The Limitations of Neck Modularity in High-Demand Primary Total Hip Arthroplasty

INTRODUCTION

Modularity, as applied to femoral stem devices used in Total Hip Arthroplasty (THA), can be defined as the use of multiple (two or more) interconnecting components that, when assembled, create a complete femoral endoprosthetic construct. This construct typically articulates with an acetabular implant to restore the function of the hip joint. The first historical application of modularity in THA femoral stem devices was the introduction of modular femoral heads to overcome the disadvantages of limited head size and offset availability. Prior to this innovation, the femoral head portion of the device was machined as part of the stem in a total monolithic construct.

The advent of modular femoral heads allowed the surgeon to intra-operatively adjust offset, leg length and head size after selection of the final femoral implant. These advantages of modularity have also been applied to the neck and main body of the femoral stem itself. Use of this expanded modularity facilitated even greater intra-operative flexibility, allowing the surgeon to adjust offset, leg length, version, metaphyseal fit/fill and diaphyseal fit/fill. However, use of modular junctions can have adverse effects on the overall structural integrity of the prosthesis and these structural limitations must be carefully considered when selecting a modular stem for implantation.

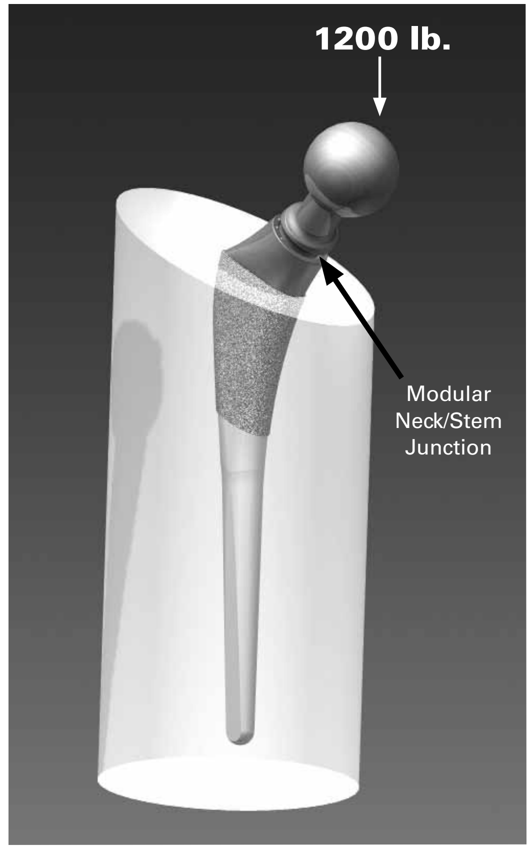

Figure 1: Femoral Stem Structural Testing Setup

FEMORAL STEM STRUCTURAL REQUIREMENTS

The standard minimum *in-vitro* testing requirement for monolithic femoral stem strength in the head/neck region is the application of 1,200 pounds for 10 million cycles.[1] Figure 1 shows a schematic of the testing setup. Some femoral stems can actually exceed this requirement; even the smallest size of some titanium tapered stems successfully pass loading at 1,750 pounds for 10 million cycles, with larger sizes even stronger.[2] By contrast, **some modular neck stems on the market today do not meet the minimum strength requirement of 1,200 pounds**.[3-5] It is very important to consider that if modular neck and body stems are to be implanted in patients where monolithic stems are typically utilized, they will be subjected to equivalent *in-vivo* loading conditions. Therefore, when selecting a modular stem, it is critical to determine if the stem is strong enough to support the anticipated *in-vivo* loading.

TECHNICAL DISCUSSION

Modular neck stems are typically designed around a single-sized modular junction that is common to the entire family of components used to assemble the final construct. Since these modular stems must accommodate a wide range of anatomies, the size of the modular junction is limited based on the size of the construct used in the smallest femur. This size constraint serves to limit the strength of the modular junction, so unlike monolithic stems, there is typically no strength increase with increasing modular stem size.

We often see discussions of the concept of *fatigue strength* (also called the *endurance limit*) of a material defined as the magnitude of stress at or below which the material can support a cyclic load indefinitely. Curve A of Figure 2 is representative of such behavior with the endurance limit being S_e. It's important to note that for different materials, such testing uses solid cylindrical rods and not actual component geometry made from the material. While monolithic devices can exhibit similar curves with an observable fatigue strength, experience has shown that modular devices most often do not, as depicted graphically in Curve B of Figure 2. The primary reason for this is the additional surfaces and shape interactions occurring at the modular junctions, which results in fretting and corrosion damage of the locked interfaces under complex loading. An example of fretting is shown in Figure 3. For these structural devices, there is not a formal endurance limit and we see the fatigue strength decreasing with the increased number of cycles applied (usage).

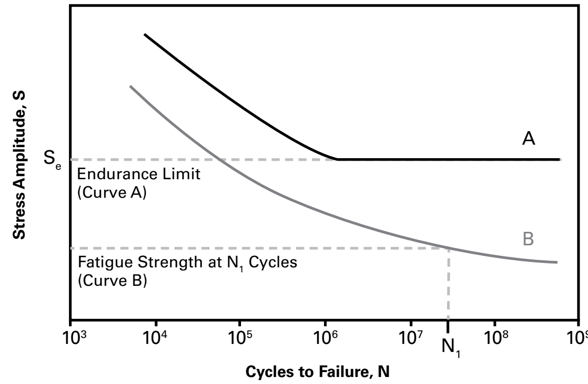

Figure 2: Fatigue Strength Curve for Monolithic (A) and Modular (B) Materials

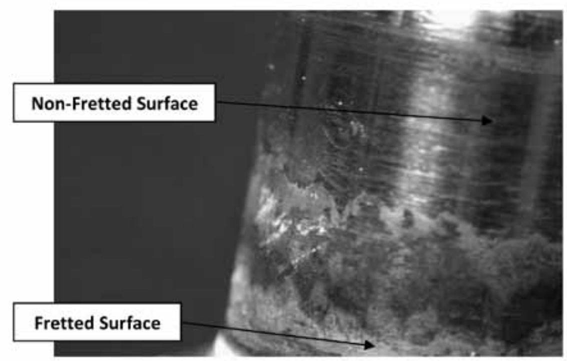

Figure 3: Example of a Fretted Surface in a Modular Hip Component

When subjected to the stresses of *in-vivo* loading, even at loads and stresses below that of the endurance limit of the base metal, the interfacial degradation at the modular junction can result in fatigue crack initiation and propagation, which may eventually lead to fracture of the device.

CONCLUSION

In summary, monolithic femoral stems are typically stronger than modular femoral stems of the same nominal size since modular stem strength is limited by the size and interface degradation of the modular junction. Therefore, the use of **modular necks** should be carefully considered in high-demand applications such as primary surgeries in young, active patients.

REFERENCES

1. ASTM F2068: 2003. Standard specification for femoral prostheses – metallic implants.
2. Data on file at Exactech.
3. **Heim CS, Postak PD, Greenwald AS**. Femoral stem fatigue characteristics of modular hip designs – Series II. Orthopaedic Transactions. 1995; 19:471-2.
4. **Postak P, Greenwald A.** The influence of modularity on the endurance performance of the LINK® MP™ Hip Stem. LIT MP-08. Orthopaedic Research Laboratories, Cleveland Clinic Health System, Cleveland, Ohio. 2001 Feb.
5. Wright Medical Technical Monograph I Profemur® Total Hip System, p 11.

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

711-12-82
Modularity Tech Profile 0709