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ORIGINAL ARTICLE

Anterior knee laxity measurement: Comparison of passive stress radiographs Telos[®] and “Lerat”, and GNRB[®] arthrometer

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KEYWORDS

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Summary

Introduction: In patients with anterior cruciate ligament (ACL) tears, anterior laxity can be measured using stress radiographs or more recently introduced electronic measurement devices.

Hypothesis: The GNRB[®] arthrometer offers a radiation-free method of measuring anterior knee laxity whose diagnostic value is identical to that of Telos[®] or Lerat stress radiographs.

Patients and methods: One hundred and fifty-seven patients (40 years [18–69]) scheduled for knee arthroscopy were evaluated using the GNRB[®] and two series of stress radiographs of both knees, one obtained using a 250-N Telos[®] device and the other using the technique described by Lerat (posterior translation of the femur/tibia under a 9-kg loading device). Arthroscopic evaluation of the ACL served as the reference standard for assessing the diagnostic performance of the radiological and instrumental laxity measurements.

Results: Under arthroscopic examination, the ACL was normal in 50.3%; “healed to roof of the notch” (partial tear) in 9.6%, “posterolateral bundle preserved” (partial tear) in 7.0%, “healed to the posterior cruciate ligament” (PCL) in 17.8%, and “empty notch” (complete tear) in 15.3%. In partial ACL tears, no significant differences in anterior laxity were found across the three measurement techniques. Telos[®] and GNRB[®] laxities were greater in the complete-tear group than in the normal-ACL, partial-tear, and healed-to-PCL groups. With the Lerat technique, the only significant differences were between the complete-tear group and the normal-ACL and partial-tear groups. Telos[®] and GNRB[®] showed similar diagnostic performance (sensitivity > 62%, specificity > 75%), whereas the Lerat technique lacked sensitivity (sensitivity = 43.2%, specificity = 82.7%) at 3mm.

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Discussion: Diagnostic performance was lower in our study than in earlier reports. The GNRB[®] performed as well as Telos[®]. The non-irradiating nature of GNRB[®] assessments allows repeated measurements for therapeutic or diagnostic purposes.

Level of evidence: Level III, prospective case-control study.

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Introduction

The anterior cruciate ligament (ACL) is the main restraint to anterior subluxation of the tibia. Tear of the ACL is necessary and sufficient to increase anterior translation of the tibia [1,2].

Anterior knee laxity measurement is useful to establish the diagnosis of ACL tear (laxity above a cut-off value), evaluate the prognosis (effectiveness of treatment), and select the treatment (as the choice of the surgical procedure varies with the degree of laxity). Anterior laxity evaluation via manual manoeuvres is inaccurate, subjective, and poorly reproducible [3,4]. Until now, stress radiography was the reference standard for measuring anterior knee laxity. However, recently introduced arthrometers provide rapid computerised measurements of knee laxity without exposing the patient to radiation.

Stress radiographs are useful in that they measure the translation of the tibia relative to the femur without interference from the soft tissues [5]. Radiographs during active knee movements are rarely used, as they are painful and have poor diagnostic performance [6]. Passive stress radiographs are usually obtained using the Telos[®] device or, more empirically, the method described by Lerat [7].

The GNRB[®] device has a jack that applies thrust forces of 67 to 250 N to the upper calf [8]. The displacement of the anterior tibial tubercle relative to the femur is measured. The data are handled by a computer, which standardises the protocol (pressure applied to the thigh and thrust force) and analyses the results (ligament elasticity curve, differential laxities).

Here, we hypothesised that the diagnostic performance of the GNRB[®] device was similar to that of passive stress radiography, the advantage being absence of radiation exposure.

Material and methods

This prospective cohort study was conducted at the Rouen University Hospital (76000 Rouen, France) between March 2010 and January 2011 in 157 patients (121 males and 36 females with a mean age of 40.0 years [18–69]). In each patient, two series of passive stress radiographs of both knees were obtained and anterior knee laxity was measured using the GNRB[®] (version 2) device, before arthroscopic treatment. The study was included with the identifier 2009-A01261-56 in the Research and Biological Sampling (*Recherche et Collections Biologiques* [CRB]) registry kept by the French Healthcare Product Safety Agency (*Association française de sécurité sanitaire des produits de santé* [AFSSAPS]). The study protocol was classified as research on

standard care and approved by the appropriate ethics committee (*Comité de protection des personnes Nord-Ouest 1*, identifier CPP-SC 2010-002).

The patients were recruited by knee surgery specialists (XR, JMA, FM, and JB). To be eligible, patients had to be scheduled for knee arthroscopy. Table 1 lists the inclusion and exclusion criteria, which took into account the radiation exposure required by the study investigations and the need to have a normal contralateral knee.

Stress radiographs of both knees were obtained using two different methods (Fig. 1).

One series of passive anterior translation radiographs was obtained using the Telos[®] device (Telos GmbH[®], Laubscher, Holstein, Switzerland) with a load of up to 250 N.

The other series was obtained using the simple and inexpensive method described by Lerat et al. [7]: with the knee relaxed in 20° of flexion, a load of 9 kg was applied to the distal thigh to induce posterior translation of the femur relative to the tibia.

All radiographic variables were measured by the same investigator (JB) using tracing paper and a graduated ruler having a precision of 0.5 mm. Anterior translation of the medial compartment (ATMC) was measured for each knee relative to the line tangent to the medial plateau, using the bony landmarks described by Jacobsen [9,10] (Fig. 2). Differential values were computed as the absolute difference in laxity between the two knees. The quality of each stress radiograph was assessed using a 5-point scale (Fig. 3) [6].

In addition, anterior laxity of both knees was measured using the GNRB[®] (version 2) device with gradually increasing loads from 67 N to 250 N, on the day before surgery, by one of four operators trained in the use of the device (S.B., J.B., S.M., J.M.A.). The normal knee was assessed first. Differential values were determined by the device software.

The arthroscopic surgical procedure was the last step in the study protocol. Regardless of the type of treatment

Table 1 Inclusion and exclusion criteria used to select the study patients.

Inclusion criteria	Unilateral knee symptoms indicating a need for arthroscopic knee surgery Apparently normal contralateral knee
Exclusion criteria	History of injury of surgery in the contralateral knee Pregnant woman or woman not using birth control Patient unwilling to participate in the study Coronal laxity in extension



Figure 1 a: passive stress radiograph according to Lerat, with a 9-kg load; b: Telos® device; c: GNRB®, computerised laxity assessment system that measures sagittal translation of the tibia at 20° of knee flexion.

(e.g., procedure on the meniscus or on the ligament or synovial membrane biopsy), the ACL was inspected and palpated using a hook. Based on the results, the ACL was classified according to the five stages described by Panisset et al. [11]: “normal ACL”, “healed to the roof of the notch” (anteromedial bundle preserved), “posterolateral bundle preserved”, “healed to the posterior cruciate ligament” (PCL), and complete tear “empty notch”. The arthroscopic appearance of the ACL was the reference standard for the evaluation of diagnostic performance of laxity measurements using stress radiographs and the GNRB®.

Statistical tests were performed by an independent statistician, who used NCSS software (Kaysville, UT, USA). Qualitative variables were compared using Fisher’s test and quantitative variables using the Kruskal-Wallis test (with Bonferroni’s correction) and the Mann-Whitney test. Receiver-Operating Characteristic (ROC) curves were plotted to evaluate the sensitivity (Se) and specificity (Sp) of each radiographic measurement (Telos® and Lerat) and of the GNRB® measurement using various cut-off values. Differences yielding *P*-values of less than 0.05 were considered significant.

Results

Of the 157 patients included in the study, 79 (50.3%) had arthroscopically normal ACLs. ACL lesions in the remaining patients consisted of “healing to the roof of the notch” in 15 (9.6%) patients, “posterolateral bundle preservation” in 11 (7.0%) patients, “healing to the PCL” in 28 (17.8%) patients, and “empty notch” in 24 (15.3%) patients.

Telo® stress radiographs were obtained in all patients. Eight patients were unable to undergo stress radiography as described by Lerat. Radiograph quality was excellent: mean scores were 9.61/10 (8–10) for the Telos® radiographs and 9.59/10 (7–10) for the Lerat radiographs (NS). GNRB® measurements were performed in all patients, although pain precluded the use of the highest thrust force (250 N) in 24 patients.

Table 2 reports the differential laxity values obtained by stress radiography. With neither of the two stress radiography techniques was there a significant difference between the two groups of partial tears (“healed to the roof of the notch” and “posterolateral bundle preserved”). Telos® measurements indicated significantly greater laxity in the

complete-tear group than in the other groups (normal-ACL, partial-tear, or healed-to-PCL groups). No significant differences in laxity were found on the Telos® radiographs between the normal-ACL, partial-tear, and healed-to-PCL groups. With the Lerat radiographs, the only significant differences were between the complete-tear group and the normal-ACL and partial-tear groups. Again, no significant differences in laxity were noted between the normal-ACL, partial-tear, and healed-to-PCL groups.

The data obtained using the GNRB® device are reported in Table 3. No significant difference was found between the two groups of partial tears. Regardless of the thrust force applied (89 to 200 N), laxity was significantly greater in the complete-tear group than in the normal-ACL, partial-tear, and healed-to-PCL groups. No significant differences were found between the normal-ACL, partial-tear, and healed-to-PCL groups.

The ROC curves were used to assess Se and Sp of each radiographic test and of the clinical test (GNRB®) depending on the cut-off value used. Cut-offs were defined for the normal ACL group versus the healed-to-PCL and complete-tear groups in order to assess the diagnostic performance of each test. The partial-tear groups were excluded from this analysis, as neither the stress radiographs nor the GNRB® measurements showed significant differences between partial tears and the normal-ACL group. The ROC curves for the two stress radiograph methods (Table 4) showed significant deviations from the diagonal, indicating that both methods were useful as diagnostic tools. Using a cut-off value of 3 mm, Telos® radiographs were 64.8% sensitive and 75.8% specific and Lerat radiographs were 43.2% sensitive and 82.7% specific. With the GNRB® device, diagnostic usefulness was documented with all the thrust forces used (89 to 250 N). With a cut-off of 1.5 mm and a thrust force of 250 N, Se was 62.2% and Sp 75.9% (Table 5).

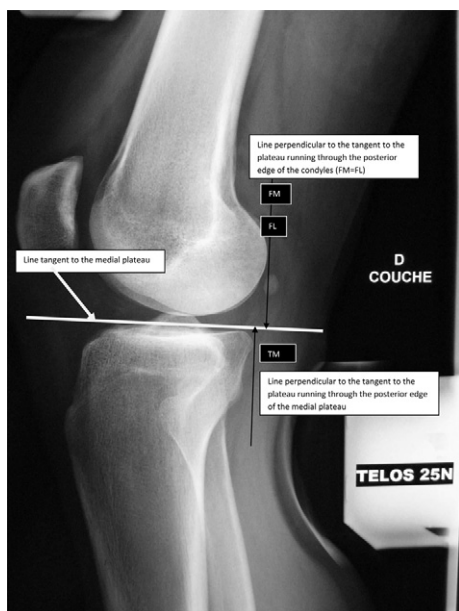


Figure 2 Method for measuring anterior translation. The distance between the lines perpendicular to the medial condyle and medial plateau (FM-TM) is equal to the anterior translation of the medial compartment (ATMC).



Figure 3 Quality score for the Telos® and Lerat radiographs.

	Good quality criteria	Number of points per criterion
Telos® or Lerat stress radiographs	Strict lateral x-ray (posterior intercondylar distance < 5 mm)	1
	Knee flexion between 10° and 30°.	1
	Incident beam at the height of the joint space linking the two tibial plateaux.	1
	X-ray radiographically clear	1
	Appropriate position of the piston (behind the proximal epiphysis of the tibia), weight (proximal to the patella), and leg cradle	1
	Total of 5 points	

Table 2 Side to side laxity values (in mm) on stress radiographs by arthroscopy category.

ACL arthroscopy category	Number of patients	Dif Telos ^a	Number of patients	Dif Lerat ^a
Normal	79	2.15 ± 1.97	75	1.92 ± 1.33
Healed to the roof of the notch	15	1.87 ± 1.6	14	1.98 ± 1.59
Posterolateral preserved	11	1.32 ± 1.59	10	1.31 ± 1.03
Healed to PCL	28	4.18 ± 3.7	26	2.58 ± 1.98
Complete tear	24	7.58 ± 5.61	24	3.85 ± 2.24
Total	157		149	

No statistically significant difference between the two partial-tear groups on the Telos[®] or Lerat radiographs.

Telos[®]: significantly greater laxity in the complete tear group than in the normal, partial-tear, or healed-to-PCL groups.

Lerat: significantly greater laxity in the complete-tear group only versus the normal and partial-tear groups.

ACL: anterior cruciate ligament; PCL: posterior cruciate ligament.

^a Mean ± SD.

Table 3 Side to side laxity values (in mm) obtained using the GNRB[®] system, by arthroscopy category.

ACL arthroscopy category	Effectifs	GNRB [®] , 89 N	Effectifs	GNRB [®] , 134 N	Effectifs	GNRB [®] , 150 N	Effectifs	GNRB [®] , 250 N
Normal	79	0.65 ± 0.66	79	0.8 ± 0.82	78	0.84 ± 0.87	71	0.93 ± 0.91
Healed to the roof of the notch ^a	15	0.61 ± 0.42	15	0.71 ± 0.52	15	0.74 ± 0.52	14	1.08 ± 0.67
Posterolateral preserved ^a	11	0.68 ± 0.45	11	0.76 ± 0.52	11	0.84 ± 0.54	10	1.03 ± 0.76
Healed to PCL	28	0.93 ± 0.7	28	1.13 ± 0.83	27	1.24 ± 0.86	20	1.45 ± 1.15
Complete tear	24	2.51 ± 1.3	24	3.4 ± 1.63	22	3.74 ± 1.72	18	4.23 ± 2.18
	157		157		153		133	

Significantly greater laxity in the complete-tear group than in the normal, partial-tear, and healed-to-PCL groups, regardless of thrust force (89 to 200 N).

^a No difference between the two partial tear groups.

Table 4 Example of sensitivity (Se) and specificity (Sp) (in %) of Telos[®] and Lerat stress radiographs for several side to side laxity cut-off values.

Cut-off (mm)	Telos ^{®a}		Lerat ^b	
	Se	Sp	Se	Sp
3	64.8	75.8	43.2	82.7
3.5	56.7	79.3	33.7	89.6
4	54	86.2	32.4	94.8

Values defined for the normal anterior cruciate ligament (ACL) group versus healed to posterior cruciate ligament (PCL) and complete tear (exclusion of partial tears), to evaluate the diagnostic value of each test.

^a n = 131.

^b n = 125.

Discussion

Our study compared anterior knee laxity measurements obtained using radiographic and instrumental techniques in the same cohort of knees investigated using arthroscopy.

We used passive stress radiographs, whose diagnostic characteristics and ease of performance are better than those of active stress radiographs [6]. We chose the widely

used Telos[®] device [12–15], whose thrust force of up to 250 N increases both diagnostic performance and reproducibility [12,16,17]. Concomitantly, we obtained stress radiographs using the technique described by Lerat et al. [7], which is easy to implement and inexpensive. Neither method was associated with pain or technical problems precluding image acquisition, in contrast to our experience with active stress radiographs [6]. Image quality was excellent, as required for reliable manual measurement of translations. We chose to measure translation relative to the medial plateau [12,18,19] and posterior cortex [7,14,20]. This method minimises measurement errors at the lateral compartment (receding edge with minimal corticalisation and with superimposition over the medial structures) [9,19], thus improving the reliability of the results [6,20–22].

Laxity measurements with the GNRB[®] are less dependent on operator experience or patient position than with the KT-1000 arthrometer [8,23]. In addition, the computerized nature of the GNRB[®] device ensures standardisation of the measurement parameters (angle and pressure) and eliminates the need for human intervention in measuring the differential values (tracing mistakes).

The reference standard for assessing the ACL in our study was arthroscopy [7,24]. However, even the five-stage classification scheme developed by Panisset et al. [11] cannot take into account the many possible arthroscopic findings of

Table 5 Example of sensitivity (Se) and specificity (Sp) (in %) of the GNRB® measurements for two side to side laxity cut-off values.

Cut-off (mm)	GNRB 89 N ^a		GNRB 134 N ^a		GNRB 150 N ^b		GNRB 250 N ^c	
	Se	Sp	Se	Sp	Se	Sp	Se	Sp
1	62.1	89.6	64.8	75.8	64.8	75.8	67.6	58.6
1.5	48.6	93.1	59.4	93.1	59.4	91.4	62.2	75.9

Values defined for the normal anterior cruciate ligament (ACL) group versus healed to posterior cruciate ligament (PCL) and complete tear (exclusion of partial tears), to evaluate the diagnostic value of the GNRB®.

^a $n = 131$.

^b $n = 127$.

^c $n = 109$.

the ACL and identification errors may have occurred, despite the considerable experience of the operators. Thus, in three patients the ACL seemed normal by arthroscopy but the GNRB® measurement indicated greater than 3 mm of laxity, strongly suggesting a tear.

This study confirms the diagnostic usefulness of Telos® and Lerat stress radiographs. However, the low Se (<40%, with high Sp) of the Lerat stress radiographs decreases the diagnostic relevance of this method and suggests that therapeutic or prognostic uses may be more appropriate. Thus, our findings support those reported by Lerat by indicating a contribution to the diagnosis [25] but indicate lower Se and Sp values than those obtained in earlier studies [7,22], which classified ACLs into only two groups, normal or abnormal.

With Telos® stress radiographs, Se was only slightly greater than 60% and Sp was greater than 80%, in keeping with previous findings by our group [6]. In other studies, diagnostic performance was better but the arthroscopic ACL classification was not as detailed. The higher values reported by Bercovy and Weber [16] are ascribable to the presence of potential laxity in more than one-third of the patients (chronic instability, anterolateral reconstruction, or knee osteoarthritis before arthroplasty or osteotomy). Se in our study was similar to that obtained by Garces et al. [24] (using a lower thrust force of 137 N) with the same 3-mm cut-off value, but their 100% Sp far exceeded ours.

The GNRB® showed useful diagnostic performance, with a number of differences compared to those reported by the designers. Thus, Se in our study was similar to that reported by Robert et al. [8] (with a 1.5-mm cut-off compared to 3 mm in the evaluation by Robert et al.) but Sp was lower by more than 10%. Furthermore, Robert et al. [8] reported that the GNRB® contributed to the diagnosis of partial tears, whereas no such contribution was found in our study in a population that was four times larger.

In patients with partial ACL tears, none of the three methods demonstrated a significant difference in laxity between the two groups of partial tears (healing to the notch and preserved posterolateral bundle, which were therefore collapsed into a single group for our statistical analysis. This absence of a significant difference may be ascribable to the small number of patients in these two groups with closely similar ACL lesions, as well as to the evaluation confined to anterior translation, since both bundles are also involved in resistance to rotational movements [26].

The ability of laxity measurements to discriminate among the various arthroscopy classes was limited, and

arthroscopic findings did not consistently match laxity measurement results in our study. With Telos® and GNRB®, laxity was significantly greater in the complete tear group than in the other three groups (normal-ACL, healed-to-PCL, and partial-tear groups). Discrimination was more limited with the Lerat method. None of the three methods showed differences between the normal-ACL, partial-tear, and healed-to-PCL groups. This finding is probably ascribable to the continuity in lesion development across these three groups: the only difference is the number of fibres with sufficient mechanical strength to resist anterior tibial translation or the quality of damaged fibre healing. Thus, in terms of mechanics and laxity, the best concept may be that of a continuum from a normal ACL to a partial tear and to healing to the PCL.

Conclusion

Passive stress radiography using the Telos® device or Lerat method is widely used and easy to perform. Although these stress radiographs assist in the diagnosis of ACL lesion type, their diagnostic performance is limited (with a 3-mm cut-off, Se 64.8% and Sp 75.8% with Telos®, and Se 43.2% and Sp 82.7% with the Lerat method). Using a 1.5-mm cut-off and a thrust force of 250 N, the GNRB® exhibited similar performance characteristics (Se 62.2% and Sp 75.9%) but was simpler to use. This method does not expose the patient to radiation and can therefore be performed repeatedly for diagnostic and monitoring purposes. We believe that the only remaining indication for stress radiographs is obesity, as a large thickness of the soft tissues under the translation sensor may result in underestimation of anterior translation.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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