Introduction

In total knee replacement (TKR), it is generally understood that imperfect surgical technique is often responsible for cases of post-operative instability and misalignment. However, the relationship between technical errors and clinical complications is often multi-factorial. On the tibial side, common errors which are known to contribute to post-operative instability and reduced function include internal rotation of the tibial tray, inadequate posterior slope, and excessive component varus or valgus. However, the prevalence of each error in surgeries performed by surgeons and trainees is unknown. In this study we measure variations in instrument placement and alignment during TKA to test the hypothesis that malrotation of the tibial component is the most common error in tibial preparation during TKR.

Materials and 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 TKR procedures in cadavers (n=2) and bone replicas (n=2) using a contemporary TKR instrument set and the assistance of an experienced surgical instructor. Prior to each procedure, computer models of each cadaver and/or bone replica tibia were prepared by reconstructing CT scans of each specimen. 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 three orthogonal directions of ±0.15mm.

Each trainee performed all steps of a standard TKR 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 were 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 were also determined. All these results were 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 percentages 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 10.0° posterior to +5.0° anterior. In 85% 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 5.4°±5.3° of external rotation, however individual values ranged from 7.6° of internal rotation to 14.4° of external rotation. 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. Our results confirm the hypothesis that malrotation of the tibial component is the most prevalent error in tibial preparation in TKR. However, errors in the varus/valgus inclination, and the posterior slope of the tibial resection plane are also common.
3. Greater attention is needed to training of surgical skills and intraoperative assessment of sources of technical error, such as component position to improve clinical outcomes of TKR.

Significance

By identifying and quantifying errors in surgical procedures, training programs and instrumentation systems can focus more efficiently on obstacles to skills acquisition in surgical training. This focused approach is expected to make surgical training faster, more efficient and cost-effective.