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THE NATURAL HISTORY OF THE ANTERIOR KNEE INSTABILITY BY STRESS RADIOGRAPHY

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ABSTRACT

Objective: To analyze the anteroposterior displacement of the knee by means of stress radiography in individuals with unilateral anterior knee instability and relate to time of instability. Methods: Sixty individuals with intact knees (control group) and 125 patients with unilateral anterior instability (AI group) agreed to participate in the study. Gender, age, weight, height, age at injury, time between injury and testing, and surgical findings are studied. Both groups are submitted to anterior and posterior stress radiographies of both knees. Anterior (ADD) and posterior displacement difference (PDD) were calculated between sides. Results: In the control group ADD and PDD are in average, zero, whereas in the AI group ADD averaged 9.8mm and PDD, 1.92mm. Gender, age, weight, height, age at trauma and presence of menisci's lesions do not intervene in the values of ADD and PDD. Meniscal injuries increase with time. ADD and PDD do not relate with the presence or absence of associated menisci's lesions. The ADD and the PDD are related to each other and increase with time. Conclusion: There is a permanent anterior subluxation of the injured knee that is related to the amount of anterior displacement that increases with time. ***Level of Evidence III, Study Types Case-control study.***

Keywords: Knee injuries/radiography. Knee joint. Joint instability. Menisci, tibial.

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INTRODUCTION

The anterior knee instability is the result of the anterior cruciate ligament (ACL) rupture, whose primary function is to limit the anterior translation of the tibia in relation to the femur.[1] The ACL injury is relatively frequent in sports practice and the instability caused by its lesion precludes the sports practice in the same skill level.[2]

Scientifically, it is an advantage to be able to measure the joint's instability in physical units.[3,4] The result of a given treatment can be quantified by the mensuration of the stability before and after this treatment.[4]

The radiological demonstration of the sagittal instability was described in 1944 by Böhler.[5] The actual measurement of the sagittal knee instability by means of radiographies before and after submitting the joint to known standardized traction, in different directions was only demonstrated in 1971 by Kennedy and Fowler.[6]

The stress radiography is the simplest and most reliable method for the evaluation of the knee laxity, specially at 20° of knee flexion.[3,4,7-11] It indicates which ligaments are injured.[4,12]

Several stress radiographic methods for sagittal knee instability have been described in the literature: passive, active, at full extension, at 20° and 90° of knee flexion.[3-10,13]

The purposes of this study are: to use a standardized passive sagittal stressradiographic method of the knee, for comparing the behavior of a population without affections of both knees, with unilateral ACL deficient patients, and determine if there are variables, such as body composition, age, meniscal injuries and time between trauma and stress radiography, that intervene in the magnitude of the anterior and posterior displacement of the tibia in intact and ACL-deficient knees.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of Hospital das Clínicas, Universidade de São Paulo number 224/93. All participants signed informed consent forms.

Thirty men and 30 women (120 knees) without history of any affection to the lower limbs such as strains, fractures, surgeries, knee angular deformities; inequality of lower limbs, neurological affections; collagen diseases or pregnancy composed the control group.

The mean age was 28.2 years old (16 to 44). The average weight

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was 62kg (42 to 92) and height of 1.66 meters (1.40 to 1.98). This group matched the anterior instability group (AI group) in age (Student T test p=0.33).
The AI group was composed of 125 individuals with unilateral anterior knee instability. All patients had a history of ACL injury, followed by symptoms and physical examinations of anterior knee instability for a period no lesser than 4 months.
Twelve women and 113 men fulfilled all the items described above. The mean age was 29.5 years old (16 to 65). The average weight was 72.2kg (51 to 110). The average height was 1.73m (1.50 to 2.05) and time between injury and stressradiography of these patients varied from 0.3 years to 32 years (average 3.94). Weight and height matched the male population of the control group.
Of the 125 patients, 79 were submitted to surgical treatment of the ACL and associated lesions. Thirty-five had isolated ACL rupture (subgroup ACL), and 44 had associated medial and/or lateral meniscus injury (subgroup ACLMM). The patients not submitted to surgical treatment were classified as subgroup not operated (N-OPER).
Weight and height of the control group (62.2 kg and 1.66m) was significantly less than the AI group (72.2kg and 1.73m) and its subgroups ACL (71.1kg and 1.73m), ACLMM (72.43kg and 1.73m) and N-OPER (72.9kg and 1.73m) (Kruskal-Wallis, p=0).
Time between injury and stressradiographic examination varied from 0.3 in all subgroups to 10 years in the ACL group (average 2.11); to 32 years in the ACLMM (average 5.72) and 23 years in the N-OPER group (average 3.56), p=0.23, Kruskal-Wallis.
The N-OPER group was older (27.5years) at trauma then the patients from the subgroups ACL (24.5years) (Dunn p=0.05) and ACLMM (24.33) (Dunn p=0.03).

Stressradiography

All the subjects from the control group and all the patients from the AI group were submitted to lateral stressradiographs of both knees at 20° of flexion. The applied force was 10% of body weight in the anterior and posterior direction.[9] These radiographic examinations were called stressradiographies or radiographic Lachman.
The anterior stress examination is made with the device placed under the proximal leg. The lock is positioned over the ankle. The load is applied over the patient's distal thigh, 5 cm above the superior pole of the patella. (Figure 1A)
The posterior stress examination is made with the body of the apparatus placed under the distal thigh. The heel rests over a rigid support. The load applied in the anterior stress is now applied over the proximal tibia, stressing it posterior. (Figure 1B)

Measurement

Initially, the posterior tibial cortex (PTC) and the posterior contour of each femoral and tibial condyle are identified. Next, the template is placed over the radiography with the referral longitudinal line over the PTC.
The distance between the parallel lines of the template that tangents the posterior limits of lateral femoral and tibial condyles are the measurement of the displacement of the lateral compartment. The distance between the two parallel lines that tangents the posterior contour of the medial femoral and tibial condyles is the measurement of the displacement of the medial compartment. The arithmetic average of these two displacements yields the displacement of this knee (maximum anterior (AD) or posterior displacement (PD)). (Figures 1C-F)
The measurement is positive if the tibial condyle is anterior to the respective femoral condyle and negative if the tibial condyle is posterior to the correspondent femoral condyle.
Once the measurements of AD and of PD are obtained for each knee of a given subject, the difference of displacement between sides under anterior (ADD) and posterior (PDD) stress must be calculated: right (R) - left (L) difference in the control group, and injured (I) - uninjured (U) difference in the AI group.
The measurement of the ADD, will be referred to as the anterior translation, and positive value of PDD, will be referred to as anterior subluxation.[12]

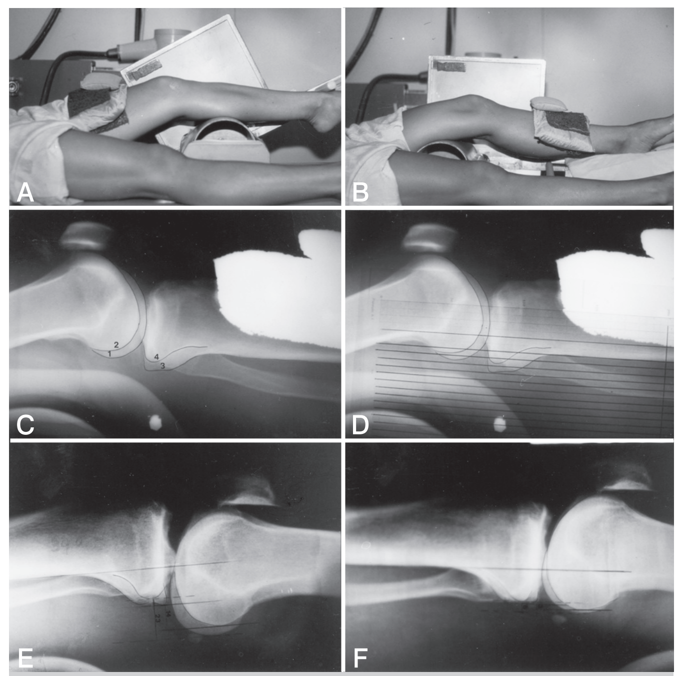

Figure 1. A) Anterior stress positioning (Anterior Radiographic Lachman Test); B) Posterior stress positioning (Posterior Radiographic Lachman Test); C) Stressradiography (posterior radiographic Lachman). Identification of the posterior contours of the femoral and tibial condyles. 1- medial femoral condyle; 2- lateral femoral condyle; 3- medial tibial condyle; 4- lateral tibial condyle; D) Stressradiography (posterior radiographic Lachman). Identification of the posterior contours of the femoral and tibial condyles and of the posterior tibial cortex (PTC). Transposition of the template for measuring the displacements of each compartment; E) Anterior radiographic Lachman of an anterior unstable knee; F) Positive posterior radiographic Lachman.

Statistical Analysis

Descriptive statistics were made for all ordinal sample values. Tests used: Student t for comparison of parametric samples; Mann-Whitney U for the non-parametric samples; For related (paired) samples, the Wilcoxon; Kruskal-Wallis to compare more than two non-parametric samples, with discrimination by the comparison of means test modified by Dunn; The Pearson correlation and the linear regression test were applied in ordinal samples.
Significance level of 5% ($\alpha = 0.05$) was adopted.

RESULTS

The results of the difference of displacement between sides for the stress examinations in the anterior and posterior directions (ADD and PDD) of the 60 control subjects are shown in Table 1. There is no gender difference and ADD and PDD were all close to zero. Age (years), weight (kg) and height (m) of control subjects did not correlate (Pearson's correlation test) with ADD and PDD values.

The results of the ADD and PDD of the 125 patients with anterior knee instability gender wise are analyzed in Table 2 showing no difference between sexes. In the Figure 2, the ADD histogram of the control and AI groups are shown. The ADD of the control and AI group with the respective values of the ACL, ACLMM and N-OPER groups are shown on Table 3. Figure 3 and Table 4 show the histogram and values of PDD in the control and AI group and subgroups.

We tested the correlation between ADD and/or PDD and age (years old), weight (kg), height (m), age at trauma, in years, and time between injury and stress radiography (TIME), We found a significant correlation between ADD and time between injury and stress radiography (Pearson's correlation coefficient of 0.2164, p=0.01). The equation would be: ADD = 9.3 + 0.22.(TIME). PDD significantly correlated with ADD (Pearson's correlation coefficient of 0.2109, p=0.021. PDD = 0.4 + 0.2.(ADD). Table 5 shows the average values of ADD and PDD with the years between injury and stress radiography. One can see the increasing values of PDD through the years, despite lack of statistical significance.

Table 1. Descriptive statistics of the anterior (ADD) and posterior (PDD) displacement difference between right and left sides, in millimeters, of the control group, according to sex. Mann-Whitney U test (α = 0.05).

	ADD		PDD	
	Male	Female	Male	Female
Mean	0.18	0.17	-0.50	-0.22
Standard deviation	1.51	1.18	1.61	1.65
Standard error of mean	0.27	0.22	0.29	0.21
Minimum	-2.5	-2.5	-3.0	-3.0
Maximum	+2.5	+3.0	+3.0	3.0
Number	30	30	30	60
Mann-Whitney U test	U= 449	p= 0.99	U= 346	p= 0.12

Table 2. Descriptive statistic of the anterior (ADD) and posterior (PDD) displacement difference, in millimeters, between the injured and uninjured sides of the patients from the AI group, genderwise. Mann-Whitney U test (α = 0.05).

	ADD		PDD	
	Male	Female	Male	Female
Mean	9.80	10.17	1.87	2.33
Standard deviation	3.89	3.77	2.98	3.21
Standard error of mean	0.37	1.09	0.28	0.93
Minimum	3.0	4.5	-3.5	-2.5
Maximum	22.5	16.5	11.0	7.0
Number	113	12	113	12
Mann-Whitney U test	U= 642	p= 0.76	U= 630	p= 0.69

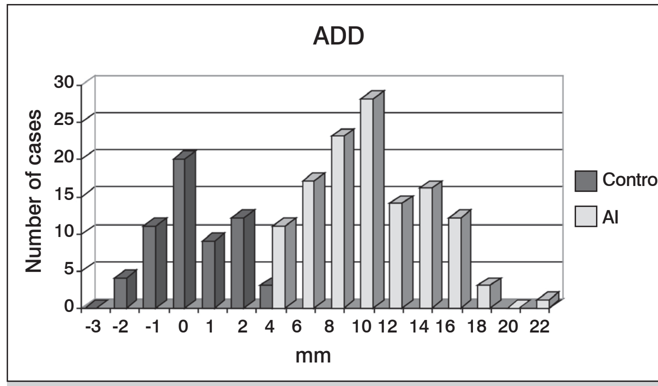

Figure 2. Histogram of the anterior displacement difference (ADD), in millimeters (mm), of the control subjects (CONTROL) and of the patients with anterior knee instability (AI).

Table 3. Descriptive statistic of the anterior displacement difference between sides (ADD), in millimeters, of the Control and AI groups and of the subgroups ACL, ACLMM and N-OPER. Kruskal-Wallis comparison test and discrimination by the C.M test modified by Dunn (α = 0.05).

	ADD (mm)				
	Control	AI	ACL	ACLMM	N-OPER
Mean	0.17	9.83	9.66	10.01	9.79
Standard deviation	1.35	3.86	3.23	4.11	4.13
Standard error of mean	0.17	0.35	0.55	0.62	0.61
Minimum	-2.5	3.0	3.5	3.0	3.0
Maximum	3.0	23.5	17.5	23.5	18.5
Number	60	125	35	44	46

Kruskal-Wallis: H=144.6756; p ~ 0*. Dunn: Control < AI, Control < ACL, Control < ACLMM, Control < N-OPER.

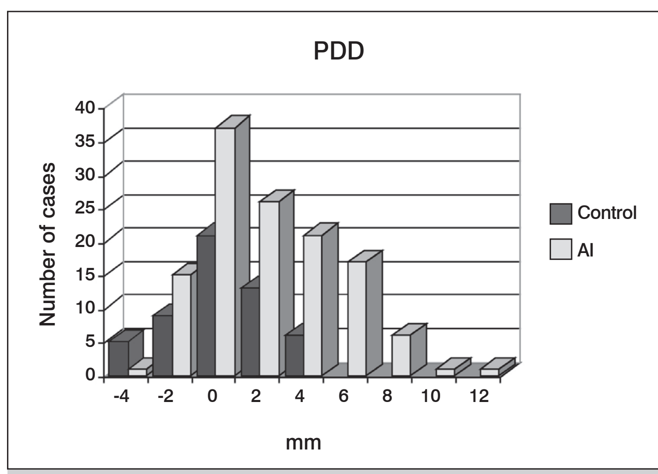

Figure 3. Histogram of the posterior displacement difference (PDD), in millimeters, of the control subjects (CONTROL) and of the patients with anterior knee instability (AI).

DISCUSSION

In our casuistic, the younger the patients that sustained ACL injuries, the more likely they were to be submitted to operative treatment, and the longer period of time between injury and treatment, more likely they were to present associated menisci injuries.[14,15]

Table 4. Descriptive statistic of the difference of posterior displacement between sides (PDD), in millimeters, of the Control and AI groups and of the subgroups ACL, ACLMM and N-OPER. Kruskal-Wallis comparison test and discrimination by the Comparison of Means test modified by Dunn ($\alpha = 0.05$).

	PDD (mm)				
	Control	AI	ACL	ACLMM	N-OPER
Mean	-0.22	1.92	2.81	2.11	1.04
Standard deviation	1.65	2.99	3.04	2.59	3.13
Standard error of mean	0.21	0.27	0.51	0.39	0.46
Minimum	-3.0	-3.5	-3.0	-3.5	-3.0
Maximum	3.0	11.0	11.0	7.0	8.5
Number	60	125	35	44	46

Kruskal-Wallis: H=38.34; p ~ 0*. Dunn: Control < AI, Control < ACL, Control < ACLMM, Control < N-OPER. N-OPER < ACL. P= 0.02*. N-OPER < ACLMM. P= 0.04*.

Table 5. Mean values of the anterior (ADD) and posterior (PDD) displacement difference (injured-uninjured difference), in millimeters, in relation to time between injury and stressradiography (TIME), in years. Less than a year, between 1.1 and 2 years; between 2.1 and 3 years, between 3.1 and 4 years; and between 4.1 and 5 years.

Time	ADD	PDD
(Year)	(mm)	(mm)
< 1	9.47	1.57
1.1 - 2.0	10.65	1.83
2.1 - 3.0	9.17	2.12
3.1 - 4.0	10.67	2.78
4.1 - 5.0	10.28	2.6

The stress radiography is a reliable method for the evaluation of the knee laxity.[3,4,7-11,16] Both the magnitude and site of force application intervene in the absolute displacement.[17] The sagittal displacement of the tibia increases with the applied force at a diminishing rate. Above 141 N practically no further increase of displacement occurs.[18] The applied load can be constant[4,7] to all individuals. We used 10% of the body weight of the patient. High loads can become uncomfortable, evoking muscle contraction of the thigh for protection of the knee.[9,17,18]

The paired right-left difference in the control subjects followed a Gaussian probability distribution[19] in average, null. (Table 1) The maximum anterior (ADD) and posterior (PDD) displacement difference between sides of control subjects was 3 mm.[10,17] Gender,[1,8,11] age, weight and height had no effect in right-left displacement differences.

The normal distribution of the anterior laxity in the AI group is shifted to the right (Figure 2, Table 2 and 3).[3,4,7,10,13,19] Gender, weight, height, age of the patient at trauma or at exam, and associated menisci injuries did not affect the results of ADD (Table 2) as described in the literature.[11] AI group and subgroups have similar ADD all significantly different from the control group ($p \cong 0$).

ADD increases with time between injury and exam ($p = 0.02$), i.e., the anterior instability increases with time. The increase in anterior laxity with time has been described[10,13] as an increased structural damage to the ACL[3] and as an overload process on the secondary restraints that finally loosens.[1]

In the progression of the anterior instability ostearthritic phenomena happens, such as narrowing of the intercondylar notch, flattening of the femoral condyles, osteophyte formation, narrowing of the joint-space, subchondral sclerosis and cyst formation.[14] We believe there is also an anterior subluxation of the joint and that it precedes all other radiographic changes[20] and it is not due to measurement technique errors.[21] This displacement of the knee axis in the direction of the instability as described by Kärrholm *et al*.,[22] has been seen in orthostatic and unloaded radiographs[8] and after ACL reconstructive surgery.[16] Greater posterior displacement of ACL deficient knees submitted to posterior stress radiography,[11] and no difference under posterior stress have been described[4,7] and may be explained because of greater load, less time of instability, or associated lesions.

Nearly 1/3 of the AI group presented PDD more than 3 mm, i.e., an anterior subluxation when submitted to posterior stress. The injured knee positioned, in average, 1.9 mm anteriorly subluxated than the uninjured side. PDD control group was, in average, -0.22 mm, ($p = 0$). Null PDD was the most frequent finding in all subjects; however, the AI group shows values up to 11 mm. (Figure 3 and Table 4)

AI group and 3 subgroups presented anterior subluxation of the injured knee, all differing from the control group ($p \cong 0$). (Table 4) Gender, age of the patients at injury or at stress radiography, weight, height and meniscal injuries had no influence on this anterior subluxation. But patients that chose not to be submitted to ACL reconstructive surgery had less anterior subluxation ($p = 0.04$).

There is a clear increase of the PDD in the first four years of anterior instability, (Table 5) but no actual correlation with time of instability. There is direct relation, between the anterior subluxation (PDD) and the anterior translation (ADD). The ADD increases with time, and PDD increases with the ADD increase. From the anatomical point of view, either these patients had capsule and/or other ligament injuries acutely with the ACL injury, or they had a loosening of the secondary restraints leading to the anterior shift of the anatomic zero position of the injured knee. Posterior instability patients have posterior subluxation[1,3,23] and, in our understanding, some of the patients with anterior instability, have anterior subluxation.

The lack of unloaded X-Rays to evaluate passive anterior shift of the knee axis is a limitation of the study. Magnetic resonance imaging confrontation would have been interesting.

CONCLUSIONS

The standardizing proposed is adequate to evaluate the sagittal displacement of the knee, without difference between sides in control subjects. ADD and PDD are not influenced by sex, age, weight, height, age at trauma or menisci lesions. The anterior instability increases with time. There is an anterior subluxation in patients with anterior instability. Patients that choose to treat conservatively, usually have less anterior subluxation. These two subluxated positions are directly related to each other.

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