Prior total knee arthroplasty suggests tissue injury during hip arthroscopy: a finite element analysis

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INTRODUCTION: Improvement in diagnostic and surgical techniques in hip arthroscopy have led to a surge in procedures over the recent years with the predicted annual frequency being four out of every 10,000 orthopedic procedures in 2017 [1]. Due to the large traction force required to achieve the appropriate joint spacing intra-operatively, an emergence of traction-related neurological and soft tissue injuries have surfaced [2]. Pre-existing hip joint pathologies and surgical procedures disrupt the biomechanical stability of the joint and significantly increase the risk of iatrogenic damage [3]. Furthermore, patients with total knee arthroplasties are often subject to intra-articular ligament releases, leading to reduced stability; however, it is not well understood how this may impact their outcomes of hip arthroscopic procedures [4]. The current study aims to investigate the biomechanical behavior of various instrumented knee joints subjected to traction forces to aid clinical understanding and advancements of hip arthroscopy techniques.

METHODS: A validated finite element (FE) model of the pelvis and lower extremity was developed from computed tomography (CT) scans of a healthy 45-year-old female. Three different models were assembled according to different TKA techniques performed: Bi-Cruciate Retaining (BCR) model, Posterior-Cruciate Retaining (PCR) model, and Posterior Stabilized (PS) model. The BCR model is noted by retaining all native ligaments of the knee joint (ACL, PCL, MCL, and LCL), whereas the PCR model was subject to ACL removal and the PS model required ACL and PCL removal (Figure 1). The pelvis was encastered to prevent translation under the traction forces as motion of the patient's trunk is restrained, intraoperatively. To simulate the loading condition of hip distraction, an axial force was coupled to the distal fibula and tibia and incrementally increased from 100N to 500N. Joint spacing and ligament strain in the hip and knee joint were analyzed to assess the effects of traction forces.

RESULTS: The medial and lateral compartment stiffness of the knee joint was analyzed under hip distraction for the three different TKA scenarios. The BCR model displayed the greatest average knee complex stiffness. Release of the ACL resulted in a larger decrease of stiffness compared to release of the PCL. There was no change in forces required for hip distraction as result of changes in the knee joint stiffness (Figure 3). The PCR and PS models were subject to excess knee joint distraction that exceeded 12 mm and ligament strain greater than 20% before adequate hip joint distraction of 10 mm was achieved. The BCR model remained below 10 mm of knee distraction and 15% ligament strain at 10 mm of hip joint distraction.

DISCUSSION: Presently, only one study has assessed the outcomes of hip arthroscopies in patients with prior lower extremity arthroplasties in a cohort of five patients with TKAs and suggested no additional risks [5]. Contrary to these previous findings, our study reveals patients undergoing hip arthroscopy with a prior TKA may experience increased soft tissue damage or iatrogenic dislocation due to reduced knee joint stability. The PCR and PS models outline a trend suggesting patients who have undergone ligament sacrificing TKAs experience large reductions in knee joint stability, causing strain levels that are indicative of soft tissue injury (Figure 2) [6]. It is well understood that osteoarthritis associated inflammation and age reduce the structural integrity of knee ligaments, thus the results of the ligament sacrificing models warrant further investigation to determine at-risk populations [7]. The BCR TKA was indicated to be the safest under the distraction conditions as joint spacing and strain levels were largely reduced comparatively; however, when surpassing 10 mm of knee joint distraction at forces greater than 350 N, the strain levels in the ACL suggest minor injury may occur (Figure 2) [6]. These results numerically agree with the literature as 50% of patients report sensations of instability and pain in the knee after hip arthroscopic procedures [2]. Our results point to the potential of increased soft tissue damage with increased TKA associated ligament releases.

CLINICAL RELEVANCE: When determining procedural risk of hip arthroscopy, prior history of the patient's TKA should be thoroughly considered. Due to inherent instability of the knee joint under traction caused by ligament releases, surgeons should exercise increased caution and incorporate techniques to lower traction forces for patients with prior TKAs.

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FIGURES:

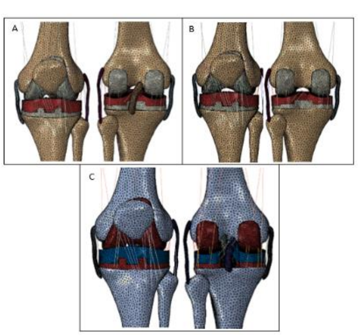

Figure 1. FE models of instrumented A) PCR TKA B) PS TKA and C) BCR TKA

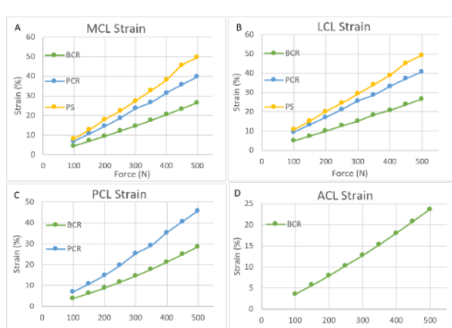

Figure 2. Measured strain in the A) MCL, B) LCL, C) PCL, and D) ACL under the traction forces.

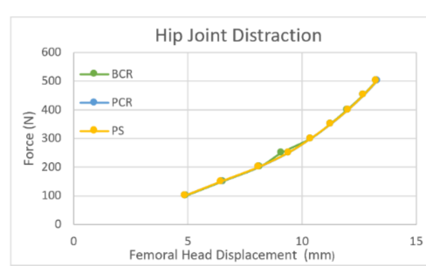

Figure 3. Hip joint distraction under axial traction force for the varying TKA implant scenarios.