INTRODUCTION

Instability/dislocation, a frequent complication following total hip arthroplasty (THA) has recently been identified as having surpassed mechanical loosening as the most common reason for revision THA surgery [1]. The hip capsule, a robust but intricate collection of soft tissue, stabilizes the hip joint during over a large range of motion by constraining motion between the acetabulum and proximal femur. Structural compromise of the capsule, either from pre-existing pathology or resulting from the surgical approach, is thus of particular concern following THA. To investigate the relationship between capsule structural integrity and THA instability, a finite element (FE) model was developed to parametrically explore the effects of capsular defects on dislocation resistance.

METHODS

A human cadaveric hemipelvis was carefully dissected of all non-capsular soft tissue. Fiber directions on the exposed, intact capsule were demarcated with silastic tubes filled with barium contrast, and the hemipelvis was CT-scanned (Fig 1A).

The CT data set was segmented to include the marking tubes, capsule and bony structures. The segmented surfaces were meshed with TrueGrid (Fig. 1B). The capsule was modeled using a micromechanical fiber-based anisotropic strain energy potential developed by Holzapfel [2]. Material coefficients were inferred using load-displacement data for capsule distraction [3]. The capsule was incorporated into an existing THA FE model (Fig. 1B), which consists of 3 parts: Femoral component (28mm), liner and backing. A metal-on-metal bearing couple was chosen, with the head, neck and liner (all CoCr) modeled as linear elastic (E=210 GPa, ν = 0.3). A sit-to-stand motion sequence [4] was used to assess the influence of capsule integrity on dislocation resistance. Capsular defects, simulating surgical incisions or incisional repair, were postulated at various positions, indexed circumferentially (Fig. 2).

Figure 1: A): CT dataset for a native (left) cadaver hip hemi-pelvis. (B): Capsule representation in the corresponding FE model. (C): Fiber directions shown for a single fiber-direction family

Figure 2: Coordinate conventions for specifying circumferential location, illustrated for a right hip in flexion. The anterior-most aspect of the capsule is assigned a value of θ=0° with θ increasing in a counter-clockwise fashion. Representatively, a longitudinal incision is shown, located at approximately 190°.
RESULTS AND DISCUSSION

For all FE runs, the resultant moment that developed to resist dislocation (designated as the resisting moment) was tracked throughout the entire kinematic input sequence (Fig. 3). The initial rise in resisting moment is caused by progressive tautening of the capsule. For the most compromising case, the capsule provided virtually no resistance to dislocation, and the resisting moment was attributable to hardware interactions only. Repair of this defect returned construct stability to near baseline levels.

Capsular release from both the acetabular and femoral attachment sites created a substantial drop in construct stability (Fig. 4). Again, repair of these defects returned stability to near baseline levels of dislocation resistance. Simulated suture tensile loads, arising from various repair techniques, were seen to be highly technique-and location-dependent (Fig. 5). Several suturing variants involved average tensile loads far exceeding the reported suture ultimate tensile strength (gray bar in Fig. 5).

CONCLUSIONS

Localized compromise of capsule integrity can dramatically reduce construct stability. Appropriate repair of these capsule deficits can recover near-normal dislocation resistance, although repair-site failure is a concern. These finite element results underscore the benefit of retaining/repairing capsular structures in total hip arthroplasty, in order to maximize overall construct stability.

REFERENCES


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