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.

Dr. Sekundiak is Assistant Professor of Surgery, Creighton University Medical Center, Omaha, Nebraska.

Address correspondence to: Todd Sekundiak, MD, 601 N 30th St, Suite 2300, Omaha, NE 68131 (tel, 402-280-4342; fax, 402-280-4584; e-mail, toddsekundiak@creighton.edu).

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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.

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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]

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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

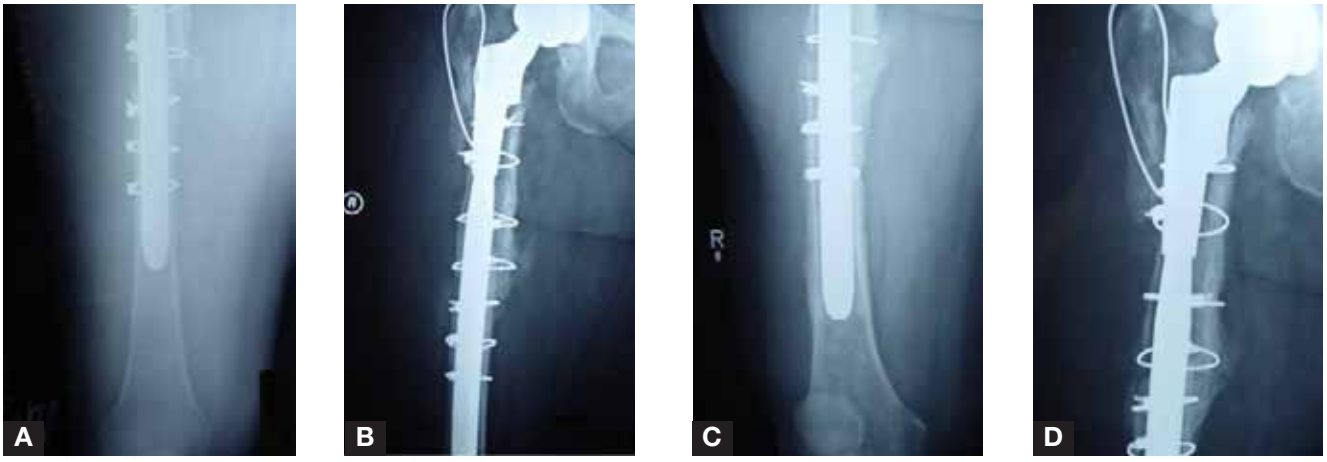

Figure 3. (A,B) Early: ZMR porous-coated stem in type IV femur early postoperative phase. (C,D) Late: ZMR porous-coated stem in type IV femur in late postoperative phase. Migration has occurred. Patient symptomatic and unable to weight-bear.

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

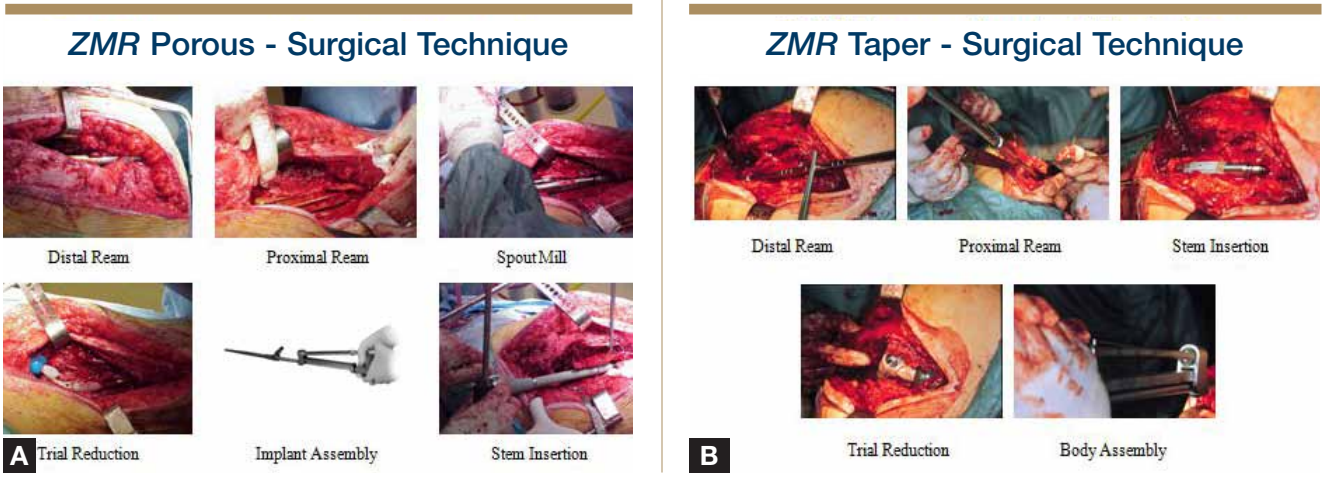

Figure 4. (A) Insertion of ZMR components as preassembled implant. (B) Insertion of ZMR components as in vivo assembled implant.

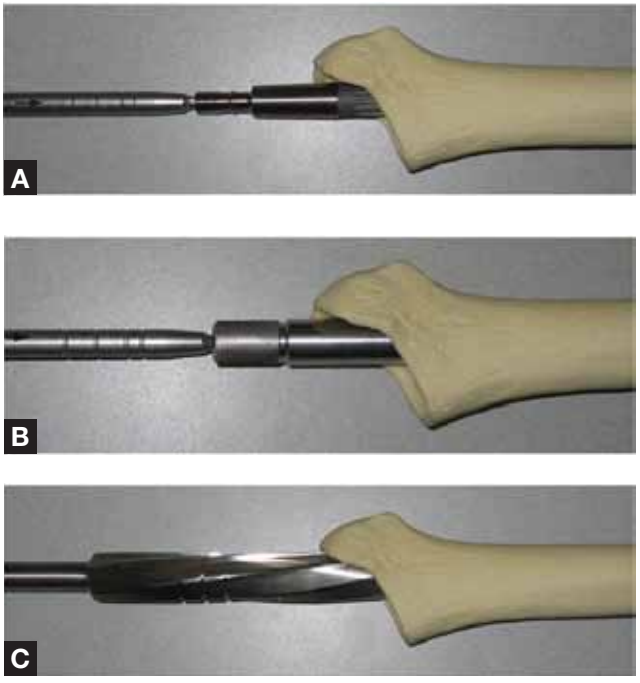

Figure 5. Over-the-junction reamers. (A) Femoral stem is inserted. (B) Stem protector is screwed onto stem. (C) Reamer prepares to set depth for body application.

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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