Effect of Increased Varus-Valgus Torque on Tibial Micromotion of a Posterior Stabilized Insert.

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Disclosures: CM, AM:-3A,4-DePuy Synthes

Introduction: Total knee arthroplasty (TKA) is widely used to treat patients suffering from knee osteoarthritis [1]. Occupying 93.5% of all TKAs in 2010, cemented implants were previously the most preferred fixation method [2]. However, cementless knee arthroplasty has become increasingly popular because of its advantages such as increased surgical efficiency and improved implant survivorship [3]. The initial fixation of a cementless tibial tray to a patient's host bone is crucial for successful bony ingrowth. For bone growth to occur onto the porous surface of the implant, interface micromotions should be optimal [6]. The magnitude of these micromotions and thus the success of cementless initial fixation can also depend on the type of implant used. Fixed bearing Posterior stabilized (PS) type TKA solutions use the post on the Insert and corresponding cam on the Femur. The post-cam mechanism substitutes the PCL functionality in sagittal plane. The kinetics across the joint could alter due to various reasons, such as ligament laxity, placement errors or implant conformity. These changes could further influence the implant micromotion. Post-TKA instability in the coronal plane can change the contact mechanics in the medial and lateral compartments of the knee, thereby changing the varus-valgus (V-V) moment across the joint. Therefore, the goal of this study was to understand computationally the effect of V-V moment on a tibial tray micromotion during stair descent activity.

Methods: Two different loading profiles were developed for this study: Normal Step-Down and Increased V-V Step-Down. Loading profiles were developed using a validated finite element (FE) lower limb model [4]. Step-down boundary conditions were extracted from the Orthoload database and converted into a usable form for the lower limb model [5]. The baseline orthoload boundary conditions were considered the normal loading profiles, while the increased V-V loading profile had the V-V moment increased by the factor of two (2xV-V). Once run through the lower limb model, the tibial loads and kinematics of the constructs were extracted. Later, the loading and kinematic data was expanded to create two full step-down cycles in a time-series format. This data was then run through a series of MATLAB scripts to convert into the amplitude cards that could be input to FE models. Micromotion was investigated using a validated FE cadaveric tibial micromotion model [6]. Each loading profile was independently applied to a contemporary PS construct with one cadaveric tibia. Upon completion of the simulations, the coordinates of 6 points were extracted (3 on the tray and 3 on the bone) (Fig. 1). These points were selected to mimic the same points used in the validation of the micromotion model. The peak change in the distance between these points was considered the micromotion of the construct. Additionally, the axis of micromotion were found in the anterior-posterior (AP), medial-lateral (ML), and superior-inferior (SI) directions.

Results: The average increase in micromotion across all locations was 20%. The percentage increase progressed higher as the surface pairs moved laterally (Fig. 2). The 2xV-V loading condition changed the micromotion by 13%, 16%, and 30% for the medial, central, and lateral point pairs, respectively. The micromotion was not sustained over the loading cycle and have one large peak toward the end of the cycle when vertical loading was the least (Fig. 3). Neither medial, lateral, or central point pairs seen AP, ML, or SI as a significant driver in the micromotion. AP component of the micromotion was the highest in both the lateral and central point pairs, while the medial point pairs had the highest micromotion in the ML direction.

Discussion: The purpose of this study was to understand the effect of increased V-V loading on the micromotion of a PS construct using a computational FE model. The micromotion was found for 3 colinear point pairs and the maximum distance change over the loading cycles were found. This has allowed us to compare the micromotion of the two loading scenarios. Doubling the V-V loading increased the loading on the medial side while reducing the loading on the lateral side and this is believed to be the cause of the more significant change on the lateral side. While the V-V loading was doubled the micromotion only increased by an average of 20%. This leads one to believe that micromotion is not overly sensitive to the loading in the V-V axis. In H. Yang et. al, they described the conformity of the insert appear to have a larger effect on the micromotion with more sensitive in the AP axis while using a CR insert. The same may be true in the PS insert. This study shows that V-V loading has minimal impact on the peak micromotion of a PS insert during SD activity.

Significance/Clinical Relevance: Increased V-V moment across the joint, which could be resultant of soft-tissue imbalance or increased conformity, may not have a significant influence in the micromotion of a tibial tray.

References: 1. Sloan M, et. al. - 2018; 2. Matassi F, et. al. - 2013; 3. Asokan A, et. al. - 2021; 4. Fitzpatrick et. al. – 2014; 5. Bergman et. al. – 2008 6. H. Yang, et. al. - 2022. 6. Grewal, R., et. Al - 1992
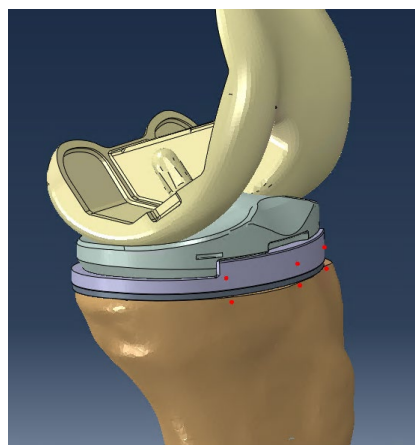
Figure 1. Maximum Micromotion of a PS construct via surface reference points
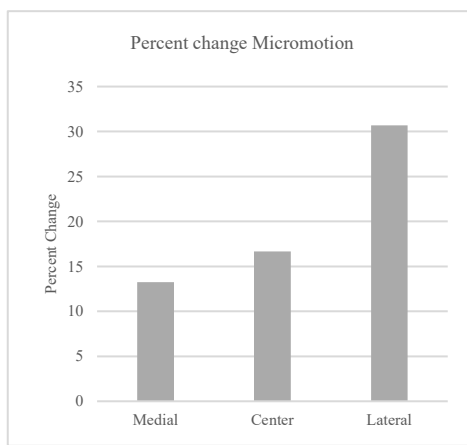

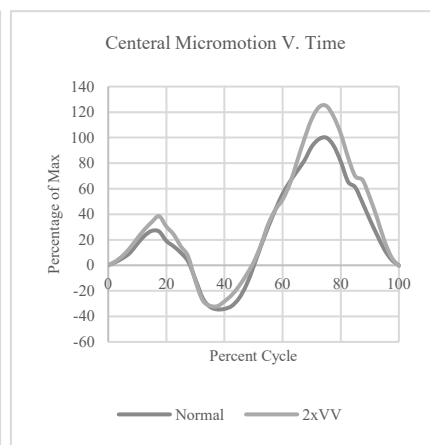*Figure 2. Percent Difference PS 2xV-V construct via surface reference points*

Figure 3. Micromotion over Time as a percentage of Maximum