Managing Length and Stability: The Role of the Modular Neck

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Good results after a total hip arthroplasty (THA) depend on several critical factors including surgical exposure, implant design, and restoration of biomechanics. The goal is to achieve a stable hip joint with a well-tensioned soft tissue envelope and an impingement-free range of motion.

Appropriate location of the hip joint center and correction of femoral anteversion, offset, and height are critical to any successful reconstruction. These goals are challenging since the proximal femoral anatomy in nondeformed hips shows a wide variation between individuals[1,2] and these variations are likely to be even greater in arthritic hips.

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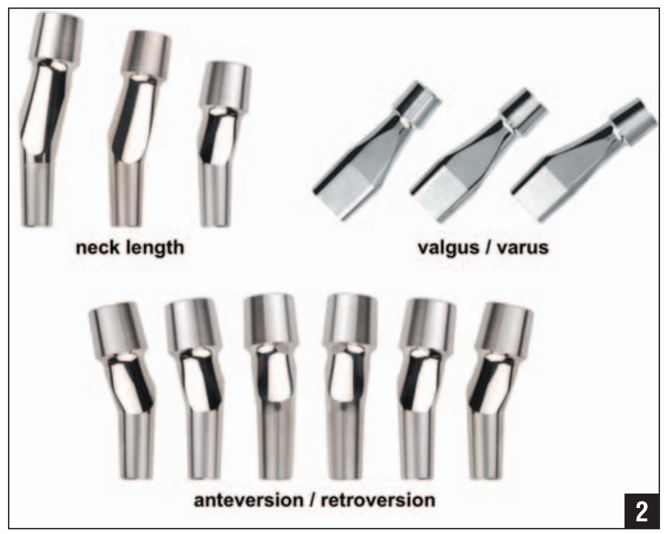

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Figure 1: Implant used in the clinical series with modular neck design (Profemur Renaissance; Wright Medical Technology Inc) combined with ceramic-ceramic bearings (Ceramtec AG). The arthroplasty was performed CT-based with computer-assisted cup placement and leg length restoration. The modularity allows the surgeon to effectively adjust the offset, leg length, and femoral version to the individual anatomy of the patient, especially in deformed hips.
Figure 2: The modular neck design allows the surgeon to correct offset and leg length intraoperatively to the individual anatomy of the patient. The surgeon may choose between geometries with different neck length (upper left), valgus/varus (upper right), or anteversion/retroversion (bottom).

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Restoration of the anatomy is difficult using femoral components without a modular neck since choice of offset is limited by the implant design and choice of implant height and anteversion are limited by the internal geometry of the femur.

Modular neck designs allow for distinct separation of intramedullary and extramedullary variables, greatly simplifying the task of appropriately correcting leg length, offset, and anteversion independently from achieving proper femoral fixation (Figures 1, 2). Additionally, the use of a modular neck prosthesis at the time of the primary procedure greatly simplifies strategies for revision surgery since the modular neck can be removed at revision, facilitating exposure and allowing for changes in offset, leg length, and anteversion

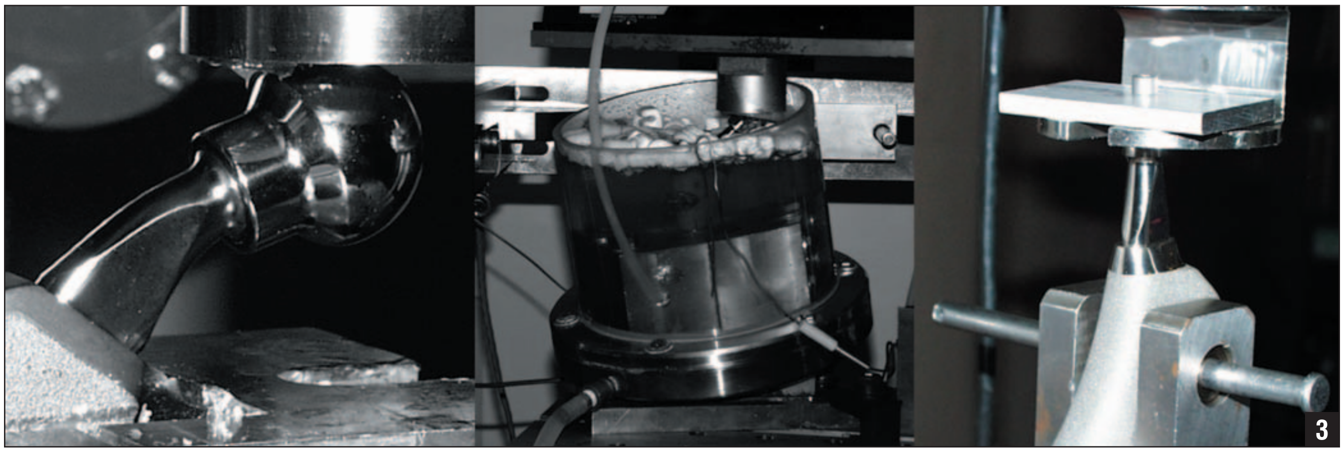

Figure 3: In an experimental study the physical characteristics of the implant were tested (Wright Medical Technology Inc). Static load to failure (left) using the longest head-neck combination occurred at a load of 18,6 kN (4152 lbs). The fatigue testing (middle) involved loading the neck at 1 million cycles with a load range of 230 to 2300 N (51.3-513 lbs) simulating deep flexion. No fracture, no dissociation or evidence of excessive fretting in form of metallic debris was observed on or around the taper surfaces for any of the implants tested (n=3). In testing tapers' resistance to dissociation, the mean separation force (right) was 4.0±1.2 kN (900±268 lbs) in the simulator (n=4).

without the need for revising the femoral component.

While there are great clinical benefits to the use of a modular neck prosthesis, appropriate concerns exist about their potential risks. These concerns include resistance to bending forces, the risk of dissociation, and the risk of fretting or corrosion at the junction with associated adverse affects on the bearing.

This article describes the mechanical testing of a modular neck femoral prosthesis and clinical experience in a series of >241 THAs using a modular neck design (Profemur Renaissance; Wright Medical Technology Inc, Arlington, Tennessee).

The physical characteristics of the modular neck prosthesis design was tested in different experimental trials (Figure 3). These tests included applying static load to failure, cantilever cyclic loading to failure, and measurement of forces required to separate tapers after assembly. Static load to failure testing was done with 1 modular neck component using a long straight neck (38.5 mm) combined with a 28-mm XXL femoral head (Profemur Renaissance). The load to failure measured with a servohydraulic test machine was 18.6 kN (4152 lbs).

Compared with a dimension- and offset-matched monolithic design (AML; DePuy) a similar load to failure force of 20.2 kN (4508 lbs) was found. These forces are definitively greater than the measured peak in vivo loading forces of approximately 2 to 8 times body weight.[3]

The fatigue testing was designed to mimic a chair-rise condition; it involved loading the stem/head/neck assembly at 1 million cycles with a load range of 230 to 2300 N (51.3-513 lbs) at a frequency of 2 Hz using a sinusoidal waveform to simulate deep flexion, ie, the load was applied perpendicular to the stem axis. This regime is equivalent to rising from a chair 50 times a day for >54 years. The components were chosen to allow maximum stresses in the taper area using a valgus/varus long neck combined with a 28-mm XXL neck.

No fracture, no dissociation, or evidence of gross fretting in the form of metallic debris was observed on or around the taper surfaces for any of the implants tested (n=3). In testing tapers' resistance to dissociation the mean separation force recorded in the test frame was 4.0±1.2 kN (900±268 lbs) for the samples assembled in the laboratory (n=4) and for the samples assembled in the cadaver specimens it was 3.3±1.5 kN (737±335 lbs) (n=2).

Viceconti et al[4] tested the risk of fretting of modular neck implants in in-vitro load tests using different neck designs and magnitudes of loading. Considering 1 million load cycles with a magnitude of loading between 300 N and 3300 N to be the average yearly load, the modular neck design would produce 0.6 mg/year of metal debris. This compares to 10 mg/year of wears debris of the monolithic designs.

Our current clinical results with the use of the modular neck design at minimum 1-year follow-up includes 241 primary THAs performed in 227 patients between October 2005 and July 2007 (Figure 4). Two hundred thirty-five THAs (98%) were performed using a tissue preserving approach called the superior capsulotomy with preservation of the abductor muscles by exposing the superior hip joint capsule posterior to the medius and minimus, and anterior to the short external rotators.[5] All these hips were replaced with the use of surgical navigation to facilitate acetabular component orientation and measurement of leg length change during surgery. Mean age at operation was 56±13 years

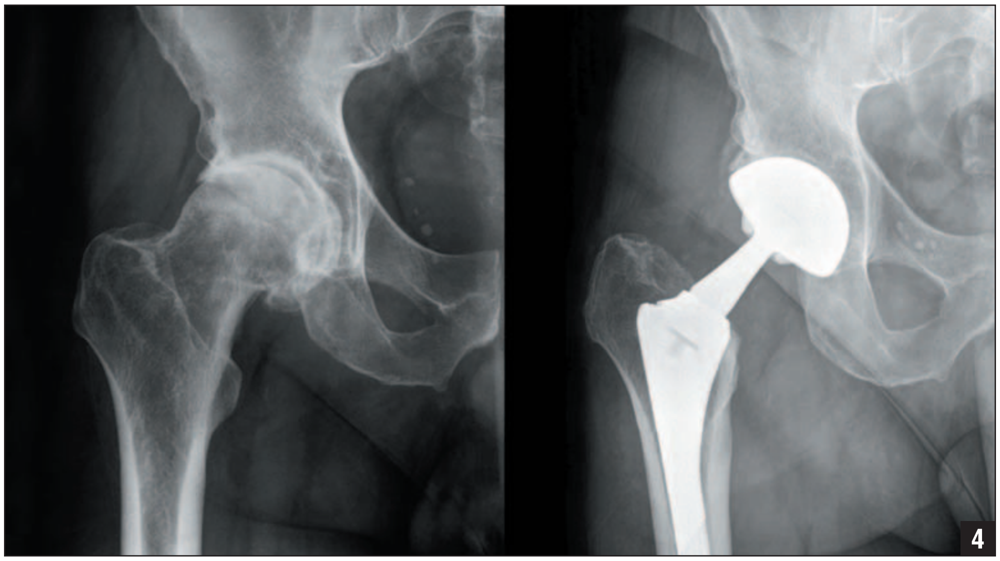

Figure 4: Osteoarthritic right hip of a 53-year-old patient (left). Postoperative radiograph after a THA using an extra long varus neck combined with an alumina ceramic-ceramic bearing with a 32-mm head and 54-mm acetabular liner (right).

(range, 17-85 years). The indication for surgery included primary osteoarthrosis or impingement (73%), hip dysplasia (14%), posttraumatic osteoarthrosis (5%), a slipped epiphysis or Perthes' disease (5%), or osteonecrosis (4%). Twenty-four hips (10%) were previously operated on. Mean follow-up was 23±6 months (range, 12-33 years). One hip (0.4%) dislocated and was treated by closed reduction without recurrence. One hip (0.4%) was revised from a metal-metal bearing to an alumina ceramic-ceramic bearing due to delayed metal hypersensitivity with placement of a new modular neck. No cases of femoral neck fracture or dissociation have been reported.

A proximal femoral sleeve was first introduced in the late 70s and early concerns were the reliability and durability of the modular interface.[6] Since then the design and the materials underwent a constant and substantial improvement. Cameron et al[7] reported 795 primary SROM modular THAs with a mean follow-up of 11 years. They found no neck fracture or dissociation. Revision for aseptic stem loosening was performed in 2 cases (0.3%) and 1 case was revised for dislocation (0.1%). Using the same implant design as in our series with a longer follow-up with a range of 3 to 7 years Mertle[8] reported on 920 primary THAs with no complications associated with the modular neck, no osteolysis, and a dislocation rate of 1.6%. Köster[9] also using the same design reported a survivorship rate of 96.5% at 10-year follow-up.

Modular stems are becoming more common in orthopedic surgery for revision cases as well as primary THA. The modularity allows the surgeon to effectively adjust the offset, leg length, and femoral version to the individual anatomy of the patient, especially in deformed hips. With this design a maximum in hip stability can be achieved. Other advantages of modularity include a simplified exposure or the ability to change head size without component removal. Initial problems with the modular junction have been overcome and also osteolysis is not more frequent than in the monolithic design.[10] Therefore the clinical use of the modular neck design is justified allowing ideal biomechanical restoration leading to optimal results.

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