The Effect Of Increasing Femoral Head Size On The Force Required For Dislocation

MATTHEW J. DIETZ, MD
ASSISTANT PROFESSOR
DEPARTMENT OF ORTHOPAEDICS
WEST VIRGINIA UNIVERSITY SCHOOL OF MEDICINE
MORGANTOWN, WEST VIRGINIA

ABSTRACT

Alternative bearings allow for the increased utilization of large femoral heads in total hip arthroplasty. This study demonstrated the effect of increasing femoral head size on the force required for dislocation during intraoperative assessment. Using a standard posterior approach, 10 cadaver hips underwent total hip arthroplasty; components were implanted in a standard fashion. The extremity was attached to a custom jig to replicate intraoperative assessment (internal rotation with 90° of hip flexion/neutral adduction). This range of motion (ROM) was repeated in triplicate using femoral head sizes of 28mm, 32mm, 36mm, 40mm, and 44mm. The ROM to dislocation (degrees) and torque (N*m) required were recorded. With increasing head sizes, there was a significant increase in torque required for dislocation (p<0.0001). The least square means torques (N*m) for each femoral head size (28–44mm) were 2.07, 2.15, 2.42, 2.74, and 3.65N*m. The corresponding least square means ROMs prior to dislocation were 43.5°, 46.2°, 50.8°, 54.3°, and 59.5°. There was a significant difference in ROM between nonadjacent head sizes (i.e., 28mm and 44mm) (p<0.0001). Total hip implant stability is multifactorial. Increasing femoral head size may confer stability during intraoperative assessment by increasing both the ROM prior to dislocation and the force required for dislocation.
INTRODUCTION

Dislocation after total hip arthroplasty remains a significant clinical problem affecting 1% to 10% of all patients undergoing primary total hip arthroplasty and 3% to 30% of those undergoing revision total hip arthroplasty. Efforts to minimize instability have included the evolution of larger femoral heads. Previous studies demonstrated that large femoral heads decrease the incidence of instability in total hip arthroplasties by increasing the range of motion prior to impingement.

The concept of large femoral heads conferring and increasing stability in total hip arthroplasty is not novel; in fact, in 1958, Sir John Charnley planned to use a 41.5mm head in his initial total hip replacements. The theoretical benefits of increased diameter of femoral heads could not become a reality until the advent of alternative bearing surfaces. The stability introduced by the use of larger femoral heads is theoretically due to (1) increased range of motion prior to impingement, (2) increased prosthetic jump distance, and (3) larger surface area providing an enhanced "suction effect". Increased femoral head size allows for greater prosthetic impingement-free range of motion and requires greater displacement distance prior to dislocation.

Burroughs et al. found that increasing femoral head size from 28mm to 38mm demonstrated an increase in range of motion (ROM) prior to impingement. We are unaware of any data analyzing the effect of femoral head size on the force required for dislocation.

As the femoral head reaches a certain size, the head-neck ratio is such that dislocation occurs as a result of bone-on-bone impingement. Our hypothesis was that increasing femoral head size increased the torque required for dislocation. This study may provide information as to the ideal balance between the risks and benefits of increasing femoral head size in total hip arthroplasty.

MATERIALS AND METHODS

Following approval from our institution’s Institutional Biohazard Committee, five fresh frozen cadavers (average age 67, all males) were obtained from our institution’s Human Gift Registry. Using a posterior Moore approach, 10 cadaver hips underwent total hip arthroplasty using the DePuy SUMMIT® Trial System (DePuy Synthes, Warsaw, Indiana). The components were implanted in a standard fashion (shell: 25° anteverision, 45° abduction; stem: 15° anteverision) by a board-certified orthopaedic surgeon specializing in adult reconstruction. The specimens were under-reamed by 1mm and a press-fit cup was placed. A screw was placed through the cup into the pelvis to prevent rotation of the acetabular component. The short external rotators were detached from their origin and were not repaired. With the specimen in the lateral position, the pelvis was secured similar to positioning of the acetabulum. The hip was positioned in 90° of flexion and neutral adduction. A knee disarticulation was performed on the operative extremity; the femoral condyles of the operative extremity were attached to a custom jig. This jig allowed for direct attachment to a fixed motor capable of reproducing internal and external rotation of the flexed hip as well as recording torque (N*m) and ROM (degrees) prior to dislocation by using a hardwired transducer (Fig. 1). Femoral head components tested were 28mm, 32mm, 36mm, 40mm, and 44mm; a standard neck length was used for all femoral head sizes.

Data analysis

The increase in torque required for dislocation to the torque required for the dislocation of a 28mm head were compared. Using the data acquired, an analysis of variance model was run with each hip acting as its own control, the range of motion to dislocation (degrees) and torque (N*m) required for dislocation were recorded for each femoral head size.

RESULTS

The experimental setup allowed for comparison of degrees of internal rotation prior to dislocation and the torque (N*m) for dislocation with each specimen acting as its own control. We compared the effects of femoral head size across all specimens. The degrees of internal rotation prior to dislocation and the torque (N*m) required for dislocation were obtained for all five specimens on both the right and left lower extremities.

Range of motion

There was evident variability in ROM prior to dislocation between all the specimens (i.e., the range of degrees for a 28mm head was 20° to 57° and 32° to 78° for a 44mm head) (Fig. 2). The results from each specimen demonstrated a linear increase in range of motion with increasing head size with regression analysis.
Using analysis of all the data for range of motion prior to dislocation, we found that range of motion prior to dislocation was 43.5° (28mm), 46.2° (32mm), 50.8° (36mm), 54.3° (40mm), and 59.5° (44mm) with a standard error of 1.79. These findings demonstrated a significant difference in range of motion with increasing head size (i.e., 28mm and 44mm) (p<0.0001) (Fig. 2).

**Torque**

For ease of comparison between specimens, the torque required for dislocation of each femoral head size was compared to the torque required for that cadaveric specimen with a 28mm head (Fig 3). The greatest increase in torque was seen in the 44mm femoral head size. The specimens demonstrated an increase of 42% to 140% of the 28mm values when an increase was evident.

Again, when the least squares regression analysis among all trials was compared, the least square means torques (N*m) for each femoral head size for all specimens were 2.07 (28mm), 2.15 (32mm), 2.42 (36mm), 2.74 (40mm), and 3.65N*m (44mm) with a standard error of 0.186. There was a significant increase in torque required for dislocation with increasing head size (p<0.0001). Between the 28mm (2.07N*m) and 32mm (2.15N*m) head sizes, there was an increasing trend but no significant difference between the two (p>0.05) (Fig 3).

**DISCUSSION**

Dislocation continues to be a major complication after total hip arthroplasty. The stability of a hip is multifactorial and relies on patient factors, surgical technique, and component selection. Biomechanical and retrospective studies have demonstrated improved wear rates with highly crosslinked polyethylene liners. These liners, along with the use of metal-on-metal prostheses, have led to use of increased femoral head sizes in hopes of gaining increased stability. The theoretical advantages of a larger femoral head are (1) improved head-to-neck ratio increasing impingement-free ROM, (2) larger diameter heads have a greater radius seated within the liner requiring further translation or jump distance prior to dislocation, and (3) larger surface area for an increased suction effect.

In this study, we attempted to recreate the intraoperative assessment of hip stability. Our hypothesis was that the increasing femoral head size leads to an increase in the torque required for dislocation. We found a significant trend of increasing torque required for dislocation with increasing head size. We did not find a significant difference between the femoral head sizes of 28mm and 32mm. Without any soft tissue reconstruction, this torque averaged 3.7N*m for the 44mm heads which was a full 1N*m greater than the 40mm head. While this finding was statistically significant, it may or may not be clinically significant. Previous studies by Sioen et al. found that soft tissue repair after total hip arthroplasty increased the torque required for dislocation by approximately 18N*m; posterior soft tissue repair has been found to reduce...
The Effect Of Increasing Femoral Head Size On The Force Required For Dislocation

DIETZ/MOUSH MOUSH/SAM ORA/KISH/HAM LIN

The dislocation rates in a posterior approach from 4% to 6% down to 0% to 0.8%.

The range of motion prior to dislocation was quite similar to the results found in other studies. We found an increasing range of motion prior to dislocation with increasing femoral head sizes. This result is expected as head-to-neck ratio increases and the impingement with larger head sizes is dependent only on bony anatomy.

Our increases in ROM prior to dislocation were not significant when compared to adjacent head sizes but were significant when compared to head sizes at least 8mm smaller or larger in diameter.

The use of increased femoral head sizes is now possible because of highly crosslinked polyethylene bearings. It has been shown that the linear wear rates associated with these bearings are independent of femoral head size and that volumetric wear rates are quite low. Improvements in biomaterials have allowed for a greater number of component choices with less concern for the deleterious effects of osteolysis and other issues that have been associated historically with larger femoral heads.

The increase in required torque combined with the increased ROM prior to dislocation adds inherent stability to hip arthroplasties using 44mm femoral heads. There were some limitations in this study; the force for dislocation was measured without any posterior soft tissue repair and without any soft tissue tensioning. Also, because we wanted to compare femoral head sizes within one specimen, some of the larger femoral head sizes may not have been appropriate for our specimens. The fixed nature of the specimen allowed for better evaluation of the femoral head sizes but eliminates the dynamic changes that occur during hip flexion. Despite these limitations, our model does replicate specific tests performed intraoperatorically to assess implant stability and could be correlated to these experiences.

While we are becoming less limited in our choice of components due to the increased toughness of the bearings, we must be continually aware that femoral head size is only one aspect of total hip stability and should not be relied upon as a crutch to compensate for poor technique, implant positioning, or patient selection.

CONCLUSION

The authors have no conflicts of interest to disclose.

REFERENCES