COMPONENT VERSION IN MODULAR TOTAL HIP REVISION

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ABSTRACT

Morphologic changes of the proximal femur make revision total hip arthroplasty challenging. Metaphyseal retroversion and diaphyseal varus are common in this scenario. Twenty-one total hip revisions using a modular femoral prosthesis were examined by obtaining three radiographs (A/P, surgical lateral, and true lateral of the femur) to assemble CAD models for determining the range of modular component positioning. An average of femoral neck anteversion was observed. Seventeen of 21 cases (81%) had retroverted metaphyseal segments (-23.2˚+/-17.4˚) and/or varus stems (-32.1˚+/-13.0˚). Neck anteversion averaged 21.4˚(+/-10.0˚). One of 21 cases (5%) resulted in component orientation similar to a non-modular prosthesis. Modular components provide options to accommodate proximal femoral remodeling not afforded by monobloc stems in total hip revision surgery.

INTRODUCTION

The benefits of modular femoral prostheses in total hip replacements have long been debated.[1-6] Modular stems provide the advantage of intraoperative flexibility to deal with the distorted femoral anatomy often encountered in revision surgery. Notable drawbacks of some designs include taper fretting/corrosion, and increased technical difficult. Clinically, several investigators have noted satisfactory results with modular implants in both primary and revision scenarios.[7-11] In revision surgery, independent neck and stem placement allows for adjustment of the rotational alignment of the components into configurations not available in common single stem revision implants. The surgeon is thus better equipped to deal with patients who have suffered from extensive bone loss, bony remodeling, periprosthetic fractures or developmentally atypical anatomy.

To our knowledge, the degree to which surgeons take advantage of rotational alignment configurations afforded by modular femoral stems has never been assessed. The present study quantifies the magnitude and direction of modular femoral components occurring in total hip revision surgery (Acumatch M-Series, Exactech Inc. Gainesville, FL, USA).

MATERIALS AND METHODS

Radiographs were obtained for twenty-one modular revision THAs in 21 patients that were performed over a thirty-month period by the senior author. Patient ages ranged from 37 to 87 years and indications for revision included twelve patients with aseptic loosening, four cases of sepsis, four periprosthetic fractures, and one mechanical device failure. Each patient had a well-fixed stem at his or her last clinical radiographic evaluation.

The Implant and Instrumentation: The AcuMatch M-Series (Exactech Inc. Gainesville, FL, USA) is a three-piece modular stem. Each component is compatible with all others such that any neck segment can be used with any size metaphyseal segment and with any size diaphyseal component. Rotational alignment of each segment is also independent. The stem is placed in a canal prepared by reaming, while the metaphysis is machined using a special reamer and guide whose location is controlled by the reamed canal.

In each case an M-series modular femoral stem with a curved distal stem was implanted. Diaphyseal diameters ranged from 13mm to 19mm with lengths between 200mm and 300mm. Metaphyseal segments were sized between 21mm extra small and 29mm small. Likewise, all femoral heads were 28mm in diameter with neck lengths ranging from –5mm to +10mm. Neck segment sizes ranged from –5mm with high offset to +30mm with standard offset.

Surgical Technique: The femur was prepared with sequential flexible reamers until the cortex was engaged. The metaphysis was machined using the “basket” guide aligned with the reamed femoral canal accommodating the existing shape of femur at that level.

Implant Trialing and Placement: Trialing was used to determine the size and rotation of the implanted

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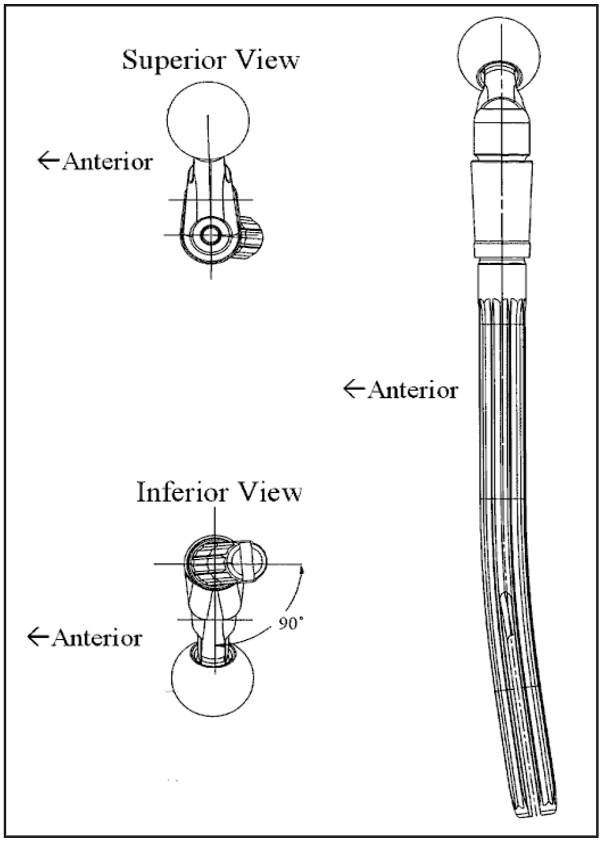

Figure 1. Implant with zero version.

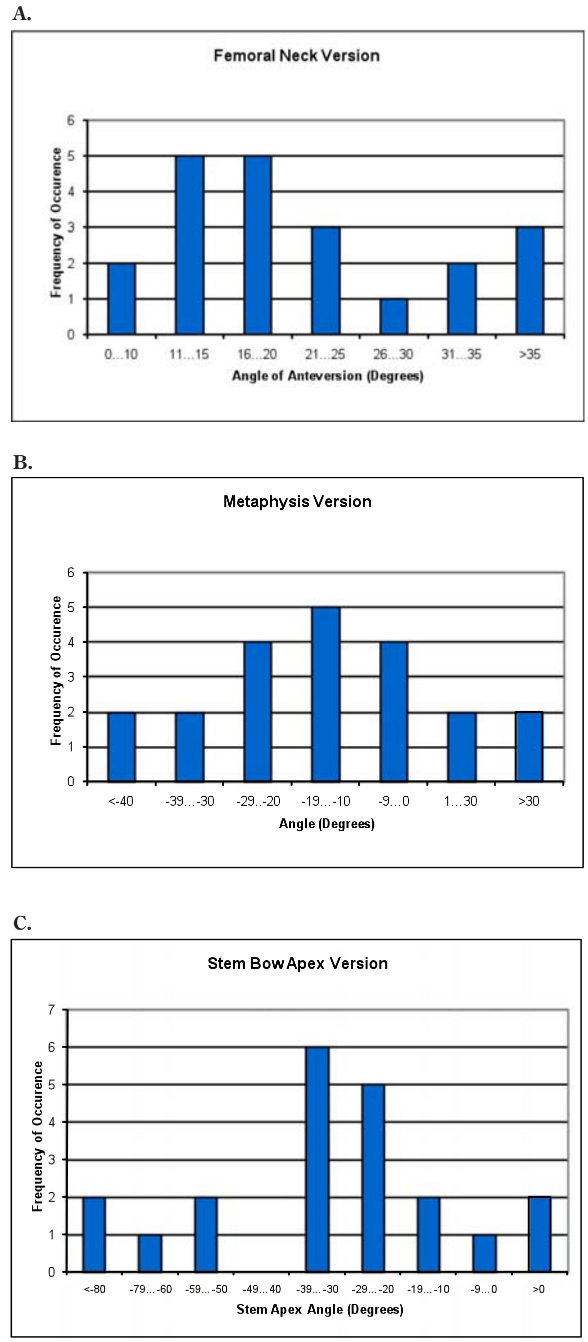

Figure 2. Distribution of neck (a), metaphysis (b), and stem bow (c) orientations.

component. The diaphyseal and metaphyseal trials were inserted together, although still able to be rotated about one another. The metaphyseal segment was positioned into the proper rotational orientation to conform to the bony metaphysis. The trial neck was applied and the locking bolt secured, fixing the orientation of the components. This construct was used as a template to assist in judging insertion of the definitive implants in a way that corresponds to the inner geometry of the bony architecture, recognizing that added adjustment can be performed with final insertion.

A diaphyseal component, 1 mm larger than the reamed canal, was introduced, engaging the sharp stem flutes to ensure rotational stability. A clothespin stem was used to reduce stress distally. The titanium plasma coated metaphyseal component with dual female tapers was introduced using an inserter that facilitates positioning and locking of the segments. The orientation of the femoral neck component (available in several lengths and two different offsets) was determined by the surgeon, and was typically 10 to 15 degrees of anteversion. Greater anteversion was required when persistent posterior instability was present.

Radiographic Analysis: Positioning of the modular femoral components was evaluated by obtaining an anterior/posterior and two lateral radiographs (true lateral of femur and surgical lateral of hip) for each patient. The radiographs from each case were retrospectively reviewed to determine the magnitude and orientation of the rotation of the components.

The surgical lateral view was used to assess the degree of anteversion of the femoral neck via the method described by Ghelman.[12] Three dimensional solid models of the individual implant components were assembled using Unigraphics (EDS Corporation, Plano, Texas), a commercial software package for computer-aided design (CAD). The individual components depicted by the CAD system were then rotated to mimic the alignment seen in the A/P radiograph. The model was then compared to the two lateral radiographs and adjustments were made to reconcile the three views. When the alignment of the model matched all three radiographs, the angle between the centerline of the neck segment and the center of the metaphyseal flare was measured. A measurement of 0° between the neck centerline and metaphyseal flare represents a version of zero. The angle between the centerline of the neck segment and the apex of the distal stem bow was also measured, with a measurement of 0° representing zero version. A component with zero verison is shown in Figure 1. With the neck anteversion established, the orientation of all components relative to the planes of the body could be assessed.

Two-tailed t-tests with unequal sample variances (student's test) were used to assess statistical significance, which was assumed to exist at $p < 0.05$.

RESULTS

An average of 21.4° +/- 10.0° (S.D.) of femoral neck anteversion was observed in our series. This value falls close to that which has been recommended by several investigators.[13-15] The metaphyseal segments averaged 35.0° +/- 40.6° version from the coronal plane. Likewise, an average of 36.6° +/- 18.0° of version was measured between the saggital plane and the apex of the stem bow. In only one case were the components oriented in the configuration shown in Figure 1. The distributions of neck, metaphysis and stem bow versions are shown in Figure 2.

As seen in Figure 3, the majority of the metaphyseal segments faced posteromedially (17/21, θ = -23.2.1° +/- 17.4° S.D.), with two facing anterolaterally (n = 2, θ = 149° +/- 8.59°), and two facing anteromedially (n = 2, θ = 20.9° +/- 16.4°). The anterolateral group, which was composed of two patients with complex periprosthetic fractures was significantly different from both the anteromedial ($p < 0.05$) and posteromedial ($p < 0.01$) groups

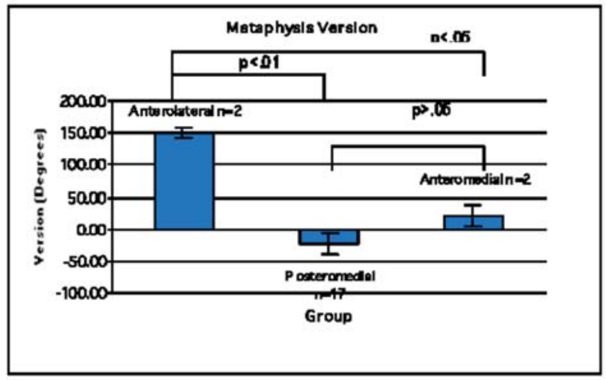

Figure 3. Metaphysis version from coronal plane by group.

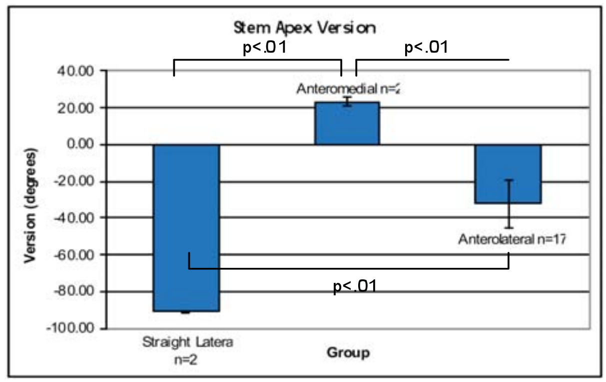

Figure 4. Stem bow version from sagittal plane by group.

indicating that such revisions seem to require a distinct set of component orientations. The two patients in the anteromedial group were admitted for infection and a periprosthetic fracture, and neither appeared to have undergone extensive remodeling.

The most common stem apex orientation was anterolateral (n = 17, θ = -32.1° +/- 13.0° from sagittal plane) followed by anteromedial (n = 2, θ = 4.8° +/- 17.5°) and straight lateral (n = 2, θ = 85°+/-0°). Each group was significantly different from the others ($p < 0.05$). Figure 4 depicts the neck and stem bow version from the sagittal plane for the directional groupings. The presence of the latter two groups indicates a deviation from the normal bow of the femur, which is directed posteriorly and medially.

Figures 5, 6 and 7 illustrate three specific cases in which rotational alignment has been significantly altered from that shown in Figure 1. Figure 5 shows a patient whose metaphyseal segment has been seated in marked anteversion in accordance with the geometry of the residual proximal femur. Here 40° of femoral neck anteversion (the most of any revision) was required to avoid

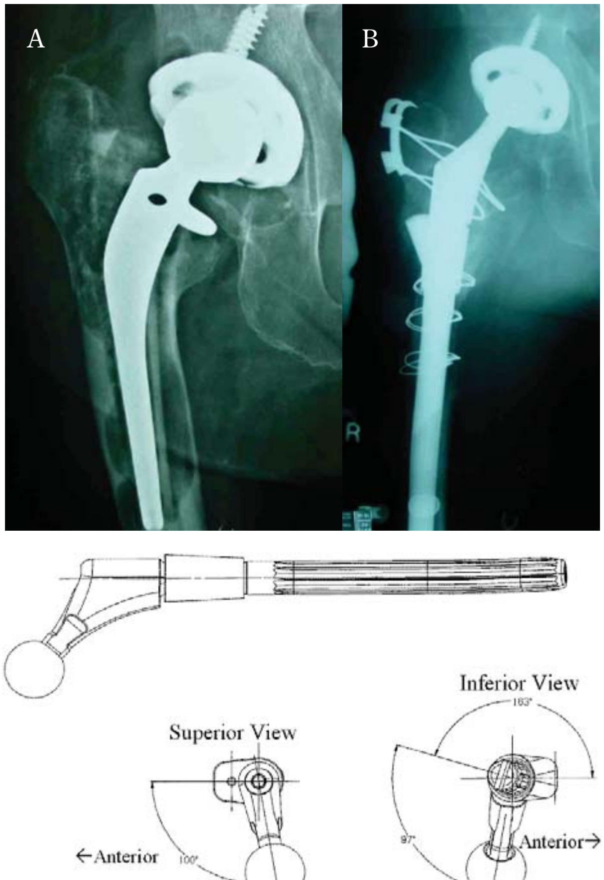

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Figure 5. Pre (A) and Postoperative (B) A/P radiographs and corresponding model (C) showing insertion of the metaphyseal segment in anteversion necessitated by a fracture of the greater trochanter and proximal femur, as well as extensive osteolysis. Metaphysis shows 100˚ version between itself and the centerline of the femoral neck, and is now anteverted 141˚ from the coronal plane. Apex of stem faces 34˚ lateral of straight anterior.

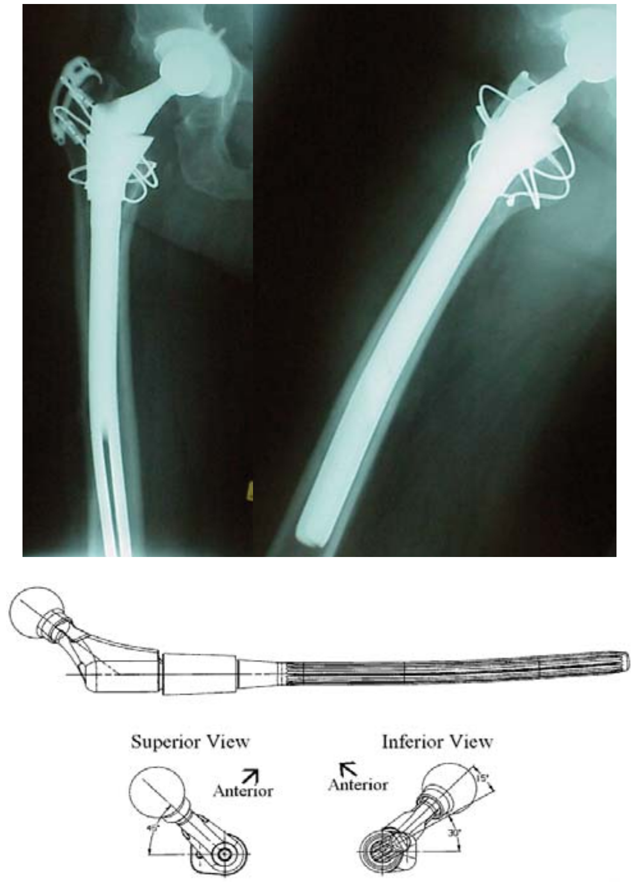

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Figure 6. A/P radiograph (A), lateral radiograph (B) and corresponding model (C) demonstrating lateral placement of distal stem bow. Metaphysis is rotated 45˚ from the centerline of the neck and is seated in 30˚ of retroversion. Apex of Stem bow faces straight laterally.

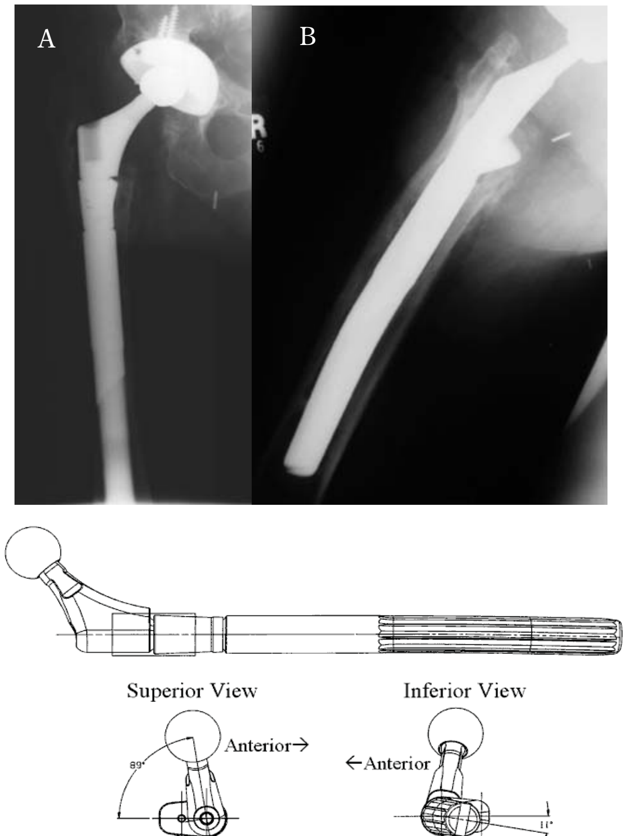
posterior instability. Figure 6 represents a distal stem segment implanted with the stem bow facing laterally to correspond to the bow of the native femur. Figure 7 depicts an instance of a metaphyseal segment implanted in marked retroversion from metaphyseal remodeling.

DISCUSSION

In only one case of twenty-one implantations was neck, metaphysis, and diaphysis orientated similarly to a one-piece stem (metaphysis facing straight medially and apex of stem bow facing anteriorly), indicating that neck and metaphysis version often needed to be established independently from stem placement. The large variances and multiple directional groupings observed suggest that the independent positioning of components afforded by a modular stem is beneficial during revision surgeries when extensive bony remodeling, periprosthetic fractures, and atypical anatomy may hinder proximal femoral fixation of single stem implants. Such fixation has been previously noted to be of paramount importance to clinical success.[16,17]

The most common metaphyseal orientation was posteromedial (81% of cases) indicating that many of the patients had undergone substantial metaphyseal remodeling into retroversion, which was often secondary to gross loosening prior to revision surgery. Bony remodeling of the proximal femur into retroversion has been postulated to occur as a result of posteriorly oriented torsional loads encountered during activities such as stair climbing, and has been noted in the literature in both cemented and press fit implants.[18,19]

Had noncemented single stem implants been implanted in many of the patients in the present study, a



C.

Figure 7. A/P radiograph (A), lateral radiograph (B) and corresponding model (C) depicting implantation with metaphyseal segment seated in marked retroversion and distal stem segment in standard position. Metaphysis is rotated 89° from neck centerline and now faces nearly straight posterior in 78° of retroverison. The stem apex faces 4° lateral of straight anterior.

tradeoff would have to be made between the femoral stem version that offered the best fixation and that which offered the best joint stability. Moreover, a compromise that places fixation as paramount and consequently deviates from optimal neck version has been observed to shift the location of peak stress on the femur, inducing larger bending moments on the anterior and posterior aspects of the proximal femoral shaft.[20] The increased stresses could potentially induce micromotion and jeopardize fixation over time.

The majority of distal stem segment apexes faced anterolaterally; this finding is consistent with the bow of the natural femur, which is in both the lateral and anterior directions. Migration of total hip arthroplasties into varus has long been seen as an indicator of aseptic loosening.[21-24] The presence of six hips (28.6% of cases) with greater than 50° version in the anteromedial direction suggests significant varus remodeling of the proximal femur as a result of loosening and varus migration of the primary arthroplasty. As was the case with the establishment of metaphysis version, the intraoperative flexibility allowed by independent stem placement may permit stem positioning that more closely approximates the native femur, and perhaps enables the surgeon to utilize a highly modular prosthesis with a curved stem in situations where implantation of a straight cylindrical stem would have required extended trochanteric osteotomy.[25] Although, as of late, there have been several reports of good to excellent union rates in revision THA using extended trochanteric osteotomy,[26-28] there still persists the risk of non-union, trochanteric fragment escape, fracture of the proximal femur, and the need for an extensively porous coated stem of a potentially uncommon length and diameter. Additionally, Noble has reported a 73% decrease in torque to failure in a cadaveric study comparing the torsional strength of the native femur to that of one which contained an implant and had been osteotomized and repaired.[29] The reduced torsional strength may be significant clinically when weighting the use of a modular stem versus a extensively porous coated stem and extended trochanteric osteotomy, since patients who undergo extended trochanteric osteotomy will need to remain non-weight-bearing for a longer time and avoid extensive abductor muscle activity longer than undergoing revision surgery with a modular prosthesis.

We conclude that during difficult revision surgeries, rotational alignments that deviate from those offered by single stem implants are both necessary and quite common. It can, therefore, be inferred that stem modularity has both tangible and quantifiable benefits during total hip revision especially when attempting to fit the implants to the residual bony anatomy.

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