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Kneeling Kinematics After Total Knee Arthroplasty: Anterior-Posterior Contact Position of a Standard and a High-Flex Tibial Insert Design

Kathryn M. Coughlin, MS,* Stephen J. Incavo, MD,* Robert R. Doohen, MD,* Kazuyoshi Gamada, PhD, PT,† Scott Banks, PhD,† and Bruce D. Beynnon, PhD*

Abstract: Deep flexion activities including kneeling are desired by patients after total knee arthroplasty. This in vivo radiographic study sought to reveal the effect of tibial insert design on tibiofemoral kinematics during kneeling. One group of patients received standard posterior stabilized tibial inserts, whereas the other group received posterior stabilized tibial inserts (Flex inserts) that were designed to allow more flexion. The patients with the Flex inserts achieved greater range of motion without different tibiofemoral contact behavior. **Key words:** kneeling, deep flexion, kinematics, in vivo, total knee arthroplasty.

Activities that involve deep flexion may improve the functional outcome and satisfaction of patients after total knee arthroplasty (TKA). In vivo kinematic studies of TKA have documented femoral rollback during weight-bearing activities such as squatting and stair-climbing [1-7]. In addition, in vivo kinematic data are now available regarding kneeling [8-10]. During kneeling, both cruciate-retaining and standard posterior stabilized TKA designs demonstrated function within intended design parameters with femoral posterior translation (rollback) occurring from 90° of knee flexion to deep flexion. In addition, neither subluxation of the cruciate-retaining design nor dislocation of the standard posterior stabilized design appeared likely to occur [8].

Increased flexion range of motion (ROM) can be addressed by both surgical and design variables with the common principle of increasing the flexion space. Introducing posterior slope into the tibial cut is a commonly applied surgical variable, which will increase the flexion space with minimal effect on the extension space. Implant design parameters include extending the posterior femoral component with a decreasing radius of curvature and removing posterior polyethylene from the tibial insert. All of these modifications have potential downsides. Increased slope of the tibial component may lead to anterior tibial polyethylene impingement, especially on the tibial post [11]. Increasing the posterior aspect of the femoral condyle requires removal of more posterior femoral bone. Decreasing posterior polyethylene thickness may result in less tibiofemoral contact area in the posterior tibial region.

Despite these tradeoffs, both patients and surgeons believe that limited deep flexion restricts function after TKA [12]. We studied patients with

*From the *Department of Orthopaedics and Rehabilitation, McClure Musculoskeletal Research Center, University of Vermont College of Medicine, Burlington, Vermont; and †Orthopaedic Biomechanics Lab, Mechanical and Aerospace Engineering, University of Florida, Gainesville, Florida.*
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Reprint requests: Stephen J. Incavo, MD, Department of Orthopaedics and Rehabilitation, McClure Musculoskeletal Research Center, University of Vermont College of Medicine, Burlington, VT 05405–0084.

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a tibial insert designed to allow a greater range of flexion (Flex insert) and a standard tibial insert that was more conforming. The anterior-posterior tibiofemoral contact positions of the femur relative to the tibia in these 2 designs were characterized during kneeling and maximum flexion during weight-bearing and non–weight-bearing conditions.

Materials and Methods

Kinematic analyses were performed on 2 groups of patients after TKA. Knee arthroplasty was performed by a single surgeon (SJI) using the posterior stabilized Scorpio design (Stryker Orthopaedics, Mahwah, NJ). The surgical technique included femoral epicondylar axis referencing for femoral rotation, flexion-extension gap balancing using spacer blocks, and no posterior slope in the tibial cut.

A total of 11 knees (7 patients) comprise the "Standard" group, and 11 knees (8 patients) the "Flex" group. Fig. 1 demonstrates the topographical differences between the posterior stabilized Flex insert (Scorpio Flex PS, Stryker Orthopaedics) and the posterior stabilized standard insert (Scorpio PS, Stryker Orthopaedics). Removal of some of the posterior polyethylene allows more available flexion space with no change in the amount of tibial bone resection. The specific implant has been used exclusively for primary knee arthroplasty since 1996 with a standard polyethylene insert. More recently, the Flex insert has become available and is now used.

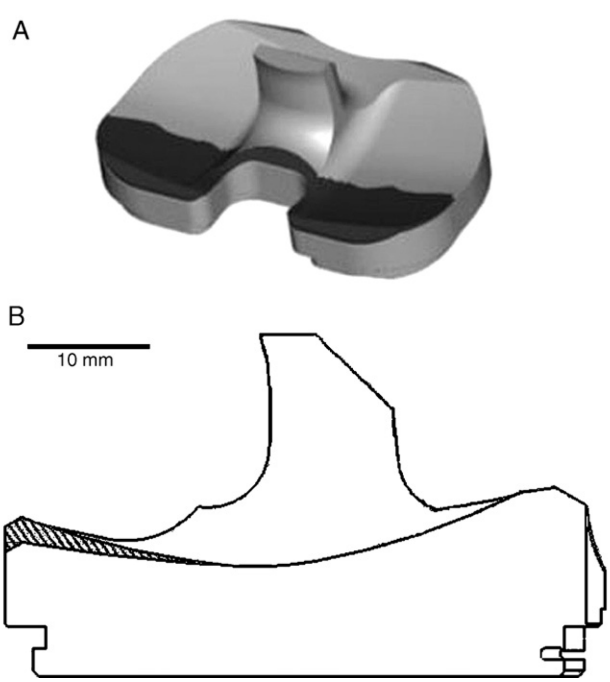

Fig. 1. The geometrical differences between the posterior stabilized Flex and posterior stabilized standard tibial inserts are represented by the shaded area. A, For the posterior stabilized Flex knee, the shaded area is removed. The increased flexion space in the Flex insert allows for more AP excursion for the same collateral ligament tension. B, This side view demonstrates the difference between the 2 designs.

Subjects in the Flex group ranged from 59 to 75 years old and underwent testing 23 ± 5 months after surgery. In the standard group, the patients ranged from 59 to 81 years old and underwent testing 50 ± 32 months after surgery. All patients were highly satisfied with their knee arthroplasty surgery, had excellent collateral ligament stability, and had Knee Society scores greater than 85 [13]. Both groups consisted of North American patients. Patients were invited to participate in the study if their knee ROM exceeded 120° of flexion. Initial data from the standard group had been previously collected and reported [8]. An effort was made to select patients who could easily kneel and achieve deep flexion. The maximum non–weight-bearing flexion films were obtained during a follow-up visit. The study was approved by the Committee on Human Research in the Medical Sciences at our institution, and informed consent was obtained from all volunteers.

A radiographic technique was used to provide 3-dimensional measurements of the position of the tibia relative to the femur during standing, kneeling, and maximum non–weight-bearing flexion. Lateral radiographs were taken with the subject standing with their leg fully extended, kneeling with a pad under the tibia tubercle with the knee at 90° of flexion, kneeling with the knee in maximal flexion, and maximum non–weight-bearing flexion (Fig. 2).

To indicate the center of the x-ray beam, a marker was placed on each film cassette. The focal distance of the radiograph was documented. The 3-dimensional position and orientation of the implant components were determined using model-based shape-matching techniques, including previously reported techniques, [14] manual matching, and image-space optimization routines. The radiographic images were digitized using a high-resolution flatbed scanner. The optical geometry of the radiographs (principal distance, principal point) was determined from the measured focal distance and the beam-center marker. The implant surface model was projected onto the digitized image, and its 3-dimensional pose was iteratively adjusted to match its silhouette with the silhouette