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.

Roentgen stereophotogrammetric analysis (RSA, Selvik 1974, 1989) has been used to quantify the effects of cruciate ligament rupture (Kårholm et al. 1988), the effect of knee bracing (Jonsson and Karrholm 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, Kårholm 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 (Kårholm 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 (Kårholm 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
Table 1. Knee displacement (mm SD) with KT-1000 and RSA in normal, injured (n 39) and postoperative (n 55) knees

<table>
<thead>
<tr>
<th></th>
<th>KT-1000</th>
<th>RSA</th>
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<tbody>
<tr>
<td>Normal</td>
<td>5.9 2.3</td>
<td>5.5 1.7</td>
</tr>
<tr>
<td>Injured</td>
<td>11 3.8</td>
<td>13 3.9</td>
</tr>
<tr>
<td>Difference injured/intact</td>
<td>4.6 3.8</td>
<td>7.3 3.8</td>
</tr>
<tr>
<td>Postoperative a</td>
<td>7.5 3.2</td>
<td>9.5 3.0</td>
</tr>
<tr>
<td>Difference postop/intact</td>
<td>1.6 2.9</td>
<td>4.0 3.0</td>
</tr>
</tbody>
</table>

aExamed 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 (Kärholm 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 foot-rest 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 (Kärholm 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 (Kärholm et al. 1988, Jonsson and Kärholm 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; Kärholm 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


