An Original Study

# The Effects of Blood and Fat on Morse Taper Disassembly Forces

Carlos J. Lavernia, MD, Luis Baerga, BS, Robert L. Barrack, MD, Evangelos Tozakoglou, PhD, Stephen D. Cook, PhD, Loren Lata, PhD, and Mark D. Rossi, PhD, PT, CSCS

## Abstract

**Biological debris between modular components using Morse tapers in hip arthroplasty can lead to weakening of the implant construct. We conducted a study to determine the effect of blood and fat within the taper interface. Tapers were divided into groups 1 (clean), 2 (surface covered with blood and fat), and 3 (blood and fat wiped off). Each taper was impacted and disassembled 5 times. There was a difference in mean disassembly force between pulls within group 2. Thus, blood and fat contamination can have a significant effect on the potential for disassembly.**

Up until the 1970s, the manufacturing industry used Morse technology in machining. By the latter half of that decade, orthopedic surgeons had begun using Morse taper technology in modular hip prostheses. "Taper" technology provides a tapered interlock for joining the femoral head with the femoral stem in total hip arthroplasty (THA).[1] The interlocking tapered shaft allows for increased efficiency in connecting parts of the prosthesis. The taper technology provides a self-locking mechanism between the femoral head and stem that is resistant to distractive and rotatory stresses. Use of the Morse taper in a modular hip prosthesis has advantages.[2,3] One advantage is the surgeon's ability to "couple" different sizes and materials (eg, metal vs ceramic) for the femoral head and stem components.[3] Thus, Morse taper technology allows for component interchangeability, or modularity, which decreases the need to maintain a large inventory of components and thus minimizes unnecessary costs.

In THA, modularity gives the surgeon more freedom when implanting the femoral stem, simply because the femoral head is not in the way. Moreover, with modularity, certain revisions are easier to perform, as the surgeon need only remove the femoral head and replace it with a new component (no need to disrupt a well-fixed femoral stem). The femoral head can also be removed to increase exposure of the acetabulum, particularly when acetabular revisions are required.[2,4,5]

Use of Morse tapers in THA has elicited some concern. Some investigators have reported fretting and corrosion between components,[6-10] which could lead to increased micromotion at the modular interface with eventual production of debris.[9-11] The debris formed at the taper interface can lead to other complications, such as necrosis, inflammation, osteolysis, aseptic loosening, granulomatous reaction, and systemic trace-metal accumulation.[6,9,11] Furthermore, fretting and corrosion with subsequent micromotion could limit the life of modular components and affect the overall strength of the design. This potential weakening of the implant could lead to decreased resistance to distractive and rotatory forces and possibly to unwanted disassembly.[12]

During surgery, debris (eg, blood, fat, pieces of bone) can land and remain on taper surfaces, despite surgeons' efforts to keep them clean. Very few studies have addressed

Dr. Lavernia is Chief of Orthopedics and Director of the Orthopaedic Institute at Mercy Hospital, Miami, Florida, and Adjunct Professor of Biomedical Engineering, Florida International University, Miami, Florida.
Dr. Baerga is a Physiatrist and Rehabilitation Specialist, San Juan, Puerto Rico.
Dr. Barrack is Chief of Staff, Orthopedics, Barnes-Jewish Hospital, and Chief, Adult Reconstructive Surgery, Washington University, St. Louis, Missouri.
Dr. Tozakoglou has a Doctorate in Mechanical Engineering, Greece.
Dr. Cook is with the Fellowship of Orthopaedic Researchers, Metairie, Louisiana.
Dr. Lata is Professor and Director of Research, Max Biedermann Institute for Biomechanics, Department of Orthopedics, University of Miami, Miami, Florida.
Dr. Rossi is Assistant Professor, Department of Physical Therapy, Florida International University, Miami, Florida.

Address correspondence to: Carlos J. Lavernia, MD, Orthopaedic Institute at Mercy Hospital, 3659 S Miami Ave, Suite 4008, Miami, FL 33133 (tel, 305-285-5085; fax, 305-285-5084; e-mail, clavernia@mercymiami.org).

*Am J Orthop.* 2009;38(4):187-190. 

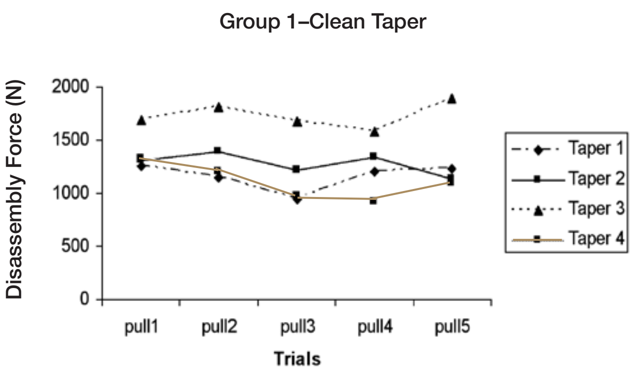


**Figure 1.** Group 1 (clean tapers), disassembly forces over pulls 1 through 5.

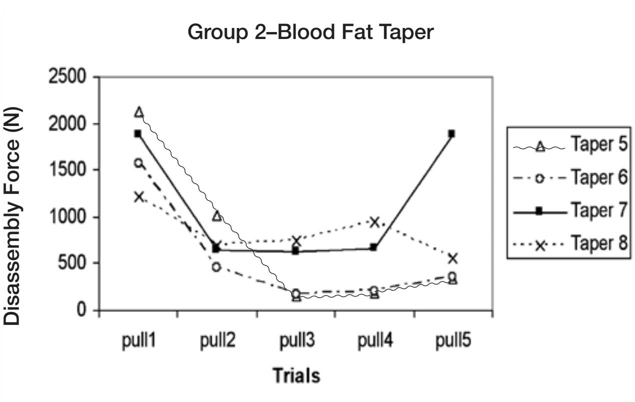


**Figure 2.** Group 2 (blood- and fat-covered tapers), disassembly forces over pulls 1 through 5.

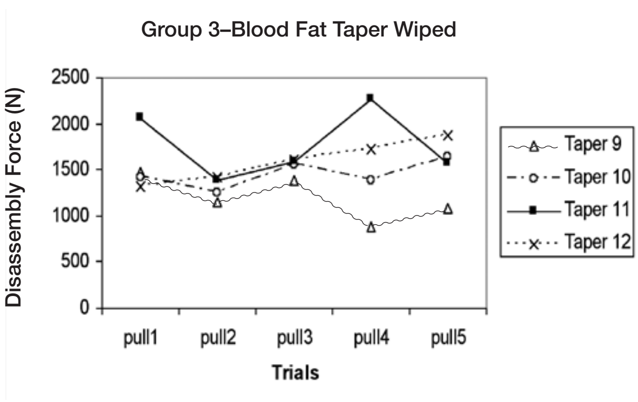


**Figure 3.** Group 3 (wiped tapers), disassembly forces over pulls 1 through 5.

the effects of biological debris on the life of modular implants.[13,14] Although there is no proof of association of disassembly forces with coefficient of friction, torsional resistance, or fretting, it seems plausible that higher disassembly forces may be associated with a "tighter fit" between components. This tighter fit could reduce fretting of the head and trunnion interface and thereby prevent micromotion.

Few investigators have evaluated the effect of debris, especially blood and fat, on taper strength. Therefore, we conducted a study to determine the effect of biological debris, specifically blood and fat within the taper interface of a modular hip prosthesis, on taper disassembly forces.

## Materials and Methods

In this study, we used 14 modular titanium alloy taper assemblies (Smith & Nephew, Memphis, Tenn) with cobalt chrome alloy heads. These tapers have the same titanium alloy and the same tolerances and specifications used in the stems of hip implants. The tapers were divided into 3 groups. Group 1 tapers (n = 5), used as received from the manufacturer, had clean interfaces. Group 2 tapers (n = 5) had their interfaces covered with blood and fat to simulate intraoperative conditions (a drop of human blood was placed on the surface of each taper, and the taper was rotated 360° in a small container containing human adipose tissue). Group 3 tapers (n = 4) were prepared in the same manner as group 2, but the blood and fat were then wiped off (a 4×4-inch surgical gauze was wiped 360° 3 times around the taper surface).

A drop tower was used to standardize the impaction force during assembly of all tapers. The drop tower consisted of a 15-pound weight that slid down a shaft. The weight hit a polyethylene impactor tip placed over the femoral head. The impact of the weight simulated a typical blow with a mallet during hip arthroplasty. The impaction force was calculated experimentally. Eight orthopedic surgeons and residents simulated impaction by hitting a transducer with an impactor and a mallet. The transducer recorded the peak force of the impact through the impactor during a mock impaction. Eight surgeons and residents repeated the procedure 5 times each. The mean peak impaction force was calculated and recorded for each surgeon. From these data, the mean impaction force for all the surgeons and residents was calculated. The drop tower impacted all 14 assemblies based on the calculated mean force from the 8 surgeons and residents.

Disassembly forces were examined by using a mechanical testing system (MTS; MTS Systems, Eden Prairie, Minn) to remove the heads from the stems. With a computer with analog-to-digital board, the MTS measures and records pullout forces. The MTS removed the heads at a constant displacement speed of 0.05 mm/s, as suggested by ASTM (American Society for Testing and Materials) standard 1636.[15] All 14 tapers were impacted and disassembled 5 times each. The force needed for each disassembly was recorded as the datum.

### Analysis

A 3×5 analysis of variance (ANOVA) was used to determine if there would be a difference between pulls (trials) within each group. The first factor, Group, had 3 levels: 1 (clean taper interfaces), 2 (blood and fat covered), and 3 (blood and fat wiped off). The second factor, Pull, had 5 levels. To determine if there would be a difference between groups collapsed over all 5 pulls, we analyzed the main effect of group from the omnibus test. As necessary, fur-

**Table.** Mean Disassembly Force (Newtons) Over 5 Pulls (Trials) for Each Taper by Group

| Group | Taper No. | Mean | SEM |
|---|---|---|---|
| Clean | 1 | 1156 | 55.70 |
| Clean | 2 | 1280 | 44.66 |
| Clean | 3 | 1728 | 55.34 |
| Clean | 4 | 1103 | 74.12 |
| Blood & fat | 5 | 765 | 374.58 |
| Blood & fat | 6 | 546 | 260.35 |
| Blood & fat | 7 | 1135 | 300.75 |
| Blood & fat | 8 | 833 | 114.69 |
| Wiped | 9 | 1195 | 106.76 |
| Wiped | 10 | 1451 | 66.61 |
| Wiped | 11 | 1773 | 165.71 |
| Wiped | 12 | 1588 | 102.30 |

Abbreviation: SEM, standard error of the mean.

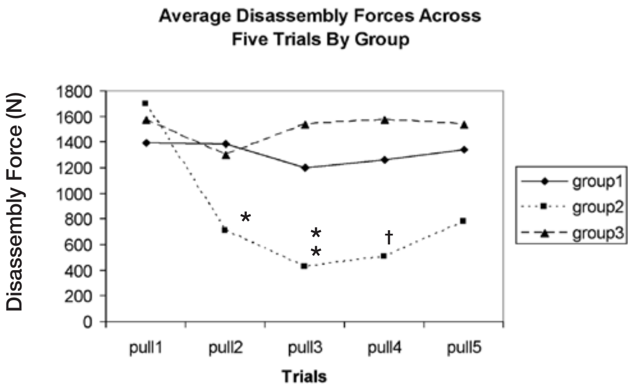


**Figure 4.** Mean disassembly forces over pulls 1 through 5 by group (group 1 = clean tapers, group 2 = blood- and fat-covered tapers, group 3 = wiped tapers). *Disassembly forces in group 2 significantly lower than disassembly forces in group 1 ($P$ = .006) and group 3 ($P$ = .013). **Disassembly forces in group 2 significantly lower than in group 1 ($P$ = .007) and group 3 ($P$ = .001). †Disassembly forces in group 2 significantly lower than in group 3 ($P$ = .016).

ther decomposition of the data would be completed using follow-up tests, such as contrasts, and main effects would be completed through multiple comparisons using the least significant difference method. Statistical significance was set at $P < .05$.

## Results

The mean impaction force for the surgeons and residents was 1633 Newtons (SD, 422 N). The mean impaction force for the drop tower over 10 pulls was 1706 N (SD, 73 N). The first group 1 (clean) taper and the first group 2 (blood and fat) taper were eliminated because the jig had come off during disassembly, so each group ended up with 4 tapers. The mean disassembly force for each taper within each group is presented in the Table.

The global ANOVA showed that there was a Group × Pull interaction ($F_{8,36}$ = 3.79, $P$ = .003, power = .97), so simple effects were evaluated for each group across the 5 pulls to determine if there was a difference between pulls. There was no difference in mean disassembly force between pulls within group 1 ($F_{4,12}$ = 2.06, $P$ = .15) and within group 3 ($F_{4,12}$ = 0.71, $P$ = .60), but there was a difference between pulls within group 2 ($F_{4,12}$ = 6.13, $P$ = .006). Mean disassembly force was significantly higher in pull 1 than in pull 2 ($P$ = .008), pull 3 ($P$ = .03), and pull 4 ($P$ = .04). Individual taper results over the 5 pulls are presented in Figures 1 to 3. As noted in Figure 2, pull 5 of taper 7 within group 2 appears to be an outlier. Thus, the lack of a difference in mean disassembly force between pulls 1 and 5 may be attributed to error in pull 5 of taper 7.

Simple effect tests were also conducted to see if there were any differences between groups within each pull. There was no difference in mean disassembly force between groups within pull 1 or within pull 5, but there was a difference between groups within pull 2 ($F_{2,11}$ = 10.50, $P$ = .004), pull 3 ($F_{2,11}$ = 17.85, $P$ = .001), and pull 4 ($F_{2,11}$ = 6.62, $P$ = .017). Post hoc analysis (Tukey honestly significant difference test) was done to assess for differences in mean disassembly force between groups within pulls 2, 3, and 4 (Figure 4).

## Discussion

In this study, the clean tapers and the tapers wiped of blood and fat had the highest mean disassembly forces. Moreover, there was no difference in mean disassembly force across each of the 5 pulls for both the clean tapers and the wiped tapers. As theorized, the tapers with blood and fat required lower disassembly force immediately after the first assembly–disassembly cycle. Although an outlier was apparent in the data, the pattern of lower disassembly force after pull 1 held constant over repeated measures in the group in which blood and fat contaminated the interfaces. Thus, our data show that preparation of the taper surface can affect taper interface strength during repeated assembly and disassembly.

As expected, there was no difference in mean disassembly force between groups within pull 1. By pull 2, mean disassembly force was much lower for the tapers with blood and fat than for the clean tapers and the wiped tapers. When biological debris (eg, blood, fat) contaminates taper interfaces, the inherent stability of the Morse taper and resistance to forces can be compromised. These results may have strong implications regarding need for revision secondary to in vivo disassembly of the trunnion and bore.

Pennock and colleagues[14] evaluated the mechanical strength of 4 different tapers with surfaces that were wet (with water or bovine solution) or dry. They found that mechanical strength changed over repeated assembly and disassembly under wet conditions (water or bovine solution exposure) and varied by manufacturer (tapers from different manufacturers behaved differently when contaminated with water or bovine solution). Along the lines of our finding that clean tapers and wiped tapers had the most mechanical strength, Pennock and colleagues noted that a much higher disassembly force was required for dry tapers than for wet tapers.

Fessler and Fricker[13] studied the effect of saline solution and blood on the coefficient of friction at the taper interface. They reported that neither distilled water nor blood had a significant effect on the coefficient of friction between an aluminum head and a titanium or cobalt alloy trunnion. The coefficient of friction at the interface between a metal head and a metal spigot did not change significantly after distilled water or Ringer solution was applied to the interface. In contrast to our study, the effect of blood on the interface between metal heads and metal spigots was not tested.

Cook and colleagues[15] reported on the effects of blood and fat on the torsional resistance of a sleeve-stem hip system. Although the design dimensions of this system differ from those in our study, the interlocking parts did constitute a Morse taper. Despite differences in our mechanical designs and constructs, there was a similar finding in our studies—a significant decrease in torsional resistance when blood and fatty tissue contaminated the interface.

The obvious limitation of our study is its sample size. With a small sample, there is less generalizability to the overall population. Sample size negatively affects power and subsequent error. Thus, we risked committing type II error in our design. Another limitation is that we used only one type of prosthesis. Given their variations in design, different manufacturers' prostheses may have different disassembly forces. We recommend not only that much larger studies be conducted but also that they compare different manufacturers' prostheses. Moreover, studies should evaluate potential contaminants individually (ie, blood only, fat only) and not as we did in this study (in combination). Doing so will aid in differentiating the true effect of biological debris rather than a combination effect.

Presumably, absence of biological debris will yield a tighter fit between interfaces, and thus much higher forces will be required to disassemble the hardware. Outcomes of a tighter, stronger fit could be decreased micromotion and fretting of the taper interface over the long term. Repetitive in vivo cyclic loading may contaminate some of our single-blow analysis. We think that some of the recently published fluoroscopic data have a pool component on the swing phase of the gait in which a ball–socket separation perhaps creates suction that may limit some of the compressive forces.[7,9,11] The implication would be longer prosthetic life and, potentially, a decreased revision rate. We recommend that, during THA, surgeons make an effort to keep taper surfaces free of debris. Furthermore, before initial assembly, taper surfaces at the very least should be cleaned with surgical gauze.

## Conclusions

Many variables can affect the disassembly force of the Morse taper. The inherent strength of the taper can be affected by impaction force, number of assembly–disassembly cycles, and wet/dry conditions. From our study results we conclude that, over multiple assembly–disassembly cycles, such as those encountered in revision surgeries, or in cases in which the surgeon initially impacts the incorrect head size, blood and fat contamination can have a profound effect on the potential for disassembly.

## Authors' Disclosure Statement and Acknowledgment

Benefits or funds were received from the Mercy Hospital Arthritis Surgery Research Foundation and Smith & Nephew, Inc. in partial or total support of the research material described in this article. Dr. Barrack also wishes to note that he holds a patent for a health-care-related product and is a paid consultant to Smith & Nephew Orthopaedics.

We thank Shilesh Jani, MS, for technical assistance.

## References

1. Skinner HB, Robert EE, eds. *Instructional Course Lectures: Current Biomaterial Problems in Implants*. Park Ridge, IL: American Academy of Orthopaedic Surgeons; 1992.
2. Barrack RL. Modularity of prosthetic implants. *J Am Acad Orthop Surg*. 1994;2(1):16-25.
3. McCarthy JC, Bono JV, O'Donnell PJ. Custom and modular components in primary total hip replacement. *Clin Orthop*. 1997;(344):162-171.
4. Cameron HU. Modularity in primary total hip arthroplasty. *J Arthroplasty*. 1996;11(3):332-334.
5. Hozack WJ, Mesa JJ, Rothman RH. Head–neck modularity for total hip arthroplasty. Is it necessary? *J Arthroplasty*. 1996;11(4):397-399.
6. Mathiesen EB, Lindgren JU, Blomgren GG, Reinholt FP. Corrosion of modular hip prostheses. *J Bone Joint Surg Br*. 1991;73(4):569-575.
7. Collier JP, Surprenant VA, Jensen RE, Mayor MB. Corrosion at the interface of cobalt-alloy heads on titanium-alloy stems. *Clin Orthop*. 1991;(271):305-312.
8. Collier JP, Surprenant VA, Jensen RE, Mayor MB, Surprenant HP. Corrosion between the components of modular femoral hip prostheses. *J Bone Joint Surg Br*. 1992;74(4):511-517.
9. Gilbert JL, Buckley CA, Jacobs JJ. In vivo corrosion of modular hip prosthesis components in mixed and similar metal combinations. The effect of crevice, stress, motion and alloy coupling. *J Biomed Mater Res*. 1993;27(12):1533-1544.
10. Cook SD, Barrack RL, Clemow AJ. Corrosion and wear at the modular interface of uncemented femoral stems. *J Bone Joint Surg Br*. 1994;76(1):68-72.
11. Urban RM, Jacobs JJ, Gilbert JL, Galante JO. Migration of corrosion products from modular hip prostheses. Particle microanalysis and histopathological findings. *J Bone Joint Surg Am*. 1994;76(9):1345-1359.
12. Barrack RL, Burke DW, Cook SD, Skinner HB, Harris WH. Complications related to modularity of total hip components. *J Bone Joint Surg Br*. 1993;75(5):688-692.
13. Fessler H, Fricker DC. Friction in femoral prosthesis and photoelastic model cone taper joints. *Proc Inst Mech Eng (H)*. 1989;203(1):1-14.
14. Pennock AT, Schmidt AH, Bourgeault CA. Morse-type tapers: factors that may influence taper strength during total hip arthroplasty. *J Arthroplasty*. 2002;17(6):773-778.
15. Cook SD, Manley MT, Kester MA, Dong NG. Torsional resistance and wear of a modular sleeve-stem hip system. *Clin Mater*. 1993;12(3):153-158.