CAN ASSESSING THE 6-DEGREE OF FREEDOM KINEMATICS OF THE KNEE DURING THE ANTERIOR DRAWER TEST IMPROVE CLINICAL DIAGNOSIS OF A PARTIALLY TORN ANTERIOR CRUCIATE LIGAMENT?

Maribeth Thomas, Susan M. Moore, Yoshiyuki Takakura, Richard E. Debski, Savio L-Y. Woo

Musculoskeletal Research Center
Department of Orthopaedic Surgery
University of Pittsburgh
Pittsburgh, PA

INTRODUCTION

The anterior cruciate ligament (ACL) plays an essential role in maintaining multi-directional knee stability and is one of the most frequently injured ligaments of the knee. The Noulis-Lachman test and the anterior drawer test are commonly used to diagnose joint instability caused by ACL deficiency. During this test an anterior force is applied to the proximal tibia with the knee placed at 90° of flexion and anterior translation is measured. Nevertheless, it is difficult for a clinician to use such a test to diagnose a partial tear injury [1-3]. The objective of this study was to quantify the 6-DOF kinematics of the ACL intact, partially torn, and deficient knee during the anterior drawer test. It is hypothesized that a rupture of the AM bundle may be more easily diagnosed during the anterior drawer examination with the knee at 90°, as the AM bundle is known to withstand the majority of the force at this flexion angle [4]. This information may lead to improved clinical examination techniques and may result in early diagnosis and treatment of partial ACL tears.

METHODS

Four fresh frozen cadaveric knees (61±5yrs) were tested. The specimens were thawed at room temperature 24 hours prior to testing, and all soft tissue was removed approximately 10 cm from the joint line of the femur and tibia. The femur and tibia were then potted in epoxy compound. A 6-DOF magnetic tracking device (The Bird, Ascension Technologies Corp.) was used to record the kinematics of the ACL intact, partially torn, and deficient knee [5]. A sensor was rigidly fixed to each bone. Joint motion description was implemented by using a third sensor to digitize anatomical landmarks [6]. To precondition the knee joint, the clinician moved the knee through five cycles of passive flexion/extension, internal/external rotation, and varus/valgus rotation. On a rigid Plexiglas table, the intact knee was positioned at 90° of flexion, with the femur rigidly fixed. The clinician then performed an anterior drawer test for four cycles, with the kinematics recorded during each cycle. The recorded kinematics included anterior/posterior, medial/lateral, and proximal/distal translations, as well as flexion/extension, internal/external and varus/valgus rotations. The load applied by the clinician was arbitrary, and the only feedback provided to the clinician was the angle of flexion. A partial tear was then arthroscopically created by transecting all fibers of the anteromedial (AM) bundle, defined as the fibers that were taut at 90° of knee flexion. The previous procedure was repeated to record the kinematics of the ACL-partially torn knee. Finally, the ACL was arthroscopically cut, and the kinematics of the ACL-deficient knee was recorded. For each specimen, a reference position was defined as the center of the joint motion coordinate system. The clinician was asked to choose the reference position based on his perception of the knee's neutral position at a flexion angle of 90°. The kinematics are reported as the average maximum translations and rotations of the four performed cycles with respect to the reference position. A one factor repeated measures ANOVA was performed to compare the ACL intact, partially torn, and deficient states, with statistical significance set at $p<0.05$.

RESULTS

Data is reported from four specimens; the ACL deficient data only includes results of 3 specimens due to experimental difficulties during data collection. Throughout the tests, the flexion angle remained at 89.4±1.1°. **Figure 1** illustrates anterior/posterior translations for the intact knee. With a partially torn ACL (AM bundle) there was no significant increase in anterior tibial translation when compared with the intact knee (1.94±0.4 vs. 2.78±1.3mm, $p<0.05$). A significant difference was found between the intact and ACL deficient states (2.78±1.3 vs. 3.58±0.8mm, $p<0.05$), as well as between the partial and ACL deficient states (1.94±0.4mm vs. 3.58±0.8mm, $p<0.05$). Intraspecimen repeatability, when measuring anterior tibial translation, was found to be ±1.3mm. For internal/external rotation, no significant differences ($p>0.05$) were found when comparing the ACL intact (2.7±1.2°), partially torn (1.8±0.4°), and deficient (1.8±0.8°) states of the knee (**Figure 2**).

Medial/lateral translations ranged from a maximum of 0.6±0.4mm in the ACL deficient knee to a maximum of 1.1±1.6mm in the partially torn state; however, no statistically significant difference ($p>0.05$) was found. Similarly, no significant difference ($p>0.05$) was found when comparing the maximum valgus rotation between knee states (ACL intact: 0.1±0.3°, partially torn: 0.1±0.4°, deficient: -0.9±0.8°).

Table 1 shows the measured reference positions of the three knee states (ACL intact, partial, and deficient) for each knee specimen. The numbers represent the change in anterior translation at 90º from the reference position of the knee at full extension. It is important to note that, while the reference position is expected to remain the same for each knee state, much variation was evident in each specimen.

DISCUSSION

In this study, the 6-DOF kinematics of the ACL intact, partially torn, and deficient knee were quantified during the anterior drawer test. The anterior tibial translation results found for partial tears of the ACL in this study agree to previously reported results where a significant difference in anterior tibial translation between the ACL intact and partially torn knees was unable to be detected [2]. All changes detected in our current study were less than 1mm, which is not clinically significant. Another previous study indicates that, at 90°, the AM bundle is withstanding the majority of the force of the ACL; therefore changes in kinematics could be expected [4]. Our results surprisingly indicate that a significant increase could not be detected, thus disproving our hypothesis. Therefore, our results suggest that the anterior drawer test is insufficient for the diagnosis of partial tears of the ACL as significant differences could not be found between the ACL intact and partially torn states.

Recently published data indicates that the reference position of the knee does not vary significantly between the ACL intact and ACL deficient states [7]. A possible explanation for the insignificant change in kinematics between the ACL intact and partially torn states is the inability of the clinician to establish a repeatable reference position during clinical examination (**Table 1**). Without feedback, the clinician was incapable of returning the knee to the same reference position during the clinical examination and changes in kinematics were not measured from the same position. Because of this limitation, the clinical exam may not be sensitive enough to diagnose a partial tear of the ACL.

In this study only one clinician performed all experimental testing. Additionally, the clinician was not blinded as to the current state of the knee (i.e. ACL intact, partially torn, or deficient) and an arbitrary load was applied to the knee during each trial. In future studies, the 6-DOF kinematics of multiple clinicians will be collected to compare ACL intact, partially torn, and deficient knees.

REFERENCES

1) Hole et al., AJSM 1996; 2) Lintner et al., AJSM 1995; 3) Thomas et al., ORS 2003; 4) Zeminski, Univ of Pitt Thesis, 2001, 5) Chao, J Biomech 1980; 6) Sakane et al., JOR 1997; 7) Ma, et al., JOR 2000.

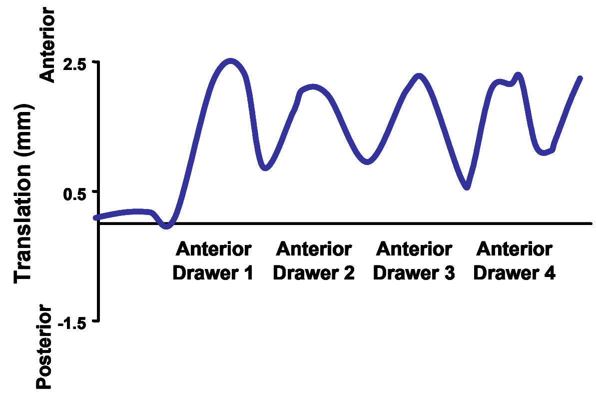

Figure 1. A representative graph illustrating the anterior/posterior translation of an intact knee during the anterior drawer test performed four times.

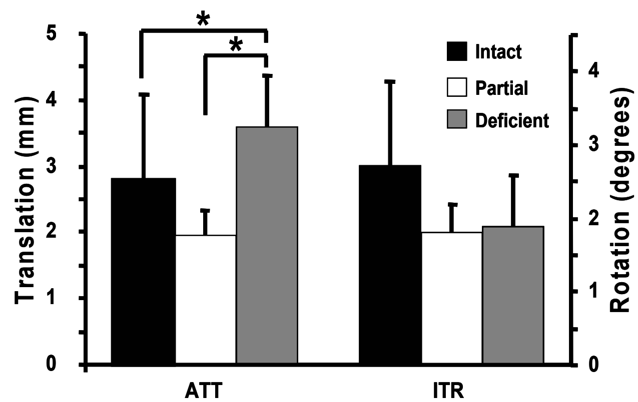

Figure 2. The maximum anterior tibial translation (ATT) and the maximum internal tibial rotation (ITR) of the 3 knee states: ACL intact, partially torn, and deficient (mean±SD, $p<0.05$).

	Specimen 1	Specimen 2	Specimen 3	Specimen 4
Intact	5.6	3.3	14.1	0.15
Partial Tear	5.5	6.8	9.9	10.9
Deficient	7.6		10.8	5.8

Table 1. The variation in the measured reference positions of the three knee states (ACL intact, partial, and deficient) for each knee specimen. Each data point represents the amount of anterior translation (mm) from full extension to the reference position of the knee at 90° of flexion.

ACKNOWLEDGEMENTS

Funding of NIH Grant AR39683 is gratefully acknowledged.