MAGNETIC RESONANCE IMAGING ANALYSIS OF PATELLOFEMORAL AND TIBIOFEMORAL KINEMATICS AFTER TOTAL KNEE ARTHROPLASTY

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INTRODUCTION

Total knee arthroplasty (TKA) is a common treatment for severe arthritis of the knee and abnormal kinematic patterns have been observed after the surgery. For example, fluoroscopic studies have demonstrated that the femur in extension is positioned more posteriorly on the tibia relative to normal and moves anteriorly (paradoxical motion) during flexion. The effects of abnormal tibiofemoral kinematics on patellofemoral position are unclear since 2D fluoroscopic analysis does not evaluate patellofemoral kinematics. Magnetic resonance imaging (MRI) offers 3D images with high contrast between bone and soft tissues, but image quality is limited due to image artifacts from cobalt chrome knee implants. Newly developed prostheses made of oxidized zirconium may reduce metal artifacts in MRI and permit kinematic analysis of patellofemoral joint after TKA. The objectives of the study are 1) to further improve MR image quality of TKA knees, and 2) to examine quantitative correlations between patellofemoral and tibiofemoral kinematics.

METHODS

Four patients (age: 48–70 years) with five well-functioning TKA knees were recruited in the study. The patients had undergone TKA using oxidized zirconium, posterior cruciate ligament retaining femoral components one year prior to the image acquisition. Informed consent was obtained from all patients after the nature of the study had been fully explained. The study was approved by and performed in accordance with the rules and regulations of the local human research committee.

The MR images were acquired with a SIGNA 1.5T echo-speed system (GE Medical Systems, Waukesha, WI) and a dual phased-array coil (USA Instruments, Cleveland, OH), using a fast spin echo sequence (3000/9.1 ms, 1.6 cm FOV and 0.31/0.31/1.5 mm^3 voxel size). Each knee was imaged sagittally in extension and flexion, as patients pushed a constant weight (28 lbs) on a foot-plate of a custom-designed, weight-bearing apparatus. An additional knee holder was designed to constrain the knee laterally and axially. Three-dimensional image reconstruction was then used to measure flexion angle (FA), internal tibial rotation (ITR), medial tibial translation (MTT), medial patellar translation (MPT), inferior patellar translation (IPT), medial patellar tilt (MPR), inferior patellar tilt (IPR) and valgus patellar spin (VPS). All measurements were made relative to the extension position except FA.

RESULTS

Image quality was significantly improved (Fig 1) as the prosthesis, bone, and periprosthetic soft tissues were clearly visualized, a result of the use of oxidized zirconium and the optimization of the MR pulse sequence. Among the kinematic measurements (listed in Table 1), the FA of Knee#1 increased when scanned without a restraining knee holder; while the MTT and MPT of Knee#5 were missing because of poor image reconstruction. The data collected were also compared with the normal kinematics data [1][2]. Fig 2 shows two examples—ITR and MPT as functions of FA along with the mean and 95% confidence interval of the normal kinematic data. It is evident that the TKA kinematics exhibits a large deviation from the normal kinematics and considerable patient-to-patient variability.

To quantitatively analyze the deviation of TKA kinematics from normal, all TKA measurements except FA were standardized as

$$\text{Standardized TKA Data} = (\text{TKA Data} - \text{Mean})/2\text{SD}$$

where Mean and SD (standard deviation) are from the normal kinematics at specific flexion angles. Two significant linear correlations between tibio- and patellofemoral kinematics were observed: (1) ITR and MPT (R=0.94) and (2) MTT and MPR (R=0.93). The first correlation indicates that the more the tibial rotation deviates internally (externally) from normal, the more the patellar translation deviates medially (laterally) from normal, a pattern that can be seen in Fig 2. The second correlation shows that the more the tibial translation deviates medially (laterally) from normal, the more the patellar tilt deviates medially (laterally) from normal.

DISCUSSION

Lateral patellar tilt after TKA is commonly observed radiographically. Proposed causes of patellar rotation have included internal femoral or tibial component malposition, pre-operative patellar rotation, and insufficient soft tissue balancing of the patellofemoral joint. Our results indicate that rotational or translational movements between the femoral and tibial articulating surfaces (tibiofemoral kinematics) can also cause changes in patellar position. These findings suggest that implant designs or surgical techniques which are associated with lateral tibial translation or external tibial rotation may cause lateral patellar tilt or subluxation in TKA. Further studies are necessary to determine if implant designs, which constrain the position of the tibiofemoral joint and produce more normal knee kinematics, may be associated with improved patellar position after TKA.

REFERENCES

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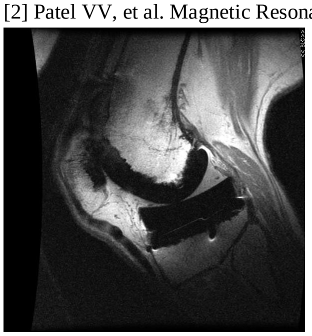

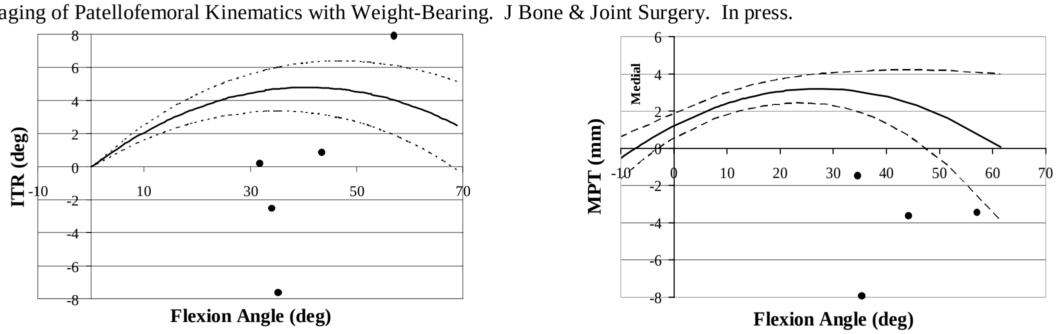

(Left) Fig 1 MR images of a TKA knee in which the bone, prosthesis and periprosthetic tissues are clearly seen.
(Center and Right) Fig 2 ITR and MPT as functions of FA. Additionally, the mean and 95% confidence interval of normal kinematics [1][2] are plotted in solid and dash lines.

Knee	FA	MTT	ITR	MPT	IPT	MPR	IPR	VPR
#1	57°	-0.9	7.9°	-3.7	34.5	-10.6°	58°	6.8°
#2	34°	-2.2	-2.4°	-1.6	18.0	-0.7°	21°	0°
#3	35°	2.0	-7.7°	-8.0	22.1	7.3°	38°	14.8°
#4	43°	0.9	0.9°	-3.8	40.8	1.5°	40°	-1.4°
#5	32°		0.2°		13.6	-1.6°	28°	1.0°

Table 1 Values of tibio- and patellofemoral measurements. All the data are made relative to the extension position.

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