Effect of High Tibial Osteotomy on Patellar Kinematics in Loaded Flexion: A Three-Dimensional Kinematic MRI Study

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INTRODUCTION

Osteoarthritis of the knee is a prevalent and disabling disease that is associated with abnormal joint mechanics [1]. One treatment approach, high tibial osteotomy surgery, seeks to restore joint mechanics to normal by realigning the lower limb. It is not clear how effectively high tibial osteotomy restores mechanics (kinematics and load transmission) at either the tibiofemoral or the patellofemoral joint of the knee. Studies have been limited because few non-invasive accurate three-dimensional methods are available for measuring joint movement under load. We have developed a Magnetic Resonance Imaging (MRI)-based method to measure three-dimensional patellar tracking in loaded knee flexion. In this study, our research questions were: 1) Is this MRI-based technique sensitive enough to measure differences in the tracking of the patella following high tibial osteotomy? and 2) How does high tibial osteotomy affect three-dimensional patellar tracking?

METHODS

We assessed patellar tracking in four subjects who underwent closing wedge osteotomy both pre- and post-operatively. A sagittal high-resolution image was acquired with the subject's knee in a relaxed, unloaded position and then a series of sagittal low-resolution scans were acquired at approximately 5 positions of static loaded flexion throughout the flexion cycle. MR imaging parameters were chosen to optimize visualization of the bone (Table 1). Bone outlines from high-resolution scans were segmented using custom software and meshed to generate models of the femur, tibia and patella. The relative positions and orientations of the bones in loaded flexion were determined by registering the high-resolution geometric bone models to the low-resolution MRI scans of loaded knee positions using the iterative closest points algorithm [2]. Position and orientation of the patella relative to the femur were described using a gyroscopic coordinate system [3]. We compared the pre- and post-operative tracking patterns using a two-way repeated ANOVA.

	Scan Type	TE (ms)	TR (ms)	FOV (cm)	T/S (mm)	Slice no.	Acquisition Matrix	NEX	Time (mins)
Sagittal high-resolution	2D SE VBED	6	435	26	2/0	38	512x256	2	14:28
Sagittal low-resolution	2D SE VBED	13	555	32	2/5	15	256x128	1	:38

Table 1: MR imaging parameters used to acquire the high- and low-resolution MR images.

RESULTS

High tibial osteotomy decreased patellar flexion by a mean of 5.06° ($p < 0.003$), decreased internal patellar spin by a mean of 1.25° ($p < 0.001$), increased medial patellar tilt by a mean of 1.59° ($p < 0.001$) and increased proximal patellar translation by a mean of 4.19 mm ($p < 0.008$) (Figure 1).

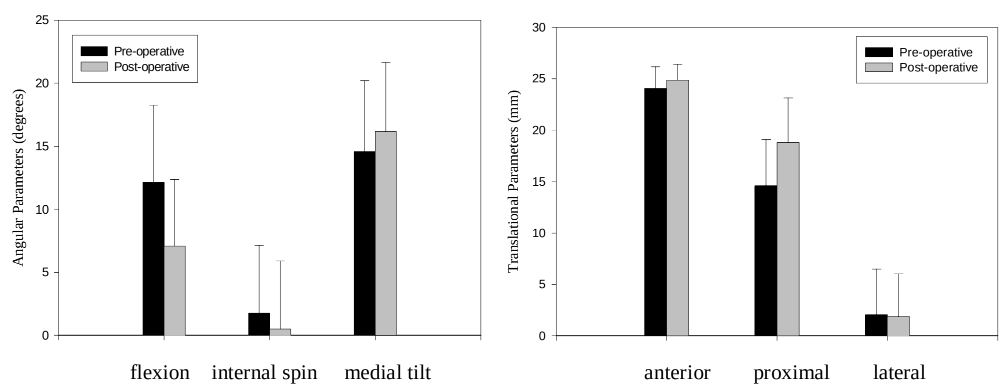

Figure 1: The mean errors (and standard deviations) of A) patellar flexion, internal patellar spin and medial patellar tilt; and B) anterior patellar translation, proximal patellar translation and lateral patellar translation. These are average values over a flexion range of approximately 40 degrees.

DISCUSSION

The significant changes in patellar movement caused by high tibial osteotomy surgery suggest that the post-operative anterior knee pain associated with these procedures is due to mechanical changes at the patellofemoral joint. A key advantage of the three-dimensional technique is that a complete description of patellar kinematics is provided. The significant difference in patellar spin, which is not normally measured in two-dimensional studies, highlights the importance of the three-dimensional approach. A limitation of the method is that titanium hardware must be used during the procedure to limit distortion in the postoperative MRI scans. Further work using this new technique may demonstrate that alternative surgical techniques (such as the opening-wedge high tibial osteotomy) affect patellofemoral joint kinematics less than the closing-wedge technique studied here.

REFERENCES: 1) Felson et al., *Arthritis Rheumatology,* 41:1343-55, 1998. 2) Besl et al., *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 14(2): 239-256, 1992. 3) Cole et al., *J Biomech Eng,* 155: 344-349, 1993.

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