Introduction: Although the "learning curve" in surgical procedures is well recognized, little data exists documenting the accuracy of surgeons in performing individual steps of orthopedic procedures. In the specific case of total knee replacement, it is generally understood that instability and misalignment are due to imperfect surgical technique. However, the technical errors that lead to these deficiencies of the joint construct are often multi-factorial and inter-connected. To make headway in improving the outcome of TKA, data are needed demonstrating which errors lead to these deficiencies in longevity and function. Once this has been achieved, training programs and instrumentation systems can focus on the elimination of these seminal errors, thereby making the acquisition of surgical skills more efficient and cost-effective. In this study we apply a validated computer-based training system to measure variations in instrument placement and alignment of tibial preparation during TKA.

Methods: A total of 43 knee replacement procedures were performed by 11 surgical trainees (surgical students, residents and fellows) in a computerized training center. After initial instruction, each trainee performed a series of four TKA procedures in cadavers (n=2) and bone replicas (n=2) using a contemporary TKA instrument set and the assistance of an experienced surgical instructor. Prior to each procedure, computer models of each cadaver and/or Sawbones tibia were prepared by reconstructing CT scans of each specimen. Models of all surgical instruments and implants were generated by reverse engineering or from CAD models. All training procedures were performed in a navigated operating room using a 12 camera motion analysis system (Motion Analysis Inc) with a spatial resolution in all orthogonal directions of ±0.15mm.

Each trainee performed all steps of a standard TKA and at each step of the procedure, the position of the bones and all instruments and implants were recorded. Specialized post-processing routines were utilized to define the anatomic axes of the tibia and the femur, and a 3D coordinate system for defining the displacement and orientation of the bones and all instruments and implants. The natural slope, varus-valgus alignment, and axial rotation of the proximal tibial surface was recorded prior to surgery and after placement of the tibial component. The changes in the relative position of the pelvis/femur or femur/tibia/patella and the arc of stable motion of the joint replacement are also determined. All these results are compared to the initial preoperative plan and to data collected from previous surgeries performed with the system.

Descriptive statistics and t-tests were used to evaluate the data derived describing tibial preparation and component placement. For evaluation of all data, acceptable limits for implantation were defined as: posterior slope: 0-10°; varus-valgus inclination of tibial resection: ±3°; and external rotation: 0-10°. The percentage of all trials falling outside these limits were calculated for each trainee and for each outcome variable.

Results: The tibial component was implanted with an average posterior slope of 3.4°±3.4°. However, individual values varied widely, from 1.00° posterior to +5.0° anterior. In 83% of trials, the trainees cut the tibia with less posterior slope than intended, (average shortfall: 2.0°±4.0°). In 14% of cases the tibial resection sloped anteriorly, whereas in another 5%, the posterior slope exceeded 10°. The coronal alignment of the tibial osteotomy averaged 0.1°±2.9°of valgus, ranging from 6.5°valgus to 5.0°varus. 19% of components were implanted in more than 3° of valgus vs 14° varus (>3°).

The average rotational orientation of the tibial component was 54°±5.3°of external rotation, however individual values ranged from 7.6°of int rot to 14.4°of ext rot. Overall, 21% of components were placed in internal rotation, and a further 29% in more than 10° of external rotation. Rotational malalignment of the tibial component was the most common error in technique encountered in the study population.

Conclusions:
1. Tibial preparation still presents significant difficulty to many less experienced surgeons, despite the use of modern instrumentation and careful didactic instruction.
2. The most prevalent error in tibial preparation in TKR is malrotation of the tibial component, especially in internal rotation.
3. The errors measured in the computerized bioskills lab replicate clinical cases often presenting with symptoms necessitating early revision.
4. Greater attention is needed to training of surgical skills and intraoperative assessment of sources of technical error. Component position to improve clinical outcomes of TKA.