6). This decreases blood loss because the stem is inserted immediately after broaching and before cup insertion. Stem insertion allows the trial reduction to be performed off the real femoral implant (Figure 7). We prefer to maximize anteversion on the femoral side to avoid excessive anteversion on the acetabular side, which can increase polyethylene wear and predispose to an anterior hip dislocation.

The modular neck stem facilitates surgical exposure in the minimally invasive posterior approach because the neck is not inserted until the trial reduction. Once the stem and cup are inserted, leg length is determined. Anteversion is determined by the Ranawat test to be between 35° and 50°. We then prefer to perform an "abduction shuck test" to determine proper offset. If this is sloppy, then offset is increased without sacrificing leg length. The capsule is also checked to see whether it can be repaired easily to the insertion site on the greater trochanter so that offset is not excessive. If the capsule is too tight, the surgeon can back down on the offset length without making the leg shorter and still be able to close the capsule, ensuring excellent hip stability.

Modular neck systems have become increasingly

popular, as they have the potential to address a wider range of patient anatomies and offer increased intraoperative flexibility. Potential concerns with the additional modular junction include fretting/corrosion and failure at the neck-stem junction. Three recent case reports of a failure of a modular neck hip stem (Profemur Z; Wright Medical Technology, Arlington, Tenn) have increased the attention being given to this potential complication.[24-26] It should be noted that 2 of these cases involved fairly large patients and traumatic falls, and the third involved failure of a neck replaced during a revision surgery. A commonality in these cases is use of long necks, which all the authors postulated as a contributing factor. As noted earlier, fatigue strength performance is influenced by amount of offset, amount of version, and, in the case of modular neck implants, taper design geometry. The Kinectiv system does not offer as much offset or version, and the neck junction is appreciably longer than that of the implants in the case reports. Although our series is preliminary, there were no cases of stem or neck failure caused by the modular design. So far, more than 25,000 THAs have been performed with this modular stem, and there have been no reported implant failures of the neck-shaft junction.[15] Historically, modularity has been a well-accepted advancement in prosthetic design, as evidenced in the early 1980 introduction of modular heads. The versatility added to the surgical procedure facilitated more accurate and stable biomechanical reconstruction. Initial concerns about strength and particulate debris eventually abated, and the modular head stem prosthetic design has become the standard. Although modular neck implants have been implanted for almost a decade, longer-term follow-up is needed to monitor the clinical effectiveness and performance of these designs.

This series illustrates the surgical advantages that have arisen from this technology. Increased preoperative and intraoperative flexibility of independent offset, version, and leg length provides more freedom to hit the "bull's-eye" in terms of head center. The distribution of head center use in this cohort shows that most modular necks implanted in the Portland series were used to achieve head center locations that would not be available in the nonmodular design with identical body. This trend is corroborated by the larger distribution. Therefore, *outlier* appears to be a misnomer. The potential weakness of this interim analysis is the relatively modest clinical follow-up. We are continuing to follow this cohort, and long-term results will be reported to determine the safety and longevity of modular neck implants.

Authors' Disclosure Statement

Dr. Duwelius wishes to note that he is a paid consultant to Zimmer, Inc., and holds patents and is a Developing Surgeon and Consultant on Zimmer's Kinectiv Stem. Dr. Hartzband wishes to note that he is a paid consultant to Zimmer, Inc. The other authors report no actual or potential conflict of interest in relation to this article.

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A Modular Hip System for Simplification of Revision Hip Arthroplasty

Todd Sekundiak, MD

Abstract

Revision femoral arthroplasty can be a daunting task. Historical success with a host of different reconstructive options has previously been reported. The Zimmer Modular Revision (ZMR®) system provides a complete armamentarium for the revision setting. For lesser femoral defects, the modular ZMR system can be used to create a custom preassembled implant. For more difficult situations, the implant can be sequentially assembled in vivo. The ZMR system can thus separate the tasks of revision femoral surgery so that the surgeon does not have to manage all issues at once. Fixation, length, offset, and implant version can all be handled independently to allow a safe, easy, and reproducible reconstruction in all settings.

Revision hip arthroplasty is unquestionably one of the most difficult orthopedic procedures to perform. Because of different failure mechanisms and different host bone and soft-tissue defects, each procedure and each implant must be individualized to accommodate these deficiencies. At the same time, successful reconstruction must be ensured so that the patient can begin early mobilization and the reconstruction can prove durable for an extended period. Revision femoral arthroplasties are becoming more and more prevalent as the number of index primary total hip arthroplasties has been increasing. Historically, great success has been reported with a host of different reconstructive options as long as the type of reconstruction was able to accommodate the severity of the defect.

The question arises as to whether there is a methodology to build on the success with these historical reconstruction options while still extending the breadth of their role. This would simplify the procedure and ensure efficiencies in this modern medical marketplace. Decreased operative time, reduced implant inventories, and fewer complications would ensure more successes of revision total hip arthroplasty.

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We previously used fully porous-coated femoral implants in all our primary and revision arthroplasties. Paprosky and colleagues, and others, have reported great success with the use of fully porous-coated femoral stems—more than 96% success in reconstructing femoral defects.[1,2] There were caveats, however, to this success. The more severe the femoral defect was, the higher the chance the reconstruction would fail.[3] Paprosky and colleagues[2] promote canal filling the femoral defect with these stems to obtain ingrowth. Failure to do so would fail to obtain ingrowth, as there would be inadequate rotational and axial stability for ingrowth to occur. There were also significant numbers of patients who experienced stress shielding, as these implants were made of very stiff cobalt-chrome and were often placed in patients with extremely osteopenic bone. These highly successful results were also a result of surgeons being extremely talented and skilled in the reconstructions and having experience with numbers of cases that some surgeons performing revision arthroplasties may never see in a lifetime. To aid in ingrowth potential, many cases required strut allografting to promote axial and rotation stability until bone ingrowth could occur.

"Success today is measured not only by achieving long-term fixation but also by replicating normal hip biomechanics—a goal that has been facilitated by modularity."

There are alternatives to porous implants, and success can be achieved with cemented femoral components, femoral impaction grafting, and even allograft prosthetic composites.[4-10] With less severe defects all of these techniques can have success, but with more severe femoral defects significant failures are more common. Each continues to have its own inherent operative complications, such as fracture, dislocation, infection, and failure to ingrow. And as with insertion of porous femoral implants, insertion techniques are of some difficulty.

To manage these multiple defects and patient types, modularity was introduced. Modular connections are being increasingly diversified in total hip prostheses to give the surgeon more choice in implant fit and more

latitude in design features. Proximally porous-coated modular femoral stems were one of the first modular revision components used. Published reports have noted few complications related to implant modularity. The difficulty in the revision setting arises from reliance on proximal ingrowth in a setting in which proximal bone is severely compromised.[11]

With any change to already successful procedures, one must also ensure that no new complications are introduced. The ZMR® femoral revision system (Zimmer, Warsaw, Ind) has been introduced to handle these issues. Modularity was earlier questioned by many surgeons, even in the primary setting, but today, with the ability to adjust head size and neck length, modularity has been almost universally accepted. Success today is measured not only by achieving long-term fixation but also by replicating normal hip biomechanics—a goal that has been facilitated by modularity.

Modularity comes at a price, and those using this technology have to accept the risks for corrosion, fretting, and potential fracture. The benefits in the revision hip setting, however, have far outweighed these risks in my revision practice. Although all metal tapers are susceptible to corrosion and fretting at these junctions, no gross wear, loss of material, or appreciable change in normal dimensions of the taper is clinically evident in a well-functioning arthroplasty.[12] There are case reports of fractures, and these fractures have occurred where there is an unsupported proximal implant. It should be made clear that all proximally unsupported femoral stems, cemented or uncemented, are also susceptible to fracture. If proximal ingrowth or support of the body cannot be obtained, then a large junction taper, which rivals a monoblock 19-mm cobalt-chrome stem in strength, should be considered.

The ZMR modular femoral revision system simplifies my operative experience while ensuring that the maximum number of hip deficiencies can be handled. The ZMR modular hip revision system allows the surgeon to separate the tasks of femoral revision, which previously had to be handled all at one time—a daunting task for experienced and nonexperienced surgeons alike. Having previously used fully porous femoral stems for all my primary and revision femoral stems, I initially felt that the more than 10,000 ZMR component combinations were redundant (Figure 1). What I later had to accept is that I needed these combinations to deal with the complications that I was still seeing with my revision practice—dislocation, leg-length discrepancy, failure of ingrowth, and severe medical complications that resulted from excessive operative time.

The ZMR system allows the surgeon to separate the tasks of femoral revision so that the combination of modular femoral components is a calculated sequential reconstruction. The ZMR system allows the surgeon to first develop a stable method of fixation by selecting the appropriate femoral stem. Once the stem has been chosen and fixed, the body is then selected to replicate the appropriate length of the extremity. Once length has been determined, the appropriate offset for that body length is then selected. Finally, the surgeon then has the ability to rotate that body of set length and offset to an infinite number of version options to optimize stability of the reconstruction. With more severe modes of failure, it is becoming more commonly recognized that the femoral anteversion required for a functional hip in the revision setting can vary extensively because of the femoral remodeling and compromised mechanics that can occur.[13,14] Previously, with nonmodular components, all these tasks were codependent. There would be no way to predict where or how these implants would fit definitively. Legs too long, implants failing to ingrow, unstable hips, and fractured femurs unfortunately were not that uncommon.[15]

"The ZMR modular hip revision system allows the surgeon to separate the tasks of femoral revision, which previously had to be handled all at one time."

Stem Options

The ZMR system is built on a mix of different body and stem options. The stems have different distal fixation options—splined, polished, cylindrical; porous cylindrical; and tapered splined (Figure 1). With the reported success of proximal ingrowth modular stems, I attempted using the cylindrical splined stems, but migration and failure were common, as I was asking already compromised proximal bone to do too much work. I could get my reconstruction to work in the early postoperative setting, but the implant would plow through the weak bone, as mechanical fixation could not be maintained until bone ingrowth could occur. Success would occur in noncompromised bone where the metaphyseal bone, Paprosky type I or II, was still intact. More severe defects would still have failures.[11]

Working on the success of fully porous-coated nonmodular components, reconstruction with modular porous cylindrical stems was also explored. The success was

Figure 1. ZMR body and stem options.

Figure 2. (A,B) Early: A ZMR tapered stem in a type IV femur in early postoperative phase. (C,D) Late: A ZMR tapered stem in a type IV femur in late postoperative phase. Migration has occurred. Patient is asymptomatic and mobilizing independently.

improved and paralleled that of nonmodular porous femoral components. The modularity allowed for factors of compensation. The first and most obvious benefit was that modular porous femoral components allowed for compensation of how the porous stem plowed and wedged itself into the host femur. For fully coated porous stems to work, they must be stable rotationally and axially. This demands that the surgeon impact these stems rigidly enough that these implants would not twist and compromise ingrowth into the bone with normal lower extremity function. A 4-cm fit has previously been discussed to ensure that these stresses can be absorbed without motion of the stem. Unfortunately, this very intimate fit means that some stems may sit proud, or, worse yet, the femur may fracture if the surgeon is overzealous in attempting to obtain this intimate fit.[15] The ZMR system enables us to compensate for the variation in fit between the trial and actual femoral stem implant by allowing us to use a different length of femoral body implant, rather than having to further impact the stem to compensate for leg-length mismatch.

For more severe defects, the other problem is that bowed femoral components are required to accommodate the associated anterior femoral bow. With nonmodular components, the amount of femoral version that can be placed within the revision reconstruction is limited. Mismatching the component's bow to the anatomical femoral bow will create a conflict and a possible fracture. However, accommodating the femoral bow can also mean that the hip can become unstable, as the fixed femoral component's version on a nonmodular femoral stem may not match the patient's anatomical version. Again, modularity allows the surgeon to independently adjust fixation and version. As femoral defects become more severe, a greater degree of femoral torsional remodeling can develop. This means that fixed version on stems cannot parallel the versional abnormalities that a surgeon might see.[3,13,14]

Obtaining distal fixation of a porous femoral stem is a daunting task, and, although I prefer diaphyseal fixation for all of my femoral components in both primary and revision total hip arthroplasty, it is simply more difficult than using tapered stems. As stem morphology improves, we see use of proximally tapered femoral stems in the primary setting increasing. The same now occurs for revisions. The difference for revisions is that distal fixation is still required for long-term success, as has previously been shown by Paprosky and others.[2,9,16] The ZMR modular tapered splined femoral stem accommodates these issues. The tapered design allows the surgeon to easily insert the component and find the point of fit. No further impaction is required. If further impaction is attempted, fracture may occur. Because the tapered stem is wedged into cylindrical bone, and because the splines engage the endosteal cortex to gain rotational stability, 4 cm of press-fit is not required.

"...fixed version on stems cannot parallel the versional abnormalities that a surgeon might see."

This is a much more effective mode of controlling rotation than using the press-fit alone. The final issue is to obtain bone ingrowth once the component has been stabilized. Use of a beaded or plasma-sprayed surface may cause the surgeon to be suspicious of the ZMR surface of corundumized titanium, but, as a revision surgeon, I assure you that these implants obtain ingrowth and need to be trephined out for removal. This surface, when used on different implants, has previously been described as obtaining bony surface ongrowth. This is a misnomer.

The question arises as to whether this tapered titanium surface could match the clinical success reported with porous cylindrical stems. The ZMR tapered femoral stem matches the morphology of the Wagner revision femoral stem (Zimmer Inc., Warsaw, Ind). This stem has had significant use and much clinical success in Europe and elsewhere.[6,9,17-19] What was noticeably different between this stem and porous cylindrical

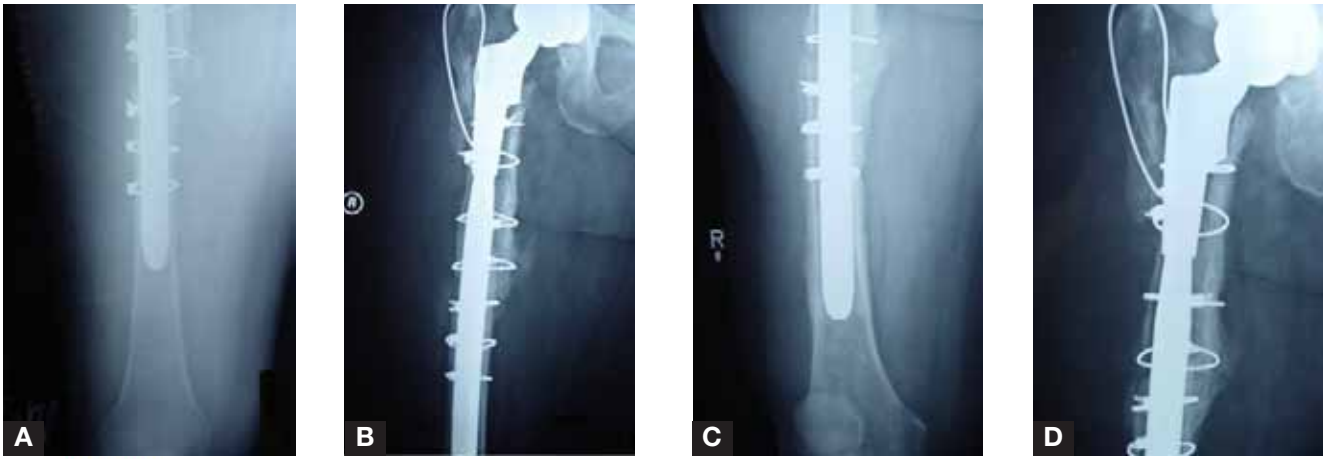

Figure 3. (A,B) Early: ZMR porous-coated stem in type IV femur early postoperative phase. (C,D) Late: ZMR porous-coated stem in type IV femur in late postoperative phase. Migration has occurred. Patient symptomatic and unable to weight-bear.

stems is that migration can occur in some patients but bone ingrowth can still be obtained. The reason is that the splines on the tapered stem block rotational stresses, even under the continual axial stresses that occur during the postoperative phase. Because of the tapered splined geometry of the implant, the implant literally wedges into position (Figure 2A,B;C,D). Porous cylindrical stems do require an extended degree of intimate endosteal fit and fill to absorb these stresses. When migration occurs, the vast majority of these stems fail, as interference fit is lost, and rotational motion prevents ingrowth (Figure 3A,B;C,D).

As with primary taper stems, the ZMR taper stem can be removed should adjustment of position be required. Preparation for the stem is done with tapered reamers. Trials using components the same size as the actual components, but without the splines, are then done. The splines of the actual implant can engage into the host bone differently and, depending on the caliber of bone, sit differently from the trial component. If the implant sits up higher than expected, the implant can be removed and reinserted once repeat reaming slightly more distal is performed. If the implant seats slightly lower than trialed, then a longer femoral body can accommodate the more engaged stem. The reverse is also possible if a shorter body is available.

The 3° tapered stem is replicated from the Wagner stem. Its engagement in the curved femoral canal achieves 3-point fixation if the cortical tube has been left intact. The tip of the stem is tapered to abut the anterior endosteal surface to prevent migration while limiting the risk for perforation (Figure 2A). The stem also engages in the mid-diaphyseal region for most of the fixation. Finally, the proximal cortical tube, if intact, prevents extension of the implant and holds the component in position.

Body Options

The ZMR bodies are of 3 different types—a porous spout body, which provides proximal fit and fill; a cone body, which allows for more version options, as there is no metaphyseal fill; and a calcar body, which provides a collar to rest on the remaining host bone. Each has

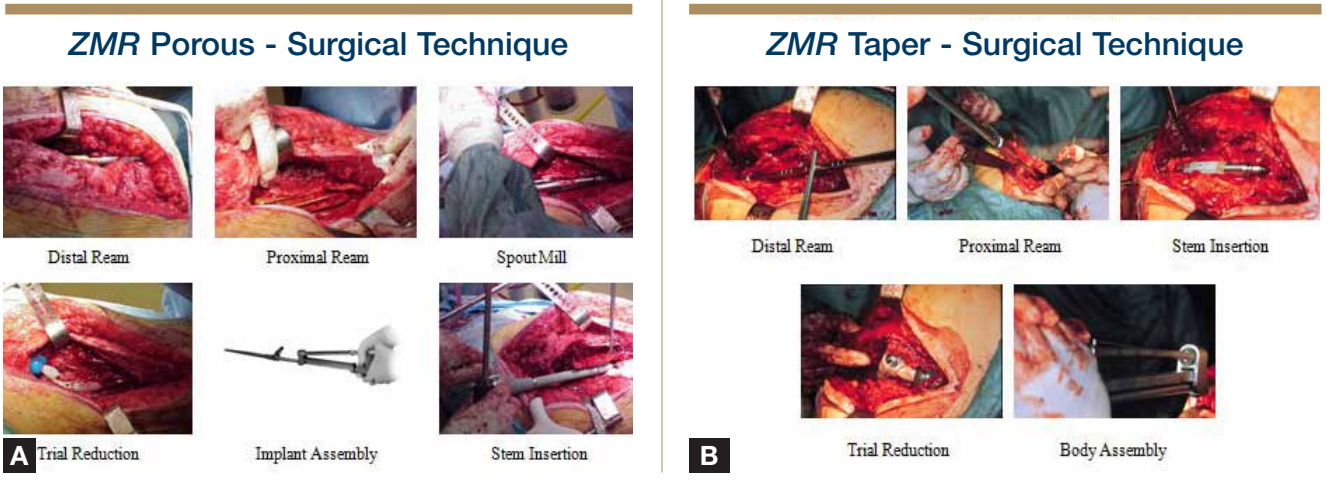

Figure 4. (A) Insertion of ZMR components as preassembled implant. (B) Insertion of ZMR components as in vivo assembled implant.

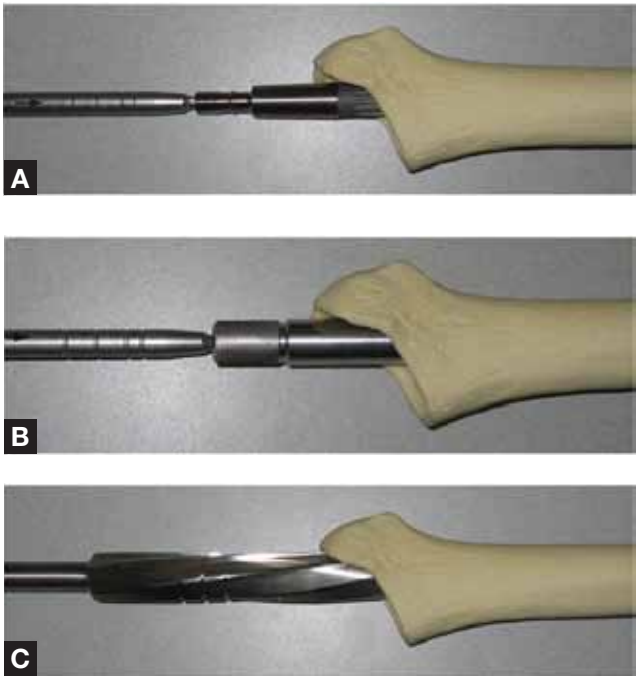

Figure 5. Over-the-junction reamers. (A) Femoral stem is inserted. (B) Stem protector is screwed onto stem. (C) Reamer prepares to set depth for body application.

3 different lengths, allowing the surgeon to accommodate 20 mm in length variance and low and high offsets; the spout body also comes in multiple diameters. To protect the taper, it is essential to get fit and fill in the metadiaphyseal region, just above the junction. For lesser defects, the tapered stem can be fixed to a spout body of the surgeon's choosing to create a custom tapered stem that can accommodate most metaphyseal variances. There is also an extra-large junction body, which can rely solely on distal fixation and has 4 sizing options to accommodate 25 mm in length variance (Figure 1).

The technique of femoral stem insertion proceeds in 1 of 2 ways. For stems of lesser defects, we tend to insert the femoral stem and body as one. The components are assembled ex vivo, and the modularity is used to create a custom preassembled stem to accommodate the revision femoral defect, which most primary stems could not accommodate. Commonly, a "crossover" technique is used. A tapered femoral stem is used to give good rotational stability, while a proximal spout body is used to give fit, fill, and possibly proximal ingrowth. Preparation proceeds by reaming the distal canal to a set depth, reaming for the body, milling for the spout, and then sequentially trialing (Figure 4A). For more severe defects, preparation proceeds by separating the tasks of revision. First, the distal canal is reamed, and fixation is assessed with stem trials. The body trial is then placed to assess length and offset. If satisfactory, the actual stem is seated to gain fixation. Preparation for the body can be done with regular body reamers or with over-the-top reamers, which fit over the actual femoral stem (Figure 5). Trial bodies fit onto the actual femoral stem, and length is again assessed. Length adjustments are performed by altering body lengths or by altering stem placement. Once length is satisfactory, the body is then rotated to adjust for version. For final adjustment of stability, a high- or low-offset option can be used (Figure 4B).

Lakstein and colleagues[20] very recently reported on the success of the ZMR porous-coated femoral stem in revision total hip arthroplasty. After a minimum 5-year follow-up, survival rates were 93.8%. The stems reported in this series were of the porous cylindrical varieties that were also used in this early follow-up setting. With the same techniques and use of the tapered splined implants, success is expected to be equivalent, if not better.[16] The tapered splined implant allows the surgeon to obtain the same intraoperative hip stability but with more ease and reproducibility. This system—using a modular tapered stem—has been advocated by Sporer and Paprosky for the most severe femoral defects in which traditional nonmodular components have failed.[13] We also advocate this system, not just for the most severe femoral defects, but also for the lesser defects. Not only does this ensure the same success as obtained with techniques used by very talented surgeons, but success is achieved with a much simpler technique.

Conclusions

The ZMR revision system has the potential for more than 10,000 combinations of body, stem, and femoral head. As a revision surgeon, I realize that these multiple combinations can initially present a more daunting task for reconstruction. On the basis of historical successes and failures, we have presented a reconstruction protocol to make these combination choices easier. Obtain fixation with the modular stem. Adjust for length with the body. Finally, rotate the body and choose the amount of offset in the body to obtain stability. As easy as one, two, three. As I became older and, I hope, more experienced, traditional reconstruction options, though successful, became too difficult. Just as in the primary hip arthroplasty setting, I have abandoned fully porous-coated implants as simpler, more effective reconstruction options became available. This is not because fully porous-coated implants have had more significant failure rates, but because these implants are just too difficult to insert in a reproducible manner. I have found the ZMR system to allow revision femoral hip arthroplasty to be successful, reproducible, and simple—an option that has not existed before.

Author's Disclosure Statement

Dr. Sekundiak wishes to note that he is a paid consultant to Zimmer, Inc., and has an ongoing relationship with Zimmer.

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Use of the Fitmore® Hip Stem Bone-Preserving System for the Minimally Invasive Anterior-Supine Approach in Hip Replacement

Jonathan G. Yerasimides, MD

Abstract

Total hip arthroplasty through a single-incision anterior approach is a minimally invasive surgical (MIS) technique that allows component placement without violation of the posterior hip capsule or "hip deltoid." This allows faster recovery without dislocation precautions. The Fitmore® hip stem (Zimmer, Warsaw, Ind) is a bone-conserving stem designed for use in MIS techniques. The technique described here is a single-incision anterior approach with the Fitmore stem using a special orthopedic table.

Total hip arthroplasty (THA) is one of the most successful orthopedic procedures. The first anterior-approach hip replacement was performed by Judet in 1947.[1] At that time, he implanted an acrylic femoral head prosthesis with a stem following the axis of the femoral neck. This construct was not biomechanically sound and did not perform well over the long term. Also at that time, Charnley was developing a procedure for a hip arthroplasty (the low-friction hip prosthesis) that would be more durable than Judet's acrylic prosthesis.[2]

In Charnley's technique, the patient was positioned supine with the operative leg draped free, and a trochanteric osteotomy allowed access to the joint. Complications with the osteotomy led to a modification, use of the posterior approach, which most surgeons in the United States use today. This approach allows for good access to the joint but comes with a variable risk of hip dislocation. Another common technique for hip joint replacement is the anterolateral, or Hardinge, approach. This approach provides for excellent stability but requires detachment and reattachment of the hip abductors. This causes a delay in recovery and occasionally a permanent deficit in abductor function.

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The modern anterior-approach THA is a merger of the ideas of two founding fathers of hip arthroplasty. With today's low-friction bearing surfaces providing improved durability, attention has been turned to surgical technique. Judet's original technique has been popularized in the United States in recent years, most notably by Matta.[3,4] Judet referred to the surgical approach as the *Heuter approach,* which likely refers to Heuter Volkmann and the approach used for drainage of tuberculosis abscess of the hip. In the United States, the approach is commonly referred to as the *Smith-Peterson approach*. For hip arthroplasty, the technique is slightly different from a traditional Smith-Peterson approach, using only the distal limb of the incision. Judet's original procedure was facilitated by the Judet/Tasserit table. This table is no longer in production, but a modern version, the Hana table (Mizuhosi, Union City, Calif), is currently used as an additional surgical tool for the procedure (Figure 1).

The major benefit of the anterior approach is preservation of natural muscle attachments and the posterior capsule of the hip. With the posterior capsule intact, hip precautions are not needed, and patients are allowed to position the leg as tolerated immediately. The gluteus medius and minimus attachments are preserved as well as the "hip deltoid." This structure, created by the joining of the tensor fascia lata and gluteus maximus by the iliotibial band, is extremely important as a pelvic stabilizer and abductor of the hip.[5] Preserving the hip deltoid and abductors allows for earlier functional recovery.

The anterior approach allows for use of many different implant designs, both uncemented and cemented.

Figure 1. The Hana table (Mizuhosi, Union City, Calif), which aids in femoral exposure by controlling the operative leg, is shown with leg externally rotated, extended, and adducted, as it would be positioned for femoral broaching. Photo reprinted with permission of Mizuhosi.

Figure 2. The Fitmore® hip stem (Zimmer, Warsaw, Ind) is a short curved stem that follows the calcar anatomy and relies on complete apposition on the calcar region with a single point of contact on the lateral cortex. Illustration reprinted with permission of Zimmer, Inc.

My personal experience ranges from shorter, abbreviated femoral stems to long, modular revision femoral components. With experience, all types of stems are implantable, but there is little doubt that shorter implants with a reduced lateral shoulder are the easiest to use. One of the newer stems specifically designed for minimally invasive surgery (MIS) is the Fitmore® hip stem (Zimmer, Warsaw, Ind). The stem is short and curved to reduce the amount of bone removed during rasping, specifically in the region of the greater trochanter (Figure 2). Because of the curved silhouette, which is designed to match the curve of the calcar, very little bone needs to be removed laterally, which is more difficult to access with the anterior approach. In addition to technical ease with the anterior approach, the stem also allows for multiple offset options, including reduced, standard, high, and extra extended. This allows for better control for soft-tissue balancing of the hip, which is critical for stability and function. In this article, I describe the surgical technique for implantation of the Fitmore hip stem using an anterior approach with the Hana table.

Surgical Technique

The patient is placed supine on the Hana table with boots locked into the leg spars. The padded perineal post is positioned, and the arms are placed straight out to the side, perpendicular to the table. The operative leg is placed in slight internal rotation to accentuate the bulge of the tensor fascia lata and in slight hip flexion to reduce tension across the rectus femoris. The incision is typically 10 cm in length, starting 2 cm posterior and 1 cm distal to the anterior superior iliac spine (ASIS). The incision is angled to follow the tensor fascia lata muscle as it originates from the ASIS and inserts into the iliotibial band (Figure 3).

Dissection is carried down to the fascia lata. This thin fascia is translucent blue and should be incised in line with the skin incision. An Alice clamp is used to grasp

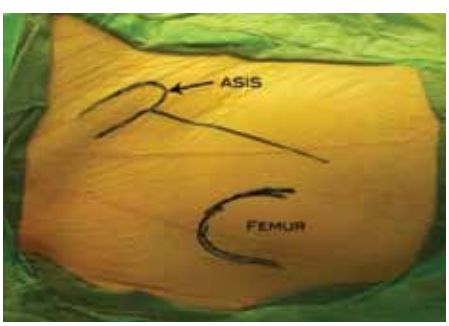

Figure 3. Incision is started lateral to the anterior superioriliac spine and is angled distally and laterally, following the orientation of the tensor fascia lata muscle.

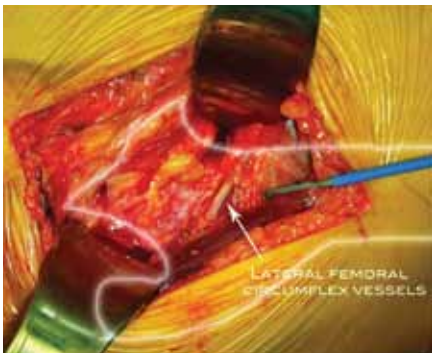

Figure 4. Lateral femoral circumflex vessels, in inferior portion of exposure, run transversely across incision and must be identified, isolated, and controlled.

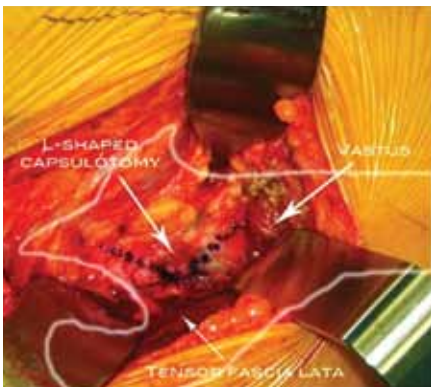

Figure 5. L-shaped capsulotomy follows intertrochanteric line just above vastus intermedius, then parallels femoral neck across acetabular rim. Reflected head of rectus femoris can be preserved or transected according to surgeon preference.

the medial edge of the fascia lata, and blunt dissection with a finger is used to strip it off the tensor fascia lata muscle belly and expose the muscular interval. Blunt dissection is used to feel the femoral neck and create a pocket superolateral to the femoral neck for placement of a blunt Cobra retractor. A Cobb elevator is used to elevate the rectus femoris from the anteromedial femoral neck, and another blunt Cobra retractor is placed under the rectus femoris around the inferomedial femoral neck. At this time, the lateral femoral circumflex vessels can be identified in the inferior portion of the operative field (Figure 4) as transverse structures at the superior border of the vastus intermedius. It is critically important to control the vessels with cautery or suture ligation.

The entire anterior hip capsule is now exposed, and an L-shaped capsulotomy is performed with one limb following the intertrochanteric line along the superior border of the vastus intermedius and the other limb paralleling the femoral neck up to the edge of the acetabulum (Figure 5). The proximal portion of the capsulotomy crosses the acetabular rim and reflected capsular origin of the rectus femoris. It is an option to retract the reflected head of the rectus to preserve it, but, in my experience, this action neither decreases pain or improves functional recovery. The anterior and lateral capsule edges are then tagged with suture for retraction and later repair. At this point, I prefer to release the capsule from the "saddle" of the femur. This is the region laterally where the femoral neck curves upward into the greater trochanter. Performing this release now makes the later femoral exposure easier. The leg is exter-

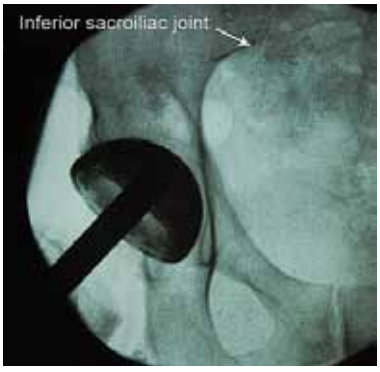

Figure 6. Cup is inserted under fluoroscopy. Apex of cup is directed toward inferior sacroiliac joint to obtain proper cup abduction. Anteversion is estimated by oval opening of cup or by using angle of insertion handle to floor, which should be 10° to 15°.

nally rotated approximately 45°, and the medial femoral neck is cleared of the capsule and the anterior iliofemoral ligament. With proper release, the lesser trochanter should be easily palpable. A sagittal saw is then used to cut the femoral neck with reference made from the "saddle" of the femur. For surgeons comfortable using the lesser trochanter as a guide, the cut can be verified with palpation of the lesser trochanter. Slight traction can be applied to the leg to distract the osteotomy, and the leg is placed in slight external rotation to clear the femoral neck. A corkscrew is placed into the cut end of the femoral neck, and the head is removed.

Retractors are then placed anterior and posterior to the acetabulum for exposure. Standard removal of the labrum and remaining soft tissue in the acetabular fossa is performed. Care should be taken to cauterize the acetabular branch of the obturator artery as it enters from the acetabular notch. I prefer to ream under fluoroscopy and perform reaming without retractors in the wound. Between each reamer, the reamed rim is palpated, and, after the final reamer, retractors can be placed around the acetabulum again to confirm complete removal of cartilage. The acetabular shell is also placed with fluoroscopy for proper positioning. My ideal cup position is 45° of abduction and 10° to 15° of anteversion. The anteversion can be measured using the floor and lifting the cup insertion handle to 10° to 15° off the neutral plane of the floor. The abduction can be estimated by pointing the apex of the acetabular shell at the inferior portion of the sacroiliac joint on the fluoroscopic image (Figure 6). A neutral acetabular liner is always used, as proper implant position is confirmed with image intensifier.

Figure 7. Shape and size of Fitmore raspers facilitate rasping of femoral canal without removing bone laterally. Rasps are inserted along calcar, preserving bone in greater trochanter. This rasping technique is easily performed through the anterior approach. Illustration reprinted with permission of Zimmer, Inc.

Attention is then turned to the femur. The femoral hook for the Hana table is placed around the femur just below the abductor tubercle. The hook is placed external to the vastus lateralis and most easily placed with the leg in a neutral rotation. After placement of the hook, the leg is externally rotated to at least 90°, extended toward the floor, and maximally adducted under the contralateral leg. The hook is locked into the bracket arm, which is attached to the femur lift on the table. The femur lift is used when elevating the proximal femur into the wound. The femur lift should not be used as a "crane" to lift the femur, as it could cause fracture. The proximal femur is lifted by hand, and the mechanical lift is brought up to the level achieved by manual elevation. A Müeller retractor is placed over the medial calcar, and a bent Hohlman is placed over the tip of the greater trochanter. The Hohlman should be placed outside the lateral hip capsule and inside the gluteus minimus muscle. The hip capsule should be completely released from the inside of the greater trochanter until the inside portion of the bone is visualized. For the most part, exposure of the femur is the rate-limiting step of the operation. Before proceeding, surgeons must be able to see clearly the entire inside of the greater trochanter. The piriformis and obturator internus tendons can be released if additional exposure is needed. The posterior capsule and the obturator externus, which inserts more distal, should never be released.

Broaching with the Fitmore system through the anterior approach is slightly different from standard broaching techniques. First, the starting point should be in the posterior middle third of the cut femoral neck. The rasp should be inserted in a curved fashion to follow the medial calcar and proximal femur (Figure 7).

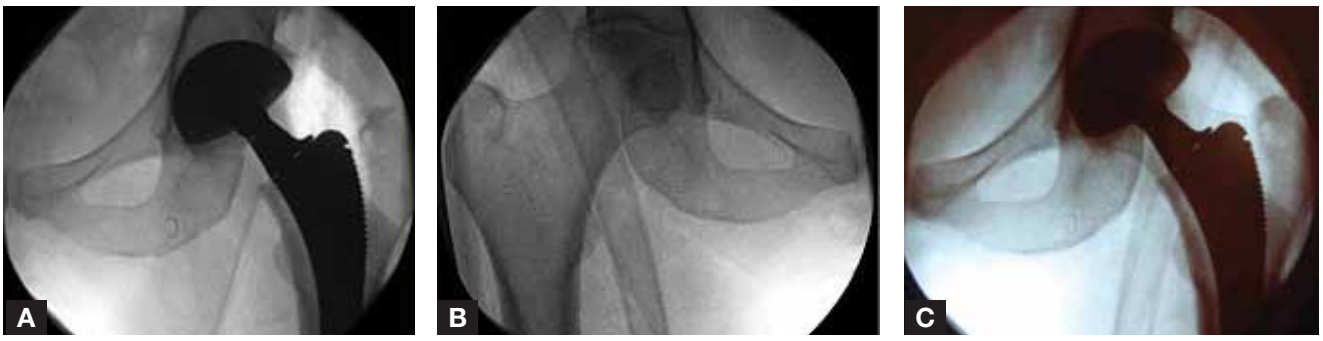

Figure 8. Fluoroscopic images of operative **(A)** and nonoperative **(B)** hip are printed during surgery and superimposed to confirm length and offset with trial implants in place **(C)**.

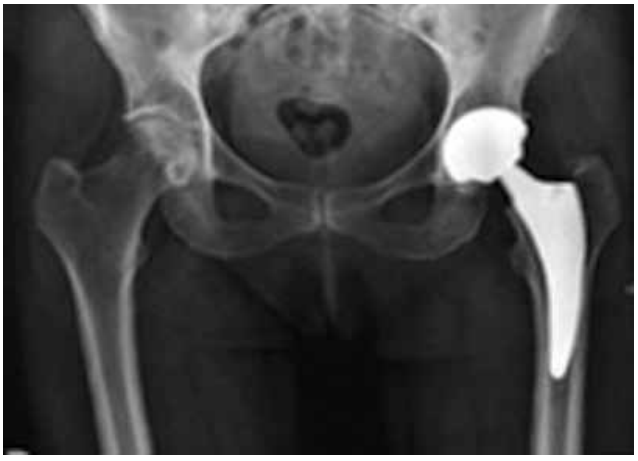

Figure 9. Final postoperative radiograph shows good component positioning with good reproduction of length and offset.

The entire medial aspect of the implant should be in contact with the medial border of the proximal femur with only one point of lateral contact. Fluoroscopy is used for leg length and offset confirmation. I prefer to use printed pictures of the trial side and the nonoperative side as intraoperative overlays (Figure 8). This is my personal preference; alternative techniques with fluoroscopy are widely used. Once length and offset have been confirmed, trials are removed, and permanent implants are inserted to the level of the trial femoral component. Again, fluoroscopy is used for confirmation.

The anterior hip capsule is then closed using the previously placed tag sutures. A deep drain is placed, and the fascia lata is closed with absorbable suture. The skin is then closed with absorbable suture and Dermabond (Johnson & Johnson, New Brunswick, NJ). I prefer using Quill (Angiotech, Vancouver, Canada) for closure, as it requires no suture knots, and I have found it to be extremely strong, withstanding wound dehiscence even in the obese. After surgery, patients are allowed weightbearing as tolerated, and no dislocation precautions are followed. A postoperative radiograph is shown in Figure 9.

I have performed more than 1400 primary THAs with the anterior approach along with almost 50 hip surface replacements and 70 revision THAs. There have been no dislocations in my consecutive series of more than 1400 primary hip replacements.

This procedure should not be considered an MIS procedure applicable only to primary hip replacement. With experience, it can be used for any hip arthroplasty procedure that does not require augmentation of the posterior acetabulum.

Conclusion

It is necessary to stress that, while this approach has proven effective, there is no published data on the success of this stem. Further study will be needed to document the outcomes with the Fitmore stem.

Author's Disclosure Statement

Dr. Yerasimides wishes to note that he is a paid consultant to Zimmer.

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