INTRODUCTION
Restricted knee flexion after total knee arthroplasty (TKA) is a multifactorial complication, although, the only consistent predictor of postoperative flexion is preoperative flexion. One potential patient-related factor is impingement between the bone exposed by the posterior femoral cut and the tibial insert. The purpose of this study was to evaluate the relationship between the exposed bone and the postoperative flexion angle using the computer model from the postoperative CT data.

METHODS

PATIENTS AND METHODS

Patients
CT scans of 42 knees were obtained within 6 months after TKA. Approval of an institutional review board and informed consent were obtained. The Nexgen Legacy posterior stabilized design (Zimmer, Warsaw, IN) was used and all femoral, tibial, and patellar components were fixed with cement. At 2 years postoperatively, range of flexion was measured during and active deep knee bend. Two groups of knees (Table 1) were selected from the original 42 knees: 6 knees with less than 110° of flexion (Low-Flex group) and 13 knees with greater than 125° of flexion (High-Flex group).

Patient-Specific Computer Model
CT scans were reconstructed to extract tibiofemoral bone geometry using Mimics (Materialise, Belgium). CAD models of the femoral and tibial implants were directly aligned to the CT images. Bone and implant geometry were imported into a dynamic, musculoskeletal modeling program (LifeMOD/KneeSIM) (Fig. 1). Soft-tissue attachment points were adjusted to patient-specific anatomic landmarks, however, soft-tissue material properties were obtained from published reports. KneeSIM uses rigid body dynamics to simulate a weight-bearing deep knee bend similar to that performed by the patients (hip load: 462.8 N). Contact was modeled between tibiofemoral and patellofemoral articular surfaces and between the quadriceps tendon and trochlea to simulate tendon wrapping during deep flexion. The maximum flexion possible before impingement between the posterior surface of the lower end of the femur and the tibial insert was recorded.

RESULTS
The KneeSIM model accurately predicted the maximum clinical flexion in the High-Flex group (Table 2). In the Low-Flex group, the KneeSIM model overestimated knee flexion. Three of the 13 knees in the High-Flex group had exposed bone, which was typically small (Fig. 3A). We found no significant differences in measured or predicted flexion when the High-Flex group were subdivided by presence or absence of any exposed bone (Fig 4). In 4 of the 6 knees in the Low-Flex group, substantial exposure bone was visible on the 3D CT reconstruction (Fig. 3B). All 4 cases of bone exposure were just above the tip of the posterior condyle and involved the posterior bone cut. The model predicted knee flexion was close that measured clinically (mean, 102° vs. 93°, respectively).

DISCUSSION
The effect of position and size of osteophytes on flexion have been previously reported in a generic model. We used a patient-specific approach to reconstruct postoperative CT data to directly predict knee flexion angle on an individual basis. Our patient-specific computer model accurately predicted knee flexion range of motion based on implant-bone impingement for the High-Flex group. In the Low-Flex group, on average the model overestimated knee flexion. However, the predictions were more accurate in the subset of patients with exposed bone. The remaining two knees (without exposed bone) likely had soft-tissue factors affecting knee range of motion, which could not be detected by the model.

No significant differences in PCO were noted between groups: 21.8 ± 1.0 mm for the High-Flex group and 21.9 ± 1.8 mm for the Low-Flex group (Student’s t-test).

REFERENCES