Laxity after cruciate ligament injury in 94 knees

The KT-1000 arthrometer versus roentgen stereophotogrammetry

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We examined 94 knees with chronic anterior cruciate ligament injuries, 55 of which had been operated with ligament reconstruction, using the KT-1000 arthrometer (89 N anterior force) and roentgen stereophotogrammetry (RSA, 150 N anterior, 80 N posterior force). In intact knees the tibial displacement did not differ between the methods. In injured knees, operated or not, the KT-1000 recorded smaller AP translations and side-differences than RSA. Thus, the stabilizing effect of reconstructive surgery may be overrated, if evaluated with the standard KT-1000 technique.

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Clinical grading of knee joint stability varies between examiners, especially after knee ligament surgery (Daniel 1991). To obtain more objective evaluation of anteroposterior laxity, arthrometers have been developed. The KT-1000 (Medmetric Corp., San Diego, CA, U.S.A.) is one of the most widely used arthrometers commercially available. This and similar arthrometers have been recommended as a complement to clinical examination in the diagnosis of anterior cruciate ligament injuries and in the follow-up after surgery (Malcom et al. 1985, Highgenboten et al. 1989, Bach et al. 1990, Steiner et al. 1990, Wroble et al. 1990, Anderson et al. 1992), but its value has also been questioned (Forster and Warren-Smith 1989, Graham et al. 1991).

Roentgen stereophotogrammetric analysis (RSA, Selvik 1974, 1989) has been used to quantify the effects of cruciate ligament rupture (Kärrholm et al. 1988), the effect of knee bracing (Jonsson and Kärrholm 1990), and in the follow-up after cruciate ligament surgery (Fridén et al. 1992, Jonsson et al. 1992). We have compared RSA with KT-1000 measurements of knee laxity using both methods as originally described (Daniel et al. 1985a, Kärrholm et al. 1988).

Patients and methods

86 patients (57 men, 29 women) with a mean age of 26 (15–42) years were examined. The patients were separated into 2 groups. The first group consisted of 39 patients with a chronic unilateral anterior cruciate ligament tear, diagnosed at arthroscopy, waiting for reconstructive surgery. 21 knees had isolated total and 1 partial rupture of the ligament. In a further 14, partial meniscectomies had been done. Injury to the medial collateral ligament had been present in 7 knees.

The second group consisted of 55 patients who had been subjected to reconstructive anterior cruciate ligament surgery. 8 of these knees were examined both before and after surgery. 38 knees had an over the top reconstruction according to Marshall et al. (1979), 4 of these without and 34 with Kennedy Ligament Augmented Device (Roth et al. 1985). In 14 knees the graft was positioned isometrically through a tunnel in the lateral femoral condyle. 3 had received a synthetic ligament.

Roentgen stereophotogrammetric analysis

2 weeks or more before the examination, at least 4 tantalum markers were implanted in the distal femur and the proximal tibia bilaterally. RSA examinations were performed with the patient in supine position and the knee in a Plexiglass cage (Kärrholm et al. 1988). The distal femur was fixed to an adjustable frame with an inflatable tourniquet to minimize femoral movements. Simultaneous AP and lateral exposures were done with the knee extended, or in 30 degrees of flexion, with or without anterior traction of 150 N or posterior traction of 80 N; the anterior traction was applied perpendicular to the longitudinal axis of the tibia about 7 cm distal to the joint line. The evaluation of the radiographs has been described previously (Kärrholm et al. 1988). A software package (UMRSA 2.3, Unikum, Umeå, Sweden), mainly based on RSA according to Selvik (1974, 1989), was used. At the preoperative

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Table 1. Knee displacement (mm *SD*) with KT-1000 and RSA in normal, injured (n 39) and postoperative (n 55) knees

	KT-1000		RSA		
Normal	5.9	*2.3*	5.5	*1.7*	n.s
Injured	11	*3.8*	13	*3.9*	**
Difference injured/intact	4.6	*3.8*	7.3	*3.8*	**
Postoperative[a]	7.5	*3.2*	9.5	*3.0*	***
Difference postop[a]/intact	1.6	*2.9*	4.0	*3.0*	***

[a]Examined 3 (n 1), 6 (n 27), 12 (n 9), 24 months or more (n 18) after surgery.
** $P < 0.01$, *** $P < 0.001$

examinations, both injured and intact knees were examined. The postoperative side-to-side differences of displacement were based on prior preoperative examinations of the intact knees. The displacement of the tips of eminentia intercondylaris tibia along the tibial sagittal axis was measured (Kärrholm et al. 1988).

To determine a cut-off RSA value for injured–normal side-to-side difference, 100 consecutive patients (including the 39 preoperative patients in the present study) with unilateral anterior cruciate insufficiency were evaluated.

KT-1000 measurements

Both knees were placed on a thigh support and a footrest providing an estimated knee flexion of 30° ± 5°. Firm pressure was placed on the patellar pad by one hand. 89 N anterior traction was used (Daniel et al. 1985b). The reference position was achieved by repeated posterior loads of 89 N until a reproducible unloaded position was obtained. The tibia was pulled anteriorly by 2 straps, 1 about 13 cm and the other 29 cm distal to the joint line. Repeated anterior tractions were performed until a constant reading on the dial was registered. Displacements perpendicular to the apparatus were measured.

The measurements by both methods were performed on the same day, except for the intact side in the operated patients. One experienced examiner performed all the KT-1000 and another the RSA examinations.

Statistics

Student's paired *t*-test, Chi-2 test and Pearson's correlation coefficients were used. $P < 0.05$ was regarded as significant.

Results

In the 100 patients with anterior cruciate ligament insufficiency, the average AP displacement by RSA was 5.2 (*SD* 2.1) mm in intact and 13 (*SD* 3.8) mm in injured knees. To indicate ligament rupture AP displacement differences injured–intact side of 2, 2.5 or 3 mm corresponded to a diagnostic sensitivity of 98, 97 and 93 percent, respectively.

Normal knees. The KT-1000 recorded about the same displacement as the RSA, with moderate correlation (*r* 0.6, *P* 0.001, Table 1).

Injured knees. The KT-1000 recorded about 2 mm smaller displacements than the RSA, with no correlation between the methods.

Ligament-reconstructed knees. The displacement with the KT-1000 was 2.0 mm smaller than by the RSA. Moderate correlation was observed between the methods (r 0.4, P 0.001).

Side-to-side differences. The side-to-side difference before surgery measured with the KT-1000 was 2.8 mm smaller than the RSA values, without any correlation between the arthrometer and the RSA (Figure 1). After surgery, the mean differences between the methods were almost the same, with no correlation (Figure 2).

Using 3 mm side-to-side difference for the KT-1000 and 2.5 mm for the RSA as a cut-off value, the KT-1000 measurements indicated ligament rupture in 28 and RSA in 38 of the 39 patients ($P < 0.01$). In 35 out of the 55 operated patients, the KT-1000 measured less than 3 mm side-to-side difference. The corresponding number for the RSA (< 2.5 mm) was 16 ($P < 0.001$).

Discussion

The amount of displacement is influenced by the size of load applied (Shino et al. 1987, Edixhoven et al. 1989, Bach et al. 1990, Steiner et al. 1990, Fridén et al. 1992). In the RSA set-up we used 150 N anterior traction (Kärrholm et al. 1988) which was the largest load that could be applied without discomfort to the patient. The KT-1000 was introduced using 89 N anterior traction, which was the reason why we used this load.

The noninvasive arthrometers are designed to measure skeletal displacements in the knee, but are influenced by the surrounding soft tissues (Shino et al. 1987). Daniel et al. (1985a) observed a high correlation (*r* 0.97) between the KT-1000 and direct skeletal measurements in vitro. For the KT-1000 both the femoral reference point at the patella and the tibial

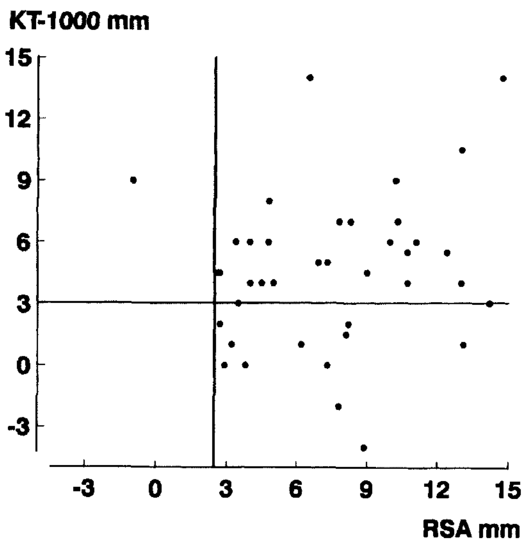

Figure 1. Scattergram of side differences between injured and intact knees (n 39) using KT-1000 and RSA displacements. Cut-off values for normal and unilateral anterior cruciate ligament injured side-to-side differences are indicated (KT-1000 3 mm, RSA 2.5 mm).

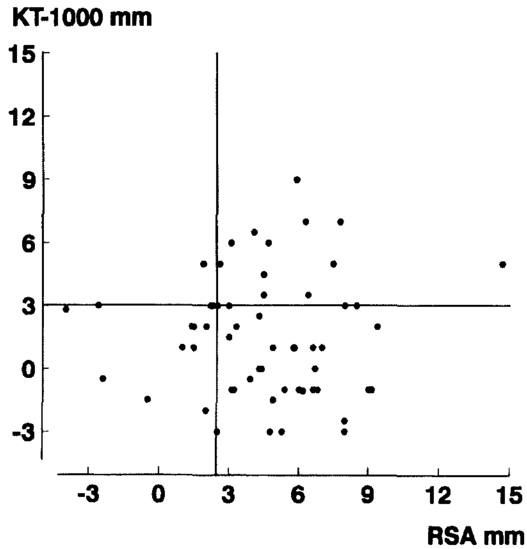

Figure 2. Scattergram of side differences between operated on and normal knees, 3 months or more after anterior cruciate ligament reconstruction (n 55) using KT-1000 and RSA displacements.

measuring point at the tibial tubercle are subjected to errors. However, patellar motion during the test seems to be of minor importance (Edixhoven et al. 1987). Contrary to our results, Stäubli and Jakob (1991) reported no correlation in intact knees and moderate (r 0.58) in injured knees between stress radiography and KT-1000 in anesthetized patients.

The tibial position in relation to the femur before the loads are applied may vary, depending on several factors (Kärrholm et al. 1988, Jonsson and Kärrholm 1990), and it is difficult to reproduce the same reference position for different arthrometers (Stäubli and Jakob 1991) or for the same device in longitudinal studies. The displacement between anterior and posterior endpoints can be used to avoid this problem (Wroble et al. 1990).

The normal laxity according to the KT-1000 corresponded to the RSA measurements of AP displacement. The higher force used with the RSA did not increase the displacement, probably because of a rapid increment in stiffness in normal knees (Markolf et al. 1976, Edixhoven et al. 1989).

The injured knees displayed smaller displacements with the KT-1000, probably because of smaller loads and a more gradual increase in stiffness.

The normal side-to-side difference has been determined to establish a cut-off value distinguishing between injured and normal knees (Bach et al. 1990, Steiner et al. 1990, Anderson et al. 1992). There are small differences between the knees of healthy subjects (Shino et al. 1987, Edixhoven et al. 1989, Wroble et al. 1990, Anderson et al. 1992), and the amplitude of the cut-off value partly reflects the reproducibility of the arthrometer used (Steiner et al. 1990). The RSA, being an invasive method, has not been evaluated by bilateral measurements of healthy knees previously and the side-to-side difference indicating rupture of the anterior cruciate ligament has been estimated indirectly. Repeatability of ± 1.6 mm (± 2SD; Kärrholm et al. 1988) and ± 2.2 mm (Fridén et al. 1992) for RSA has been reported and, according to the results of the present study, a cut-off value of 2.5 mm for the RSA seems appropriate.

Daniel et al. (1985a) recommended a side-to-side difference of more than 3 mm as the limit for diagnosing an anterior cruciate ligament injury with the KT 1000. This level seems to be widely accepted and has been used by us, although lower values have been suggested (Steiner et al. 1990). Using this difference as a tool to evaluate the surgical outcome, fewer patients returned to normal stability with RSA than with KT-1000. 133 N force or the maximum manual test with the KT-1000 (134–178 N, Daniel et al. 1985b) result in greater side-to-side difference (Dahlstedt and Dalén 1989, Steiner et al. 1990, Anderson et al. 1992). However, Steiner et al. (1990) reported unchanged diagnostic accuracy of chronic tears of the anterior cruciate ligament with 133 N. Thus, the use of different loads is probably not sufficient to explain the differences between the KT 1000 and RSA in this study.

In conclusion, when used as originally described (89 N force) and compared to 150 N RSA, the KT-1000 recorded smaller displacements in injured and in operated but not in normal knees, which has implications in the interpretation of the postoperative results regarding knee stability. The discrepancy may be the result of smaller loads, different application of forces and indirect skeletal measurements by the KT-1000.

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References

Anderson A F, Snyder R B, Federspiel C F, Lipscomb A B. Instrumented evaluation of knee laxity: a comparison of five arthrometers. Am J Sports Med 1992; 20 (2): 135–40.

Bach B R Jr, Warren R F, Flynn W M, Kroll M, Wickiewiecz T L. Arthrometric evaluation of knees that have a torn anterior cruciate ligament. J Bone Joint Surg (Am) 1990; 72 (9): 1299–306.

Dahlstedt L J, Dalén N. Knee laxity in cruciate ligament injury. Value of examination under anesthesia. Acta Orthop Scand 1989; 60 (2): 181–4.

Daniel D M, Malcom L L, Losse G, Stone M L, Sachs R, Burks R. Instrumented measurement of anterior laxity of the knee. J Bone Joint Surg (Am) 1985a; 67 (5): 720–6.

Daniel D M, Stone M L, Sachs R, Malcom L. Instrumented measurement of anterior knee laxity in patients with acute anterior cruciate ligament disruption. Am J Sports Med 1985b; 13 (6): 401–7.

Daniel D M. Assessing the limits of knee motion. Am J Sports Med 1991; 19 (2): 139–47.

Edixhoven P, Huiskes R, de Graaf R, van Rens T J, Slooff T J. Accuracy and reproducibility of instrumented knee drawer tests. J Orthop Res 1987; 5 (3): 378–87.

Edixhoven P, Huiskes R, de Graaf R. Anteroposterior drawer measurements in the knee using an instrumented test device. Clin Orthop 1989; 247: 232–42.

Forster I W, Warren-Smith C D, Tew M. Is the KT1000 knee ligament arthrometer reliable?. J Bone Joint Surg (Br) 1989; 71 (5): 843–7.

Fridén T, Ryd L, Lindstrand A. Laxity and graft fixation after reconstruction of the anterior cruciate ligament. A roentgen stereophotogrammetric analysis of 11 patients. Acta Orthop Scand 1992; 63 (1): 80–4.

Graham G P, Johnson S, Dent C M, Fairclough J A. Comparison of clinical tests and the KT1000 in the diagnosis of anterior cruciate ligament rupture. Br J Sports Med 1991; 25 (2): 96–7.

Highgenboten C L, Jackson A, Meske N B. Genucom, KT 1000, and Stryker knee laxity measuring device comparisons. Device reproducibility and interdevice comparison in asymptomatic subjects. Am J Sports Med 1989; 17 (6): 743–6.

Jonsson H, Kärrholm J. Brace effects on the unstable knee in 21 cases. A roentgen stereophotogrammetric comparison of three designs. Acta Orthop Scand 1990; 61 (4): 313–8.

Jonsson H, Elmqvist L G, Kärrholm J, Fugl Meyer A. Graft lengthening after surgery of the anterior cruciate ligament. Roentgen stereophotogrammetry of 32 cases. Acta Orthop Scand 1992; 63: 587–92.

Kärrholm J, Selvik G, Elmqvist L G, Hansson L I, Jonsson H. Three-dimensional instability of the anterior cruciate deficient knee. J Bone Joint Surg (Br) 1988; 70 (5): 777–83.

Malcom L L, Daniel D M, Stone M L, Sachs R. The measurement of anterior knee laxity after ACL reconstructive surgery. Clin Orthop 1985; 196: 35–41.

Markolf K L, Mensch J S, Amstutz H C. Stiffness and laxity of the knee—the contributions of the supporting structures. A quantitative in vitro study. J Bone Joint Surg (Am) 1976; 58 (5): 583–94.

Marshall J L, Warren R F, Wickiewicz T L, Reider B. The anterior cruciate ligament: a technique of repair and reconstruction. Clin Orthop 1979; 143: 97–106.

Roth J H, Kennedy J C, Lockstadt H, McCallum C L, Cunning L A. Polypropylene braid-augmented and nonaugmented intraarticular anterior cruciate ligament reconstruction. Am J Sports Med 1985; 13 (5): 321–36.

Selvik G. Roentgen stereophotogrammetry. A method for the study of the kinematics of the skeletal system. Thesis, University of Lund, Lund, Sweden 1974. Reprint: Acta Orthop Scand Suppl 1989; 232: 1–51.

Shino K, Inoue M, Horibe S, Nakamura H, Ono K. Measurement of anterior instability of the knee. A new apparatus for clinical testing. J Bone Joint Surg (Br) 1987; 69 (4): 608–13.

Steiner M E, Brown C, Zarins B, Brownstein B, Koval P S, Stone P. 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) 1990; 72 (9): 1307–15.

Stäubli H U, Jakob R P. Anterior knee motion analysis. Measurement and simultaneous radiography. Am J Sports Med 1991; 19 (2): 172–7.

Wroble R R, Van Ginkel L A, Grood E S, Noyes F R, Shaffer B L. Repeatability of the KT-1000 arthrometer in a normal population. Am J Sports Med 1990; 18 (4): 396–9.