NON-INVASIVE IN-VIVO ANALYSIS OF THE PIVOT SHIFT PHENOMENON USING AN ELECTROMAGNETIC DEVICE

INTRODUCTION
In the clinical assessment of ACL deficient knees, the pivot shift test has been performed to evaluate rotational instability. However, evaluation of the pivot shift test depends on the clinician’s subjective opinion, and there has been no established method to quantitatively evaluate the dynamic instability elicited in this test. In previous studies, kinematics during the pivot shift phenomenon has been analyzed only in in-vitro or as an intraoperative invasive measurement [1] [2] [3]. The purpose of this study was to develop a non-invasive measurement system for assessment of three-dimensional dynamic instability during the pivot shift phenomenon and to examine the feasibility of such a system in clinical evaluation.

METHODS
Subjects: Ten patients with unilateral ACL deficiency (3 men, 7 women) were evaluated. One examiner performed the pivot shift test in a manner recommended by the International Knee Knee Committee (IKDC) eight times for each subject

Kinematic measurement of the pivot shift phenomenon: To record kinematics during the pivot shift phenomenon, three-dimensional electromagnetic sensors (Fastrack, Polhemus, sampling rate 40 Hz) were attached to the plastic braces located at the distal femur, proximal and distal tibia. Anatomical reference points (the medial and lateral epicondyles, the greater trochanter of the femur, the proximal edge of the fibula, the medial edge of the tibial plateau, the tibial tubercle, and the distal edges of the medial and lateral malleolus of the ankle) were digitized using a probe equipped with an additional sensor. In the analysis of three-dimensional kinematics of the pivot shift phenomenon, the relative motion of the tibial tubercle with reference to the distal femur was calculated and used as an index.

Relationship between kinematic results and clinical grading: At each test session, clinical grade was determined by the examiner and the kinematic measurement was simultaneously performed. In a qualitative evaluation of the kinematics of the pivot shift phenomenon, the total amount of the posterior translation and the maximum postero-laterally directed velocity were adopted as parameters. The relationship between the clinical grading and the kinematic results were then assessed. Statistical analysis was performed using One-Factor ANOVA and a post hoc test to detect the difference between each of the clinical grades. A p-value of 0.05 was considered significant.

RESULTS
Kinematic measurement of the pivot shift phenomenon: When the pivot shift was clinically positive, a sudden posterolateral translation of the tibial tubercle was observed. This sudden posterolateral translation occurred on average at 36.1 degrees of knee flexion and finished within 0.5 seconds with a sharp change in the posterolaterally directed velocity (Fig.1). This motion seemed to correspond to the reduction component of the pivot shift phenomenon [1] [3].

Relationship between kinematic results and clinical grading: Among the 80 pivot shift tests performed by one examiner, pivot shift test results were classified as clinical grade 0, 1, 2, and 3 in 5, 33, 33, and 6 test sessions, respectively. In the statistical analysis, significant relationships were demonstrated between the clinical grade and both the posterior translation and the velocity of the tibial tubercle during the reduction component of the pivot shift test (One-Factor ANOVA; p<0.001). According to the post hoc test regarding posterior translation and maximum velocity, there were significant differences between each of the clinical grade groups except between grade 1 and grade 2. (Fig.2, 3)

DISCUSSION
In this non-invasive study, in-vivo kinematics of the reduction component of the pivot shift phenomenon could be detected as a sudden posterolateral translation of the tibial tubercle, and a sharp change in the postero-laterally directed velocity was a good index for determining the beginning and the end point of the reduction component of the pivot shift phenomenon. In the clinical analysis of the feasibility of this measurement system, the posterior translation and the maximum velocity of the tibial tubercle were shown to be good indicators in quantitative evaluation of the pivot shift phenomenon.

Fig.1 The sudden posterolateral translation was coupled with the sharp change of the postero-laterally directed velocity
B: beginning point E: end point

Fig.2 maximum velocity in posterior translation and clinical grade

Fig.3 maximum velocity in posterolateral direction and clinical grade

REFERENCES