Stability in Press-Fit Femoral Hip Prostheses

J. Aldridge, MD, Hampton Roads Orthopaedics and Sports Medicine; S. Dunitz, MD, Tulsa Bone & Joint; N. Johanson, Drexel University College of Medicine; A. Lewis, Exactech; G. Miller, PhD, Exactech; Y. Mittal, MD, The Orthopaedic Center

INTRODUCTION

The articulation of an anatomic hip, the femoral head on the acetabulum, is a complex system that has the capacity to sustain loads as high as six times body weight. The femoral stem prostheses used in hip arthroplasty are designed to osseointegrate into the femur and to recreate femoroacetabular biomechanics. The hip joint reaction forces that are associated with articulation are transferred through the prosthesis and to the femur, which results in a biological response to the resulting stresses. The femoral stems available in today's orthopaedic market have differing design features and modes of fixation, yet the same goal in mind: to provide a stable hip reconstruction that restores patient mobility and comfort.

FEMORAL STEM DESIGNS

Femoral stem prostheses can be separated into many categories. The first differentiating category is cemented versus press-fit fixation. Although cemented prostheses continue to be used in certain patients and markets around the world, press-fit stems are used most frequently in today's market. Press-fit stems interface directly with the bone and achieve initial stability through an interference fit with the femur or 3-point fixation in the sagittal plane *(Figures 1 and 2)*. The interference fit is a result of the stem geometry being generally larger than the prepared femoral cavity. The femoral hoop stresses that result from the interference fit and the femoral reaction forces, which result from loads being transferred through the implant, may lead to bone remodeling. Long-term stability due to bone ingrowth or ongrowth is influenced by stem geometry and is typically aided through a roughened or porous surface and/or secondary coating.

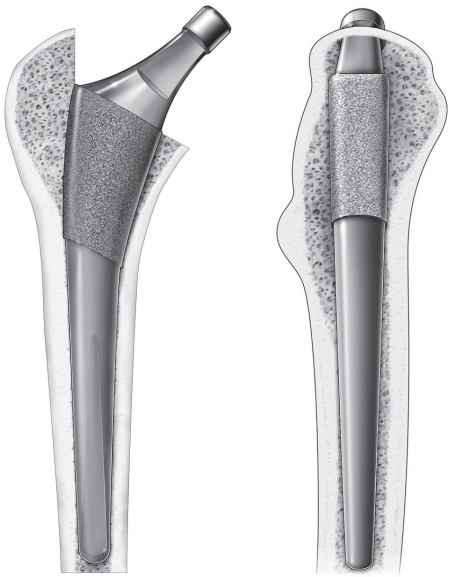

Figure 1: Novation® Tapered

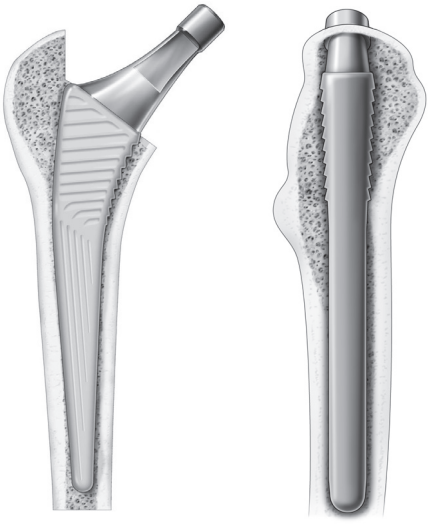

Figure 2: Novation Element®

TYPES OF PRESS-FIT

Fit-Fill

One type of press-fit femoral stem has been categorized as "fit and fill". The term "fit and fill" originated early in hip arthroplasty when surgeons were primarily cementing femoral stems. As press-fit stem designs evolved, the term "fit and fill" continued to be used and has evolved into a class of press-fit implants that attempt to circumferentially fill the

Figure 3: Novation Tapered

Figure 4: Novation Element

femoral cavity.[1] Recently, the orthopaedic industry has begun to use the terms "fit and fill" more universally. Exactech would like to define the context in which we use these terms. ***Fit*** is the state of stability of the implant and can only be assessed by feel. ***Fill*** is a visual assessment of the shape and sizing of the prosthesis into the femur.

Wedge Fit

A second category of press-fit stems is described as "wedge fit". This category of implant achieves stability by filling medial to lateral without filling anterior to posterior. The "wedge fit" stems and other styles of press-fit stems prove that a femoral stem can achieve stability by fitting without filling.[2] Studies have shown that due to the variations in femoral anatomy, femoral stems contact the femur at discrete locations and rarely fill the femoral cavity in both the medial-to-lateral and anterior-to-posterior planes *(Figures 3 and 4)*.[3] It is important that the design of each prosthesis is explained so that the user can understand how the implant will fill the cavity pre-operatively and predict the mode of fixation which will be achieved intra-operatively.

NOVATION® TAPERED—
EXACTECH'S "FIT AND FILL" PROSTHESIS

The Novation® Tapered *(Figure 1)* is a press-fit proximally coated prosthesis of the "fit and fill" style. The Novation Tapered has a trapezoidal cross-section proximally with dual tapers in the medial-to-lateral and anterior-to-posterior planes of 3 and 5 degrees, respectively. As the stems increase in size, the proportions of the Novation Tapered proximal trapezoid increase more quickly from anterior to posterior than medial to lateral. The proportions of the stem are designed to fill the proximal femoral cavity from anterior to posterior or medial to lateral. Due to variations in femora, the primary mode of fixation varies between medial-to-lateral wedging and anterior-to-posterior 3-point fixation. A minimum of one of these fixation modes is required for the stem to fit the femur and create a stable construct.

The Novation Tapered operative technique is a ream then broach technique. The taper of the reamer matches the distal taper of the broach and serves to size the distal canal. After sequential reaming has been performed, the femur is broached so that the last broach used matches the final size reamer used. When gaining access to the femur, the surgeon should be sure to lateralize into the greater trochanter and broach neutral, as varus placement of the broach could lead to an undersized stem. The surgeon can assess the stability of the broach by the resistance following impaction and carefully performing a torque test using the broach handle.

Throughout broaching, the surgeon will be looking to establish anterior-to-posterior (A/P) and/or medial-to-lateral (M/L) fill. Cancellous bone may be present medially and laterally with a stable construct due to anterior-to-posterior fill *(Figure 3)*. Attempting to fill medial to lateral in all femora could lead to an oversized implant and should be avoided, as this could lead to a stiffness mismatch between the stem and femur, which may result in complications including thigh pain and distal hypertrophy. Post-operative radiographs of stable Novation Tapered stems illustrate 3-point fixation and medial-to-lateral wedging modes of fixation *(Figures 5 and 6 respectively)*, which can occur independently or simultaneously.

Summary of Key Surgical Steps

1. Ream
2. Establish A/P and/or M/L **FILL**
3. Assess stability of broach

Points to remember:

- Stem grows faster Anterior to Posterior
  - Contacting the medial calcar is not a requirement for the stem to be stable.
- Trust the 3-Degree Tapered Reamers to size the canal
- Use pre-operative planning to determine stem sizing and appropriate neck cut.

NOVATION ELEMENT® — EXACTECH'S "WEDGE FIT" PROSTHESIS

The Novation Element® *(Figure 2)* is a press-fit fully hydroxyapatite (HA) coated "wedge fit" style prosthesis. The Novation Element has a proximal trapezoidal and distal rectangular cross-section. In the coronal plane, the stem has a 6-degree taper and in the sagittal plane, the stem is parallel sided with a taper along the proximal one third of the stem. Proximally, the Novation Element has horizontal grooves that help convert the hoop stress of the femur to compressive loads, which provide additional axial stability. Vertical grooves distally help provide long-term rotational stability. As the stems increase in size, the medial-to-lateral proportions of the stem increase more quickly than the anterior-to-posterior proportions. The fixation of the Novation Element stem is primarily due to medial-to-lateral wedging of the stem's 6-degree taper with anterior-to-posterior 3-point fixation occurring in some femora. Filling of the proximal femur from anterior to posterior should not be expected with this style of prosthesis. As a result, cancellous bone may be present on the proximal anterior and posterior surfaces of the prosthesis *(Figure 4)*.

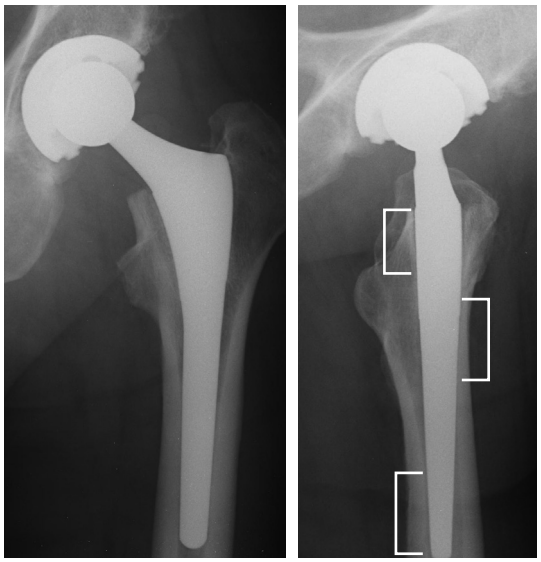

Figure 5: 3-Point Fixation in Novation Tapered

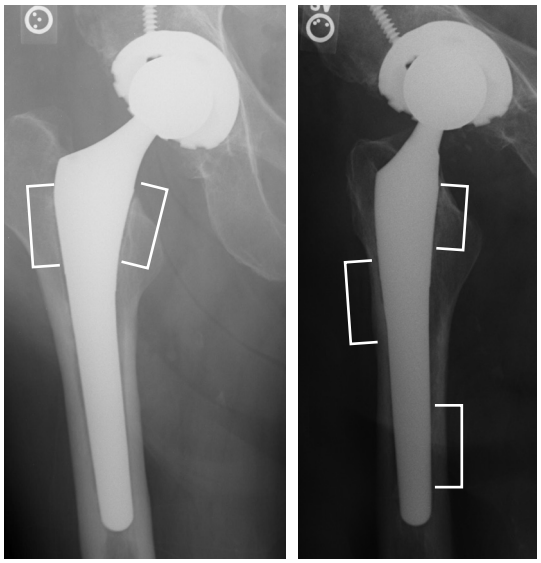

Figure 6: Fit and Fill in Novation Tapered

The Novation Element is implanted using a broach-only surgical technique. Surgeons have found that using pre-operative planning aids in determining the desired neck resection level will best recreate the patient's leg length for the planned prosthesis. The compaction style broaches provide a bed of compacted cancellous bone to interface with the implant. When gaining access to the femur, the surgeon should be sure to lateralize into the greater trochanter and broach neutral, as varus placement of the broach could lead to an undersized stem. While broaching, the surgeon should be looking for the medial corners of the broach to contact the medial calcar and the broach to fill the femoral cavity from medial to lateral *(Figure 4)*. As progressive broach sizes are used, the surgeon can assess the stability of the broach by the resistance following impaction and carefully performing a torque test using the broach handle. The Novation Element prosthesis may appear undersized on radiographs due to the four corners of the rectangular prosthesis contacting the oval femoral canal. Post-operative radiographs of stable Novation Element stems illustrate 3-point fixation and medial-to-lateral wedging modes of fixation *(Figures 7 and 8 respectively)*, which can occur independently or simultaneously.

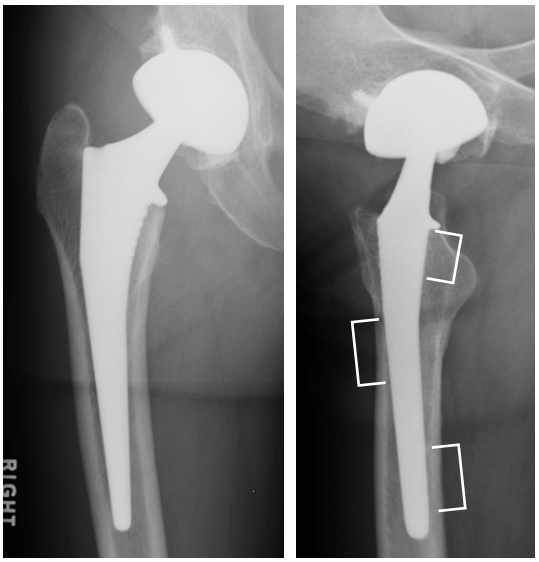

Figure 7: 3-Point Fixation in Novation Element

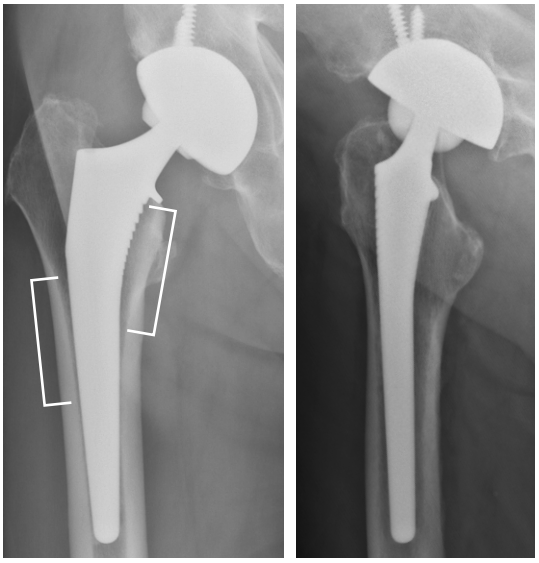

Figure 8: Medial-to-Lateral Wedging in Novation Element

Summary of Key Surgical Steps

1. Broach neutral
2. Establish M/L **FILL**
3. Assess stability of broach

Points to remember:

- Stem grows faster medial to lateral
  - Look for broach to contact two points of medial calcar.
- Use pre-operative planning to determine stem sizing and appropriate neck cut.

REFERENCES

1. **Walker PS, Robertson DD.** Design and fabrication of cementless hip stems. *Clin Orthop Relat Res.* 1988 Oct;(235):25-34.
2. **Swanson TV.** The tapered press fit total hip arthroplasty: a European alternative. *J Arthroplasty.* 2005 Jun;20(4Suppl 2):63-7.
3. **Nobel PC, Alexander JW, Lindahl LJ, et al.** The anatomic basis of femoral component design. *Clin Orthop Relat Res.* 1988 Jul;(244):309-10.
4. **Petty W.** *Total Joint Replacement.* Ed. by W. Petty. Philadelphia, W.B. Saunders Co., 1991, Chapter 13.

352-377-1140
1-800-EXACTECH
www.exac.com

Exactech®

A Great Day in the O.R.™

711-12-83
Stability in Press-Fit Fem 0611