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ORIGINAL ARTICLE

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Instrumented measurement of anterior-posterior translation in knees with chronic anterior cruciate ligament tear

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Abstract Anteroposterior translation of the knee joint was measured with a Knee Signature System device on 12 women and 14 men with a unilateral, chronic, isolated, anterior cruciate ligament (ACL) tear. A control group with stable knees consisted of 10 women and 10 men. Anterior translation at 178 N load of the uninjured knees was 8.0 mm (± 2.2 mm) and in knees with an ACL tear, 14.2 mm (± 4.2 mm). Corresponding values for anteroposterior translation were 12.1 mm (± 2.5 mm) and 19.3 mm (± 4.9 mm), respectively. A difference of 3 mm or more in anteroposterior translation at 178 N load between injured and uninjured knees indicated an ACL tear with 85% specificity and 88% sensitivity.

Introduction

The anterior cruciate ligament (ACL) provides important stabilizing control for the knee joint through the full range of motion [9]. Functional stability is provided by passive (ligaments and joint geometry) and active restraints (muscles) [11]. One or two of the knee ligaments act as primary restraints, while other ligaments provide secondary restraint [7]. The ACL is the primary stabilizer in anterior translation of the knee joint [3]. Insufficiency of the ACL is essential in the pivot shift phenomenon [9].

The anterior drawer, Lachman and pivot shift tests are the subjective evaluations most frequently used to assess ACL instability. In order to produce objective data in measuring anteroposterior translation in the knee joint, instrumented testing devices have been developed [1, 4].

There are several factors which influence the clinical evaluation of knee instability: flexion angle, tibial rotation, muscle tone, magnitude and point of application as well as direction of the displacing force [6]. Manual monitoring of these factors is difficult.

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The aim of this study was to establish limits for pathological anteroposterior translation in chronic ACL tears. The sensitivity and specificity of the method is also evaluated.

Patients and methods

Twelve women and 14 men with a mean age of 29.9 years (range 16–41 years) were examined at the Orthopaedic Hospital of the Invalid Foundation. All had unilateral chronic ACL tears (mean 2.8 years after injury) which were confirmed arthroscopically. A partial tear of the medial collateral ligament had been treated with brace in one case, otherwise no combined ligament lesions were included. One ACL had been sutured shortly after injury in one patient, but the knee became unstable. No late reconstructions of the ACL were done. Medial meniscus tears were diagnosed in five knees, of which two were sutured and three resected. Correspondingly, one lateral meniscus tear was sutured and three resected.

Reference values for anteroposterior translation were obtained by measuring 10 women and 10 men (mean age 33.7 years, range 18–51 years) who had not suffered knee injuries and were symptom-free.

The bilateral measurements of the knees in the ACL patients and reference subjects were carried out with a KSS arthrometer (Knee Signature System, Acufex Microsurgical, Norwood, Mass., USA) (Fig. 1). The arthrometer has an electrogoniometric linkage

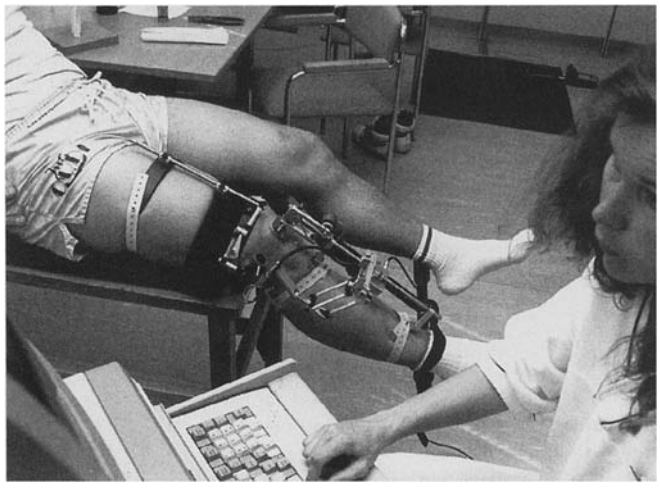

Fig. 1 Arthrometer measurements being carried out with a Knee Signature System

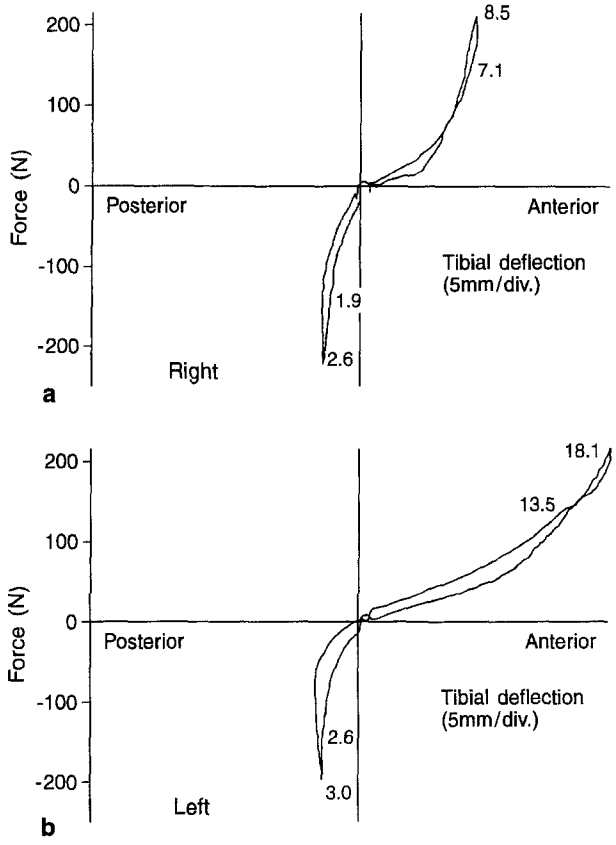

Fig. 2 **a** Anterior and posterior translation of an uninjured, control knee. **b** The injured knee with a chronic anterior cruciate ligament (ACL) tear in the same patient

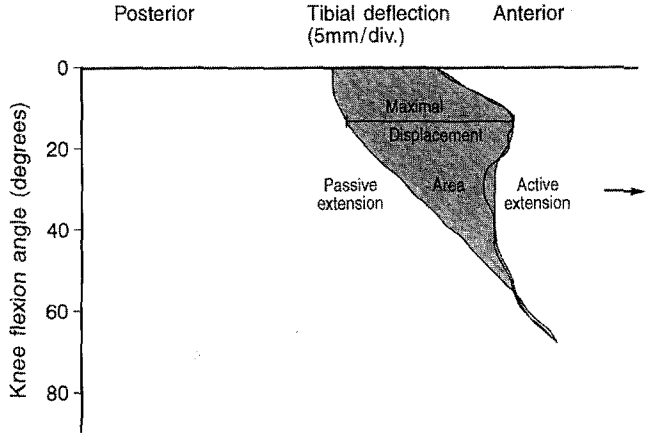

Fig. 3 The maximal distance and surface area between the deflection curves caused by active and passive extension of the knee with corresponding angle of knee flexion in a knee with an ACL tear

and is able to measure tibiofemoral motion in four degrees of freedom. The data are computerized, and the results can be printed in graphic form (Figs. 2 and 3). In this study, only anteroposterior translation was analysed. The measurements were performed using a load of 100 N and 200 N on both knees with 30° of knee flexion (Figs. 1 and 2). The translation values to be reported were taken at 89 N and 178 N. In addition, the maximal difference of anteroposterior translation between active and passive knee extension plotted by the arthrometer as well as the corresponding angle of knee flexion were defined (Fig. 3). The area between the active and passive deflection curves (Fig. 3) was measured with a planimeter (Planix, Tamaya Technics). The arthrometer was calibrated before each measurement.

In the clinical examination the anterior drawer, Lachman and pivot shift tests were performed. Arthroscopy of the knee was performed in all patients and reconstruction of the ACL in selected patients. Statistical analysis was carried out with the *t*-test.

Results

Anterior and anteroposterior translations were significantly greater at both 89 N and 178 N loads in injured than in uninjured knees ($P < 0.0001$, Table 1). Translation values at 178 N load are presented in Fig. 4. No difference

Table 1 Anterior, posterior and anteroposterior (AP) tibiofemoral translation (mm) at 89 N and 178 N loads in knees with an ACL tear and the contralateral uninjured knees (mean ± SD)

	Injured knee ($n = 26$)	Uninjured knee ($n = 26$)	Significance *P*-value
Anterior 89 N	10.8 ± 3.7	6.1 ± 2.0	< 0.0001
Anterior 178 N	14.2 ± 4.2	8.0 ± 2.2	< 0.0001
Posterior 89 N	3.6 ± 1.5	2.5 ± 1.2	0.059
Posterior 178 N	5.0 ± 2.0	4.2 ± 1.7	0.037
AP 89 N	14.3 ± 4.2	8.6 ± 2.2	< 0.0001
AP 178 N	19.3 ± 4.9	12.1 ± 2.5	< 0.0001

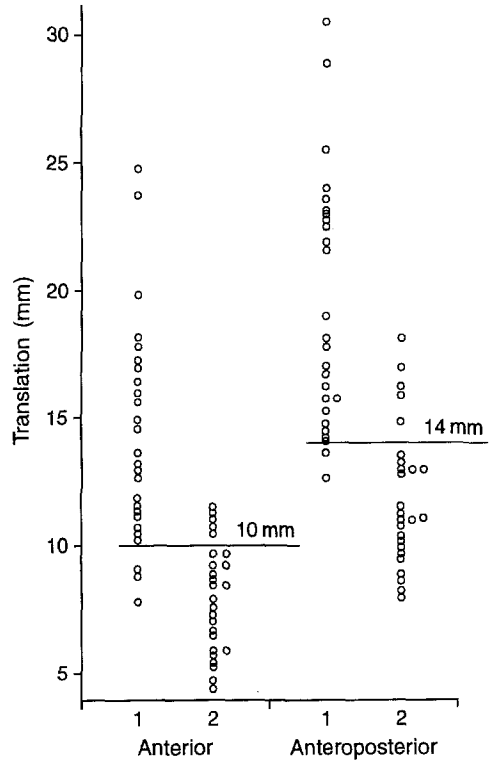

Fig. 4 Measurement results presented graphically in anterior and anteroposterior translation (mm) at 178 N load in 26 patients with a unilateral chronic ACL tear. Threshold limits of 10 mm and 14 mm are marked to determine sensitivity and specificity of the examination method. *1* Knee with an ACL tear, *2* uninjured knee

Table 2 Differences between deflection curves in active and passive extension of the knee in patients with a unilateral ACL tear. The uninjured contralateral knee is used as the control

	Injured knee (n = 26)	Control knee (n = 26)	Significance P-value
Maximal displacement (mm) between the curves	9.5 ± 2.3	5.7 ± 1.5	< 0.0001
Flexion angle (°) of the knee with corresponding maximal displacement of the curves	15.4 ± 5.9	21.4 ± 6.8	<0.001
Area (cm^2) between active and passive curves	16.1 ± 4.7	9.3 ± 2.9	< 0.0001

Table 3 The best sensitivity and specificity values of anterior and anteroposterior (AP) translation in unilateral ACL instability at various threshold limits

	Threshold (mm)	Sensitivity	Specificity
Anterior 89 N	8	77%	77%
Anterior 178 N	10	85%	81%
AP 89 N	11	77%	85%
AP 178 N	14	92%	81%

Table 4 Sensitivity and specificity (%) of the arthrometer in side-to-side difference in patients (n = 26) with a unilateral ACL injury compared with reference subjects (n = 20) with unijured knees bilaterally

	Side-to-side difference			
	≥ 2.0 mm	≥ 3.0 mm	≥ 4.0 mm	≥ 5.0 mm
Sensitivity				
Anterior 178 N	85	77	69	62
AP 178 N	92	88	81	69
Specificity				
Anterior 178 N	80	85	95	100
AP 178 N	65	85	90	95

was found between women and men ($P > 0.05$). At 89 N load there was an almost significant difference in posterior translation ($P = 0.059$) between the injured and uninjured knees, while at 178 N load a statistically significant difference was observed ($P = 0.037$, Table 1). The maximal difference of deflection curves in anteroposterior translation between active and passive knee extension and the area between the active and passive deflection curves were significantly greater in the injured knee ($P < 0.0001$, Table 2). The angle of knee flexion corresponding to the maximal anterior translation was significantly smaller in the injured knee ($P < 0.0001$). No difference was found between women and men ($P > 0.05$).

The sensitivity and specificity [14] of the arthrometer were tested using various selected threshold values (Table 3, Fig. 4). As optimal threshold values giving best sensitivity and specificity values, 10 mm in anterior and 14 mm in anteroposterior translation at 178 N load were defined (Fig. 4). A side-to-side difference of 3 mm or more at 178 N load in anteroposterior translation was found to give the best sensitivity and specificity values (Table 4).

Table 5 Anterior, posterior and anteroposterior translation (mm) at 178 N load in uninjured knees of patients with an ACL rupture in the contralateral knee. Reference subjects had not suffered knee injuries in either knee

	Uninjured knee in ACL patients (n = 26)	Reference group (n = 20)	Significance P-value
Anterior 178 N	8.0 ± 2.2	8.4 ± 1.8	0.433
Posterior 178 N	4.2 ± 1.7	3.7 ± 1.5	0.306
AP 178 N	12.1 + 2.5	12.1 + 2.6	0.970

The anterior drawer test was positive in all but one of the ACL tear patients, the Lachman test was positive in all, and the pivot shift test positive in 21 patients (80%). In the pivot shift-negative patients, anterior translation was 12.4 mm (± 2.4 mm) at 178 N load and anteroposterior translation 16.2 mm (± 4.0 mm). These values did not differ statistically significantly from the pivot shift-positive patients. There was no difference in anterior or anteroposterior translation between the uninjured contralateral knees of patients with an ACL tear and knees of the control group without previous knee injuries (Table 5).

Discussion

The mean anterior translations with various devices ranged from 3.5 to 9.9 mm for uninjured knees and from 6.8 to 13.9 mm for ACL-deficient knees at 89 N load. The corresponding values at 178 N load (maximum manual test) ranged from 5.1 to 9 mm and from 10.9 to 16.8 mm, respectively [1]. The translation values of the present study compare well with other reports of KSS measurements [1, 10, 15]. Reproducibility of the instrumented measurements of anteroposterior translation has been generally accepted [15], although contradictory reports have been published [8].

In spite of an intact posterior cruciate ligament, there was still a significant difference in posterior translation between the injured and uninjured knees. This is explained by the arthrometer not finding the neutral point or starting position. Therefore, some of the posterior displacement was in fact anterior translation. To avoid confusion, it would be better to report total anteroposterior translation values and side-to-side differences [13].

Active extension (active Lachman test) of the knee produced distortion of the deflection curve, which indicated ACL instability with great accuracy. However, the assessment is rather time-consuming and therefore less suitable for clinical use. Moreover, reproducibility of the method has been inadequate [13].

When looking at sensitivity and specificity of instrumented translation measurements in this study, 10 mm and 14 mm at 178 N load were found to be the optimal

threshold values for anterior and anteroposterior translation, respectively. Andersson and Gillquist [2] established 92% sensitivity and 70% specificity at 180 N load with the Stryker arthrometer (Stryker, Kalamazoo, Mich., USA). In our study the sensitivity at 178 N load was similar, while specificity was somewhat better.

Anderson et al. [1] noted significant variations in the side-to-side difference in patients with ACL deficiency using five different arthrometers. Daniel et al. [5] found that 92% of subjects with uninjured knees had a KT-1000 arthrometer-measured (MEDmetric, San Diego, Calif., USA) side-to-side difference in anterior translation of no more than 2 mm, while in 96% of patients with unilateral ACL tear the injured–normal knee difference in anterior translation exceeded 2 mm. Rangger et al. [12] reported KT-1000 injured–normal knee translation of 3 mm or more in 99% of patients with chronic ACL tear when the maximal manual load was used. It should be borne in mind that translation measurement values cannot be generalized from one device to another [1].

On the basis of the present study with the KSS arthrometer, a difference of 3 mm or more at 178 N load between the injured and uninjured knee reliably revealed an ACL tear. According to our findings, measurements made at 178 N load are more reliable than those at 89 N load.

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References

1. Anderson AF, Snyder RB, Federspiel CF, Lipscomb AB (1992) Instrumented evaluation of the knee laxity: a comparison of five arthrometers. Am J Sports Med 20: 135–140
2. Andersson C, Gillquist J (1990) Instrumented testing for evaluation of sagittal knee laxity. Clin Orthop 256: 178–184
3. Butler DL, Noyes FR, Grood ES (1980) Ligamentous restraints to anterior-posterior drawer in the human knee. A biomechanical study. J Bone Joint Surg [Am] 62: 259–270
4. Daniel DM, Malcom LL, Losse G, Stone ML, Sachs R, Burks R (1985) Instrumented measurements of anterior laxity of the knee. J Bone Joint Surg [Am] 67: 720–725
5. Daniel DM, Stone ML, Sachs R, Malcom LL (1985) Instrumented measurement of anterior knee laxity in patients with acute anterior cruciate ligament disruption. Am J Sports Med 6: 401–407
6. Edixhoven P, Huiskes R, Graaf R de, Rens TJG van, Slooff TJ (1987) Accuracy and reproducibility of instrumented knee-drawer tests. J Orthop Res 5: 378–387
7. Emery M, Moffroid M, Boerman J, Fleming B, Pope M (1989) Reliability of force/displacement measures in a clinical device designed to measure ligamentous laxity at the knee. J Orthop Phys Ther 1011: 441–447
8. Fleming BC, Johnson RJ, Shapiro E, Fenwick J, Howe JG, Pope MH (1992) Clinical versus instrumented knee testing on autopsy specimens. Clin Orthop 282: 196–207
9. Galway HR, McIntosh DL (1980) The lateral pivot shift: a symptom and sign of anterior cruciate ligament insufficiency. Clin Orthop 147: 45–50
10. Neuschwander DC, Drez D, Paine RM, Young JC (1990) Comparison of anterior laxity measurements in anterior cruciate deficient knees with two instrumented testing devices. Orthopedics 13: 299–302
11. Noyes FR, Grood ES, Butler DL, Malek M (1979) Clinical laxity test and functional stability of the knee: biomechanical concepts. Clin Orthop 146: 84–89
12. Rangger C, Daniel DM, Stone ML, Kaufman K (1993) Diagnosis of an ACL disruption with KT-1000 arthrometer measurements. Knee Surg Sports Traumatol Arthrosc 1: 60–66
13. Riederman R, Wroble RR, Grood ES, VanGinkel L, Shaffer BL (1991) Reproducibility of the Knee Signature System. Am J Sports Med 19: 660–664
14. Sackett DL, Haynes RB, Tugwell P (1985) Clinical epidemiology. A basis for clinical medicine. Little, Brown, Boston
15. Steiner ME, Brown C, Zarins B, Brownstein B, Koval PS, Stone P (1990) Measurement of anterior-posterior displacement of the knee. A comparison of the results with instrumented devices and with clinical examination. J Bone Joint Surg [Am] 72: 1307–131