IN-VIVO PASSIVE KINEMATICS OF OSTEOARTHRITIC KNEES

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INTRODUCTION

Osteoarthritis (OA) can lead to pain, disability, and loss of range of motion in the knee. The pre-operative condition of the knee has been shown to influence the functional outcome of treatments for OA [1]. A greater understanding of how motion of the knee is affected by OA may facilitate the assessment of the efficacy of potential treatments. We used a computer-assisted navigation system to study the passive kinematics of osteoarthritic knees intra-operatively and answer two questions: 1) Does the varus or valgus malalignment of the knee measured in full extension persist with flexion of the knee? and 2) Do "femoral rollback" (posterior translation of the femur on the tibia with flexion) and "screw-home" (external rotation of the femur with flexion) motions seen in a normal knee remain in an OA knee?

METHODS

Twelve patients undergoing a primary total knee arthroplasty for treatment of OA gave informed consent to participate in this study. Patients were grouped by limb alignment: mechanical axis varus alignment (six patients), neutral alignment (four patients), and valgus alignment (two patients).

After exposure of the knee joint at the beginning of the operation, the surgeon attached passive optical reference frames from the navigation system onto the medial side of the distal femur and proximal tibia. He circumducted the femur and used a calibrated optical stylus to identify landmarks on the patient's distal femur, proximal tibia, and ankle to establish anatomic reference frames in the femur[2] and tibia[3]. While supporting the leg with an open palm so as to avoid applying external loads to the limb, the surgeon then manipulated the subject's leg through two full cycles of knee flexion and extension. The navigation system recorded the position and orientation of the femur and tibia throughout the motion pattern. We measured the displacement of the origin of the femoral reference frame (OFRF) with respect to the origin of the tibia reference frame to assess translation and determined the flexion, varus/valgus, and internal/external rotations of the knee[4]. Repeated measures analysis of variance (ANOVA) was used to evaluate the differences in kinematics between the three OA groups from 20° to 105° of flexion, the range of motion common to all subjects.

RESULTS AND DISCUSSION

The varus/valgus malalignment measured in full extension did not persist with flexion of the knee, but the neutrally aligned limbs generally maintained their neutral alignment (Figure 1). All groups trended towards a slightly varus alignment in deep flexion, resulting in overall significantly different patterns of varus/valgus rotation between groups ($p < 0.001$).

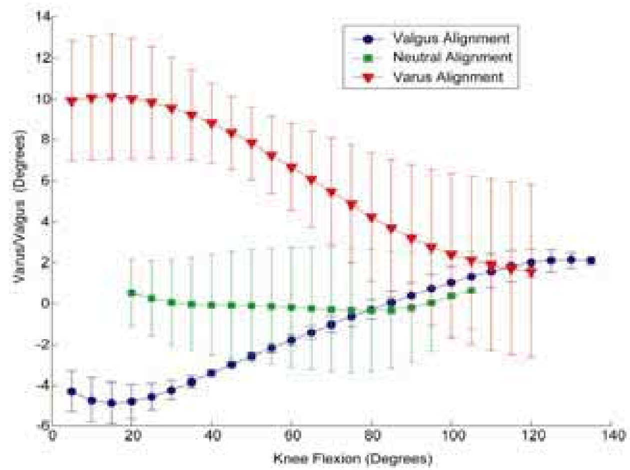

Figure 1: Mean varus (+)/valgus (-) angles for 3 OA groups. Error bars represent 1 standard deviation.

A very limited "screw-home" motion was present in all OA groups. In varus knees, the femur externally rotated by an average of 3.0° ± 4.4° over the common range of knee flexion. In the neutral and valgus groups, we observed an average of 5.0°± 6.9° and 1.0°± 2.6° of external rotation, respectively. No differences existed between the groups ($p > 0.6$). These magnitudes of rotation are all less than what has been observed in normal knees, where as much as 25° of rotation has been reported [5].

The expected "femoral rollback" was present in the varus and valgus groups. In varus knees, the OFRF translated posteriorly an average of 10.7 ± 3.0 mm. Similarly, in valgus knees, the OFRF translated posteriorly and average of 8.0 ± 0.9 mm. However, the motion of the neutral knees was significantly different than the other two groups ($p < 0.001$). In neutral knees, the OFRF translated anteriorly an average of 7.0 ± 5.8 mm before translating posteriorly 7.7 ± 5.0 mm from the most anterior point.

This study represents the first intra-operative characterization of the in-vivo passive kinematics of advanced osteoarthritic knees. Computer-assisted navigation systems, in which reference frames are directly and rigidly attached to bone, are a valuable research tool and represent a safe and reliable means of collecting intra-operative kinematic data.

REFERENCES

1. Harvey, I.A., et. al.. *JBJS Br* 75, 950-955, 1993.
2. Yoshioka, Y. et al.. *JBJS* 69-A, 873-880, 1987.
3. Yoshioka, Y., et al.. *JOR* 7,132-137,1989.
4. Grood, E.S., Suntay, W.J.. *J BioMech Eng* 105, 136-144, 1983.
5. Wilson, D.R., et al.. *J Biomech* **33**, 464-473, 2000.