AN IN VIVO MEASUREMENT OF DYNAMIC INSTABILITY IN THE ACL DEFICIENT KNEE DURING THE PIVOT SHIFT TEST USING AN ELECTROMAGNETIC DEVICE

INTRODUCTION
In a clinical practice, pivot shift test[1] sometimes remain positive after ACL reconstruction despite successfully restored anterior stability. Recently clinical demand for evaluating remaining instability after ACL reconstruction has risen. This clinical test evaluates dynamic instabilities perceptually, which is difficult to be quantified only by three-dimensional measurement. To assess such dynamic instabilities quantitatively and obtain clinically comparable parameters, not only three-dimensional displacement but also its acceleration should be measured.

MATERIALS AND METHOD
The study group comprised 30 patients who underwent unilateral ACL reconstruction. No patient had a history of injury or abnormality in the opposite knee. All the measurements were carried out under general anesthesia prior to arthroscopic ACL reconstruction.

An electromagnetic device (FASTRAK, Polhemus, Vermont) was used to perform a six DOF kinematics measurement of the knee joint.[2] The system consisted of a transmitter which produced an electromagnetic field, and three electromagnetic receivers. Two of the receivers were used for motion measurement of the tibia and femur, and were attached to a plastic brace by a circumferential Velcro strap placed on the thigh and the shank. (Figure 1) The anatomical landmarks were digitized with a third receiver before the 6 DOF kinematics measurements. The acquired position data of each landmark was converted to the relative position of the two receivers attached to either the thigh or the shank, and used to provide each co-ordinate system on the femur and the tibia. The 6 DOF kinematics were computed according to a three-cylinder open-chain mechanism proposed by Grood et al.[3] The 6 DOF can be recorded at the sampling rate of 60 Hz.

6DOF kinematics under two passive testing maneuvers was measured for both knees using this system. The maneuvers were the pivot shift test and passive flexion. Clinical grading of the pivot shift test was determined manually by the examiner as none (-), glide (+), clunk (++), and gross (+++). Passive flexion served as the referral motion for analyzing the amount of change in knee kinematics by the pivot shift test. A typical example of measurement result in an ACL deficient knee is shown in Figure 2. The difference of tibial anteroposterior (A-P) position between two passive testing maneuvers was computed and defined as coupled anterior tibial translation (c-ATT), and its peak value was defined as the peak c-ATT.

Once the c-ATT reached its peak, the tibia started to move posteriorly defined as coupled anterior tibial translation (c-ATT), and its peak value position between two passive testing maneuvers was computed and showed in Figure 2. The difference of tibial anteroposterior (A-P) position between two passive testing maneuvers was computed and defined as coupled anterior tibial translation (c-ATT), and its peak value was defined as the peak c-ATT.

The peak c-ATTs were obtained in ACL deficient knees averaged at 22.0 ± 0.9° and in ACL intact knee averaged at 22.3 ± 1.8°. Those flexion angles have no difference (p=0.43).

The PTAs had an average of -2001 ± 186 mm/sec² in the ACL deficient knees and -797 ± 45 mm/sec² in the intact knees. There were also significant differences (p<0.01) in the PTAs. (Figure 4) At each pivot shift grade, the ACL deficient knees yielded a significantly larger peak c-ATT and the PTA than the ACL intact knees, except for the PTA in the knees which graded (+++) in the pivot shift test (p=0.08). Moreover in the ACL deficient knees, the peak c-ATT and the PTA were larger in correlation with the pivot shift grades (p=0.03 and P<0.01), while the intact knees demonstrated no correlations (p=0.14, both). (Figure 5, 6)

DISCUSSION
The peak c-ATT in each knee represented the tibial anterior laxity during the pivot shift test, and the considerable increase of the peak c-ATT could be regarded as a tibial anterior dislocation, resulting in detection of the pivot shift phenomenon. The peak c-ATT is a sort of anterior laxity measurement, just like KT-1000 measurement, however the peak c-ATT was measured under combined loading condition of the pivot shift test instead of simple anterior drawer loading.

The peak c-ATT was supposed to be clinically valuable for two reasons. One was that it was a continuous value to evaluate the three-dimensional magnitude of the tibial anterior translation or dislocation. The other was that it was needed to extract the proper acceleration of tibial translation from whole range of testing motion. The acceleration of tibial posterior translation or reduction is yielded just when the c-ATT reached its peak. The PTA, which appeared at the moment of changing the direction of tibial anterior translation to the posterior, could represent the dynamism of the pivot shift phenomenon, while the c-ATT can demonstrate mere static displacement. Acceleration directly reflects force in physics, therefore the PTA can reflect some force applied to the knee during the pivot shift phenomenon. It can be assumed that the force would induce the feeling of giving way when the force was sufficiently large. The PTA could also be monitored even in ACL intact knees clinically graded none (-) in the pivot shift test, however the PTA in such knees was supposed to be too small to be detected by hand.

Pivot shift phenomenon[4] consists of combined kinematics and its dynamism, and it is still unknown which factor would mainly deteriorate subjective symptom and knee function. Though the static measurement of knee laxity is not supposed to be a resolution, the measurement of its dynamism as acceleration can make a breakthrough to establish more patient-oriented assessment.

REFERENCES

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