External rotation stress imaging in syndesmotic injuries of the ankle

Comparison of lateral radiography and radiostereometry in a cadaveric model

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ABSTRACT We compared the value of 7.5 Nm external rotation stress in diagnosing tibiofibular syndesmotic injuries of the ankle on lateral radiographs with radiostereometric analysis (RSA) in 10 cadaveric legs. After sectioning 2 ligaments, RSA showed an increase in posterior translation and external rotation of the fibula. This increase in posterior translation was smaller than the posterior displacement of the fibula on the lateral radiograph, and RSA showed mainly an increase in external rotation of the fibula that can not be measured on conventional radiographs. We conclude that instability of the syndesmosis in cadaveric ankles can be detected with 7.5 Nm external rotation stress RSA, but that external rotation stress lateral radiography is unreliable.

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If the tibiofibular syndesmosis is completely ruptured after injury of the ankle, diastasis can be seen on anterior-posterior (AP) or mortise (M) radiographs of the ankle. More subtle changes in syndesmotic width, however, are often missed. Many parameters, measured on AP and M views of the ankle, have been described, and are commonly used for making decisions about treatment. However, a recent study has shown that these are unreliable (unpublished data). In a cadaveric study with an external rotation stress of 5.0 Nm applied to the ankle, Xenos et al. (1995) showed that transection of the anterior tibiofibular ligament, the anterior part of the deltoid ligament and the interosseous ligament resulted in only slight widening of the tibiofibular joint, as measured on the M view. Nevertheless they found a positive correlation between diastasis measured directly at the anterior syndesmosis, and posterior displacement of the fibula, as measured on a lateral (LAT) ankle radiograph. Since the displacement of the fibula during external rotation stress is probably a combination of posterior translation and rotation, the radiographic projection of the fibula on the LAT radiograph changes, and reduces the accuracy of the measurements. This might even be worse if the leg rotates due to the external rotation stress applied.

We compared the value of external rotation stress imaging on LAT radiographs with external rotation stress radiostereometric analysis (RSA) for syndesmotic injuries of the ankle in a cadaveric model.

Material and methods

10 fresh-frozen cadaveric lower extremities (mean age 88 (81–102) years) were sectioned through the knee. Macroscopic and radiographic examinations showed that all specimens had intact collateral and syndesmotic ligaments of the ankle

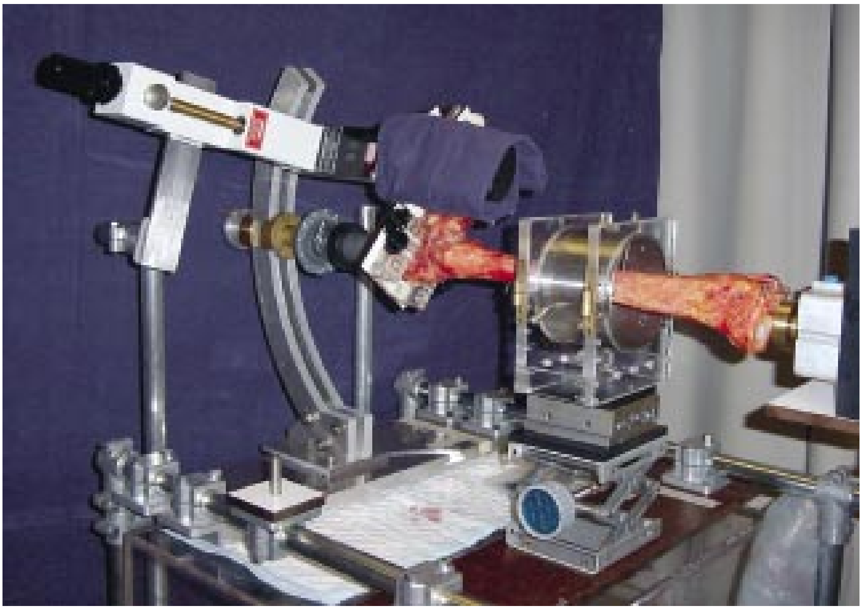

Figure 1. Testing device: the tibia is secured, the foot is attached to a plate, allowing full range of motion, 7.5 Nm external rotation stress is being applied.

with no evidence of preceding trauma, disease or osteoarthrosis.

All soft tissues from the knee to the tarsometatarsal joints, apart from the interosseous membrane and ligaments and capsules of the ankle, were removed. 5 Tantalum markers (0.8 mm) were placed in each distal tibia, fibula and talus. The specimens were placed on a testing device that secured the tibia, while the foot was attached to a plate, permitting full motion of the ankle (Figure 1). The ankle was placed with the intermalleolar line parallel to the floor, and the foot in a neutral, plantigrade position. This was considered the zero starting position.

External rotation stress on the ankle was applied using a Telos device (Austin and Associates, Fallston, MD) with a force of 150 N on the first metatarsal bone, 5 cm distal to the center of rotation of the ankle (Lundberg et al. 1989). This resulted in a moment of 7.5 Nm (Figure 1). Two pairs of RSA radiographs were made, using a uniplanar calibration cage (Tilly Medical, Lund, Sweden): 1 pair in the zero starting position of the foot and ankle, and 1 pair with the external rotation stress applied. After the RSA radiographs were taken, a LAT radiograph was taken while the ankle was kept in exactly the same position. RSA and LAT ankle radiographs were done in the following 4 conditions: 1) intact situation, 2) anterior tibiofibular ligament (ATiFL) or posterior tibiofibular ligament (PTiFL) or anterior part of deltoid ligament (ADL) sectioned, 3) ATiFL and ADL or PTiFL sectioned, 4) ATiFL and PTiFL and ADL sectioned. The order of transection was determined, using a modified Latin-square distribution, in such a manner that the order of subsequent series of transections was a permutation of the previous series (e.g., abc, bca, cab, etc.)

All RSA radiographs were processed and analyzed at Leiden University Medical Center using RSA-CMS software (Medis, Leiden, The Netherlands). The error of calculation with this software is about 0.11 mm and 0.24° (Vrooman et al. 1998). The motion of the fibula relative to the tibia was expressed as 3 translation parameters and 3 rotation parameters of the fibula relative to the tibia. Positive directions for translations along the coordinate axes were lateral-medial, caudal-cranial, and posterior-anterior. Positive directions for rotations about the coordinate axes were plantar flexion, internal rotation, and adduction.

On the LAT radiograph, the distance between the anterior tibial and anterior fibular cortex (ATAF) and the distance between the posterior tibial and

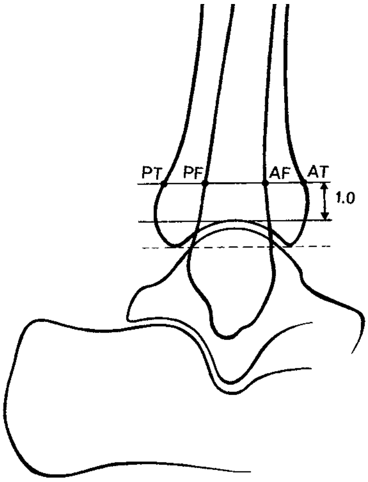

Figure 2. Measurement points on LAT radiograph:
AT = anterior tibial cortex
AF = anterior fibular cortex
PF = posterior fibular cortex
PT = posterior tibial cortex

posterior fibular cortex (PTPF) were measured. All measurements were made on a line 1 cm above and parallel to the tibiotalar joint surface (Figure 2). The measurements were recorded twice to the nearest 0.5 mm by 3 independent observers using a ruler. As the differences in the recordings among the different observers never exceeded 1.0 mm, the mean of all 6 measurements was calculated.

For statistical analysis, Wilcoxon's matched pairs signed rank test and Pearson's correlation test were used with the significance level set at $p < 0.05$.

Results

Intact ligaments

After application of 7.5 Nm external rotation stress in the intact situation, the mean posterior translation of the fibula on the LAT radiograph was 5.4 mm relative to the anterior tibial cortex, and 4.8 mm to the posterior cortex. With RSA, we found a mean medial and posterior displacement of 0.7 mm, and a mean external rotation of 3.6° of the fibula (Table).

Sequentially sectioned ligaments

With RSA, an increase in posterior translation was found after transection of both ATiFL and PTiFL ($p= 0.04$) (Table). Furthermore, a nonsignificant increase in external rotation was detected after transection of ATiFL ($p = 0.07$) and an increase in external rotation after transection of all ligaments ($p = 0.03$), and an increase in rotation around the sagittal axis after both ATiFL and AD ($p= 0.04$) or all ligaments ($p = 0.01$) had been sectioned.

Comparison of LAT radiographs with RSA

Correlations were found between posterior translation of the fibula on the LAT radiograph when measured in relation to the posterior tibial cortex, and lateral translation of the fibula with RSA in the intact situation ($r = 0.677$, $p = 0.05$), and after transection of ATiFL ($r = 0.957$, $p = 0.04$). Posterior displacement of the fibula on the LAT radiograph was not correlated with posterior translation assessed with RSA.

Discussion

The translations of the fibula found with RSA after 2 or more ligaments were sectioned, were too small to be detected by radiography. The same is true of the rotations of the fibula. The increased translations and external rotation of the fibula did not become statistically significant after transection of ATiFL alone, which was probably due to the small number of observations, but also to rotation of the fibula after transection of ATiFL alone. This in itself, without stress applied, is enough to increase external rotation of the fibula (unpublished data). The question arises whether an isolated rupture of ATiFL exists at all, since in our experience MRI in patients with syndesmotic instability nearly always show a thickened and amorphous deltoid ligament reflecting a previous injury. This finding should be investigated further.

Larger displacements of the fibula could have been found if a greater external rotation moment had been applied. We used a pressure load of 150 N for the stress investigations in this study. This is a purely empirical value that is internationally accepted (Scheuba, Guidebook Telos). We tested this force on ourselves, and found that a further increase in pressure was intolerable, while it did not increase the external rotation created in the ankle, as measured with a goniometer. Since our intention was to validate this stress examination

Displacement of the fibula relative to the tibia after sequential sectioning of the syndesmotic and deltoid ligaments, during 7.5 Nm external rotation stress. Figures are mean and range

Sectioned ligaments [c]	LAT [a]		RSA [b]					
	Posterior translation (mm)		Translations (mm)			Rotations (°)		
	Anterior	Posterior	L-M	Ca-Cr	P-A	P	Int	Add
Intact								
mean	5.4	4.5	0.71	0.33	-1.59	0.74	-3.58	1.20
range	3.0–10.7	0.8–7.0	0.22–1.41	-0.43–0.79	-3.35–0.85	-1.98–2.65	-7.38– -1.02	0.21–2.07
ATiFL								
mean	7.1	5.4	0.82	0.14	-2.14	1.60	-6.19	1.34
range	4.0–10.5	3.0–7.2	0.58–1.19	0.09–0.22	-3.14– -1.41	1.07–2.05	-8.18–-2.69	0.55–1.81
AD								
mean	4.3	4.0	0.98	0.57	-2.60	1.28	-2.83	1.44
range	4.0–5.0	3.3–5.0	0.85–1.09	0.48–0.73	-3.34– -1.50	0.59–2.42	-5.67–1.20	0.78–2.11
PTiFL								
mean	5.7	4.6	0.74	0.44	-1.78	1.06	-4.84	1.97
range	2.0–9.0	0.0–7.0	0.66–0.81	0.32–0.56	-1.79– -1.77	1.01–1.11	-6.83– -2.85	1.92–2.03
ATiFL+AD								
mean	6.9	5.2	0.52	0.33	-2.30	1.72	-5.79	1.59
range	4.5–11.5	2.7–7.5	-0.06–0.95	0.14–0.58	-3.02– -1.56	0.74–2.91	-10.4–0.18	0.82–2.51
ATiFL + PTiFL								
mean	5.4	4.6	0.96	0.05	-2.43	1.47	-7.02	1.33
range	3.7–8.0	1.0–7.0	-0.01–1.41	-0.17–0.32	-3.71– -0.92	0.79–2.36	-12.2– -2.85	1.15–1.55
ATiFL + AD + PTiFL								
mean	5.6	4.7	1.01	0.14	-1.86	1.00	-6.36	1.66
range	2.8–11.0	0.7–7.7	0.10–2.15	-0.08–0.36	-6.15–3.45	-4.01–3.76	-15.3– -1.19	0.45–2.40

[a] Posterior translations of the fibula were measured to the anterior and posterior tibial cortex

[b] Translations and rotations with radiostereometric analysis were considered positive in the following directions: lateral-medial (L-M), caudal-cranial (Ca-Cr), posterior-anterior (P-A), plantar flexion (P), internal rotation (Int), adduction (Add)

[c] Sectioned ligaments: anterior tibiofibular (ATiFL), posterior tibiofibular (PTiFL), anterior deltoid (AD)

for eventual use in clinical practice, we felt that an increase in the external rotation moment was not an alternative.

In agreement with our findings, Xenos et al. (1995) found that anatomic diastasis after sectioning of the ligaments of the syndesmosis correlated with posterior translation of the fibula on the LAT radiograph when a 5 Nm external rotation stress was used. The posterior displacements we measured on the LAT radiograph were 2–3 times greater than those found with RSA, and similar to those found by Xenos et al. (1995), despite the fact that they used a smaller moment. This is probably due to rotation, a view which is confirmed by the RSA findings and the fact that the displacements relative to the anterior and posterior sides were unequal.

In the fibula, it was difficult to obtain an appropriate marker distribution because the markers could not be distributed far enough from the fibular central axis because of the small diameter of the fibula. However, we have tried to insert the markers in a similar pattern in all legs. The translations we show are translations of the geometric center of the markers. Because we had similar patterns of markers, the effect of marker scatter on the value of the translations can not have been large. The main influence on the scatter of the translation results was caused by other factors, such as differences in leg geometry.

In this study, fresh-frozen material was used. Freezing has little, if any, effect on the mechanical properties of ligaments (Woo et al. 1986). This is reflected by the fact that the displacements found in this study did not exceed the external rotation and posterior displacement of the fibula reported in healthy volunteers (Beumer 2003).

In conclusion, 7.5 Nm external rotation stress RSA can be used to detect some forms of (combined) syndesmotic instability, at least in this cadaveric model. As the posterior displacement of the fibula with RSA did not correlate with the posterior displacement measured on the LAT radiograph, it is unfortunately not possible to distinguish between healthy and injured ankles using conventional radiography.

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