Lesiones ligamentosas de la rodilla

Las lesiones de los ligamentos de la rodilla, y en concreto las del ligamento cruzado anterior, son algunas de las más habituales en traumatología deportiva. En la última década se han producido avances en la reconstrucción de los diferentes ligamentos de la rodilla, en el conocimiento de la biología y de la biomecánica de la incorporación de los injertos, en nuevos materiales y dispositivos para su fijación, y en nuevas pautas de rehabilitación. A pesar de ello, todavía no hay consenso sobre cómo prevenir estas lesiones, cuál es la mejor técnica para tratar o reconstruir los ligamentos, qué injerto es mejor, el dispositivo de fijación más fiable, cómo estimular la biología, qué pauta de rehabilitación es más efectiva y adecuada, o de qué modo analizar de forma objetiva los resultados. Además, es difícil comparar los resultados obtenidos en los estudios debido al gran número de variables que pueden influir en ellos, y que son tremendamente difíciles de homogeneizar.

En este libro se revisa el estado actual del conocimiento, haciendo hincapié en los temas más controvertidos sobre los cuales no hay consenso, ante los que cada autor establece su opción.

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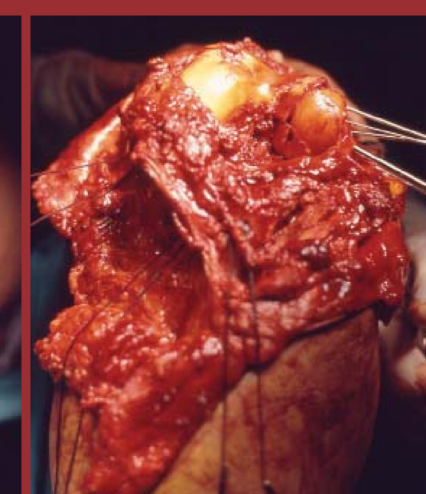

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Chapter 12

New tools for diagnosis, assessment of surgical outcome and follow-up

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Synopsis

Objective evaluation of antero-posterior and rotatory laxity of the knee is a critical issue in anterior cruciate ligament (ACL) research. This is essential to allow surgeons to rigorously evaluate the outcome of the different available techniques. Furthermore it will make it possible to carry out advance predic-

tions of which patients can benefit from a particular approach, i.e. partial reconstructions, single- or double-bundle techniques. The ideal method should be able to assess anatomic and functional features of the ACL-deficient knee, besides being accurate, reproducible and cost-effective. This is an overview of the most recent achievements and the scientific-technical considerations in this particular area of research. This chapter presents the advantages and limitations of robotic systems and manual instrumented devices compared to manual tests that are commonly used in the clinical setting. It also highlights the Porto-knee testing device as a new tool to assess laxity in ACL-deficient knee during magnetic resonance imaging. Insights of intraoperative navigation-assisted tools are also considered.

Introduction

Today, it is globally recognised that anterior cruciate ligament (ACL) has two functional bundles: the anteromedial (AM) bundle (mainly resisting anterior tibial translation) and posterolateral (PL) bundle (primarily restrains against rotatory laxity).[1] This concept revolutionised ACL repair by inducing more "anatomic" single- or double-bundle reconstructions[2,3] and renewed interest in augmentation/partial repair procedures.[4]

Prevention of arthritis remains to be a target for ACL reconstruction but presently patients have higher expectations and demand the complete repair of anatomy and functional recovery including highly demanding activities.[5,6]

The influence of ACL in joint stability under torsional load has not been completely established.[7] Several studies[3,7,8] concerning clinical outcomes of double-bundle ACL reconstruction have been reported, but measuring the improvements in clinical outcomes compared to single-bundle reconstruction has proven to be a difficult task.[3]

Subjective clinical evaluation including manual tests is not suitable to compare results of "standard" ACL single-bundle repair with more anatomic double-bundle reconstruction.[9] The ideal tool to evaluate the knee should be a means to assess both the "anatomy" and the "function" in the same examination. Furthermore it should make it possible to measure anteroposterior translation and rotation, be cost-effective, accurate and possible to reproduce.

We have proven in the past that it is effective in restoring anteroposterior instability but there are still doubts concerning the surgical effectiveness to systematic control rotation, particularly during pivoting sports. However, as in the past, our efforts can only be expected to accomplish success once we are provided with the proper tools to measure the effects of our advances or changes.

Partial ruptures present some interesting features such as less aggressive surgery and respect for biology,[4,10] justifying the increased interest for this concept. However these lesions are particularly difficult to recognise pre-operatively[11] and the *status quo* of the remaining bundle (biologic and biomechanical) is also a problematic issue.

For all the aforementioned reasons, a greater interest in ACL research has been noticed namely in respect to the development of better tools aimed at: *1)* identifying risk factors; *2)* assisting in decision making with regard to treatment options (surgical or conservative treatment, best patient-matched technique); and *3)* identifying partial ruptures (including the biomechanical status of the remaining bundle).

1 Methods for the assessment of anatomical and functional features of the ACL-deficient knee

1.1 Clinical examination of the knee – Manual tests

The most commonly used clinical manoeuvres to assess laxity in the ACL-deficient knee are Lachman and pivot-shift tests. These methods are currently used for "in office" diagnosis and the evaluation of repair.

However, manual examinations are influenced by surgeon's training and personal experience and training[12] and although the pivot-shift test is a better predictor of clinical outcomes when compared to any uniplanar examination, the Lachman test is still the most commonly used.[13-15]

It has been shown that the Lachman test is not especially consistent across examiners.[16] The performance of the pivot-shift is more reliable either when described as a "feeling" of abnormal movement or based on results of instrumented measures.

It must also be considered that besides the variability inherent to examiners hands, there are also different techniques to reproduce this test, which have been widely used worldwide (including Losee, Noyes, Jakob, Hughston).[17] The application of combined internal rotation and valgus torques to the knee can more precisely recreate the anterolateral subluxation that occurs in the knee joint during the pivot-shift test.[18] The amount of force applied has inter- and intra-examiner variation. Furthermore, limitations of the pivot-shift test, particularly in a awake patient must be considered. It has also been acknowledged that mechanised pivot-shift achieves greater accuracy compared to manual testing.[19]

1.2 Manual instrumented devices

Manual instrumented tests aim to be more objective than manual examination alone. It also provides results that can be easily shared and analysed. Furthermore, most devices are easy to carry and can still be used "in office". However they also share some limitations, such as the absence of bony landmarks to consider, that they are operator-dependent and influenced by muscle guarding.

Several arthrometers have been proposed, which reflects the need to develop an objective method to quantify anteroposterior translation and the rotatory laxity of the knee joint for diagnostic purposes, detecting risk factors and controlling surgical outcomes.

Since the first report,[20] the KT-1000™ laximeter (MEDmetric®, San Diego, CA, USA) is the most widely used knee ligament testing system because it is user-friendly. Actually, this instrument is still the reference that new devices have been tested against.[21] However, this is an operator-dependent device, it does not measure rotation and it has also been associated with false negative results and questionable reproducibility.[22,23] The KT-2000™ ligament arthrometer (MEDmetric® Corp) uses the same method as the KT-1000™. But the main difference concerns the data output, which includes a graphic presentation of the amount of tibial displacement relative to the magnitude of applied force via an X-Y plotter.

Besides KT-1000™ and KT-2000™,[24] some other devices are commercially available. These include the CA-4000 Electrogoniometer (OSI, Hayward, CA),[25] the Genucom Knee Analysis System (FARO Medical Technologies, Montreal, Ontario Canada),[26] the Kneelax3 (Monitored Rehab Systems, Haarlem, The Netherlands),[27] the Rolimeter (Aircast Europa, Neubeuern, Germany),[28] and the Stryker Knee Laxity Tester (Stryker, Kalamazoo, MI).[29,30]

All these devices have similar limitations (intraclass correlation coefficient [ICC], 0.6) and have not proven to be more effective than the clinical examination.[24] However they can provide objective measurements that facilitate data processing and sharing information.

Publication year	Study type	A-P translation	Rotation	Comments
Park *et al.*,[35] 2008	Clinical	–	+	Knee at 60° of flexion; women have increased external rotation laxity
Tsai *et al.*,[34] 2008	Clinical	–	+	Reliability of a device to measure knee rotation in healthy human subjects
Robert *et al.*,[21] 2009	Clinical	+	–	Does not assess rotation; performed in 0° rotation; reproducibility better than KT-1000™; possibility to identify partial ruptures
Branch *et al.*,[12] 2010	Clinical	–	+	Knees with greater tibial internal rotation have higher risk for ACL injury; women have increased external rotation laxity
Mayr *et al.*,[33] 2011	Clinical	+	+	Knee flexion of 30° with varus/valgus stress posts for the knee. Tibial external/internal rotation was imposed with a torque of 2 Nm on the footrest with the ankle locked in dorsiflexion; differentiate isolated ACL rupture and ACL rupture combined with medial instability
Woo *et al.*,[31] 2009	Cadaveric	+	+	This study summarizes major contribute from this research group concerning study of knee kinematics using robotic system with several inherent publications
Musahl *et al.*,[19] 2010	Cadaveric	–	+	Mechanized pivot-shift tests better than manual exams
Citak *et al.*,[15] 2011	Cadaveric	–	+	Mechanized pivot-shift tests better than manual exams

Table 1. Recent publications of robotic devices for knee laxity testing.

1.3 Robotic systems

In order to overcome bias inherent to manual force application, different robotic systems have been proposed that comprise mechanical methods to apply load or torque in a controlled manner (magnitude, direction, rate).[15,19,21,31-36] Recently published studies are summarised in table 1.

The group from Pittsburgh has contributed great insight into the understanding of knee joint kinematics in multiple-degree-of-freedom using robotic systems.[31]

Considering anterior-posterior laxity alone, the Genurob (GNRB) knee laxity testing device (Genurob, Montenay, France), provides an anterior directed force to the posterior proximal calf region with the knee at 0° rotation and 20° flexion in a rigid leg support.[21] The load is delivered gradually and the software compares side-to-side differences in the amount of anterior tibial translation. It also provides a force-displacement curve whose slopes reflect ligamentous elasticity. Hamstring relaxation status is controlled by superficial electrodes on the thigh. Authors could find differential laxity thresholds at 250 N to be 1.5 mm for partial and 3 mm for complete ruptures. They also produced insights about the contribution and influence of surrounding soft tissue structures and the role of ACL double-bundle concept.

In cadaveric hip-to-toe models, Musahl *et al.*[19] and Citak *et al.*[15] were able to demonstrate that instrumented pivot-shift tests can produce more reliable and consistent measurements of pivot-shift phenomenon. Tsai *et al.*[34] determined the reliability of a device to measure knee rotation in human subjects with normal knees including intra-tester, test-retest and inter-tester reliability. They concluded that the proposed method presents acceptable limits of reliability for clinical use and interpretation.

Park *et al.*[35] compared ten healthy men and ten healthy women with the knee at 60° of flexion. They concluded that women had increased external rotation laxity. Branch *et al.*[36] also report similar gender related findings. Furthermore, the data from the robotic assessment of laxity were considered in order to detect the additional risk factors for ACL injury. Healthy knees of patients with previous contralateral ACL repair and knees of healthy volunteers were studied. Assuming that the opposite knee of patients with a previous ACL reconstruction present biomechanical characteristics of greater risk for ACL rupture, it was stated that knees with greater tibial internal rotation have higher risk for ACL injury when compared to healthy volunteers.

Mayr *et al.*[33] proposed a method for clinical use targeted at awake, non-anesthetised patients, which consists in measuring the anteroposterior translation and rotation of the knee joint. The device requires fixation of the foot at 30° of knee flexion with varus/valgus stress posts for the knee. Tibial external/internal rotation was imposed with a torque of 2 Nm on the foot rest with the ankle locked in dorsiflexion. Anterior translation of the tibia in relation to the femur was measured in neutral position, internal and external rotation. Intra- and inter-rater reliability was validated in ten healthy volunteers. Ten patients with isolated ACL rupture, ten patients with ACL rupture and medial instability and ten patients with additional lateral instability were evaluated and side-to-side differences were used for calculation. The authors concluded that it is possible to objectively differentiate isolated ACL rupture and ACL rupture combined with medial instability. The method proved to be reliable and reproducible by different examiners and by the same examiner at different times.

All these systems have been used mainly for research purposes and have not yet been included in routine clinical practice. They have the merit of providing objective data related to joint laxity but are time-consuming and cannot provide information about any morphologic changes in the knee.

1.4 Stress radiography/radiostereometry

The combination of a stress device and radiography (stress radiography) has been proposed both as a knee laxity measurement technique for ACL[23,37,38] and as posterior cruciate ligament (PCL) assessment.[39,40] The Telos device (Telos GmbH, Laubscher, Hölstein, Switzerland) is the most representative example of such a device. It makes it possible to measure anterior and posterior drawer displacements controlling the magnitude of load transmission. The method considers the displacement of the midpoint between the tangents to the posterior contours of the tibial condyles drawn perpendicular to the tibial plateau and relative to the position of the corresponding midpoint between the 2 posterior aspects of the femoral condyles.

The intra- and inter-tester reliability of Telos device was reported by Staubli *et al.*[41] This method presents an advantage over the previous ones, since it considers bony landmarks to measure translation thus avoiding issues related to soft-tissue artifact. However, it requires more equipment, personnel and additional exposure to radiation. No further information of knee joint soft tissue, cartilage or menisci status is provided.

Radiostereometric analysis, originally presented by Selvik *et al.*[42] was proposed as a method to enhance the precision of translation measurement of the knee joint by stress-radiography. This is an invasive method that relies on implantation of tantalum beads, but is highly accurate (within 0.1 mm). For this reason, it has also been proposed to assess migration of arthroplasty components throughout time.

There are reports stating the advantage of the Telos method over KT-1000™.[23] But limitations have been recognised even combining radiostereometric analysis, based on the absence of a stress device that can produce reliable joint translation.[43]

1.5 Porto-knee testing device as a tool for instrumented evaluation during magnetic resonance imaging

The Porto-knee testing device (PKTD) (see figure 1) is a knee laxity testing device for the measurement of anterior-posterior tibial translation and internal rotation of the tibia during the magnetic resonance imaging (MRI) examination, thus combining the assessment of "anatomy" and "function" during the same examination.

PKTD is made of polyurethane, allowing it to be used during MRI scans, in positions in which the knee is placed under stress due to the inflation of cuffs, making it possible for the examiner to control the magnitude of load transmission up to 46.7×10^3 N/m^2, applied in the posterior proximal calf region.

The device can be adjusted at different degrees of knee flexion and different degrees of external/internal rotation inflated by the footplate. It can also be used for PCL evaluation by changing the position of the cuff thus transmitting force to the anterior aspect of the tibia.

Measurements are achieved using sets of MRI images with 1mm spacing and 3D reconstruction upon load application.

The measurement (in mm) is performed using a line perpendicular to tibial slope crossing the most posterior point of the tibial plateau and its distance to a parallel line crossing the most posterior point of the femoral condyle. This pro-

Figure 1. Photograph of the PKTD developed at the Saúde Atlântica F.C. Porto Sports Center.

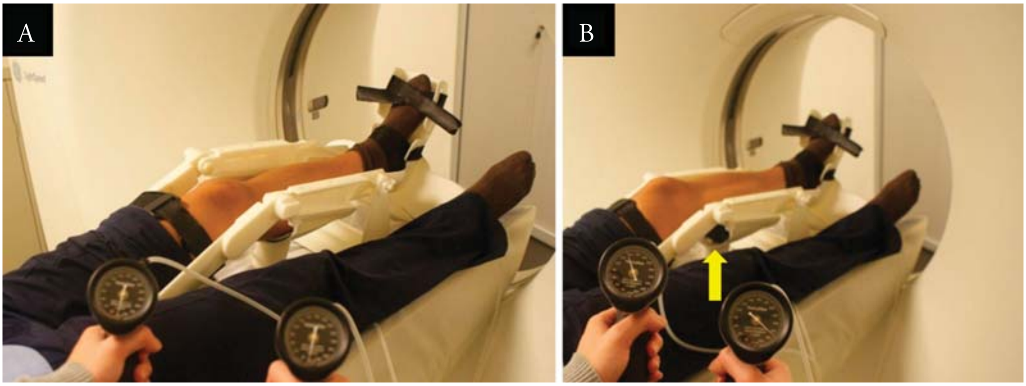

Figure 2. Photographs of PTKD: without pressure (A), and with pressure (B). Arrow indicates cuff inducing anterior tibial translation upon pressure application in posterior proximal calf region.

cess is repeated without and with pressure for medial and lateral compartments identifying the same points as bony landmarks (see figure 2).

The difference in each of the two points of measurement is calculated between the two sets (without and with pressure) obtaining the anterior translation, in millimetres, for medial and lateral tibial plateaus (see figure 3). The method may include the assessment of ACL-deficient knees alone or in a side-by-side comparison.

In a recent clinical study,[44] it was demonstrated that the PKTD-MRI method is reliable in the assessment of anterior-posterior translation (comparing to KT-1000™) and rotatory laxity (compared to lateral pivot-shift under anaesthesia) of the ACL-deficient knee. It also showed the capacity to identify partial ruptures (confirmed later by arthroscopic findings), although this issue was not specifically addressed throughout the study. By putting stress on the ACL during the exam, the method makes it possible to simultaneously evaluate the mechanical behaviour of partial ruptures and improve the visualisation of "biological"/signal features of the ruptured and the remaining bundle.

Ongoing study is now comparing the results of the method, considering different degrees of rotation during anterior-posterior load transmission that is aimed at improving the capacity to identify populations with increased risk factors for ACL rupture.

1.6 Intra-operative navigation

Despite improving the pre-operatory clinical assessment, the previously described methods share the limitation of not providing a suitable tool to improve surgi-

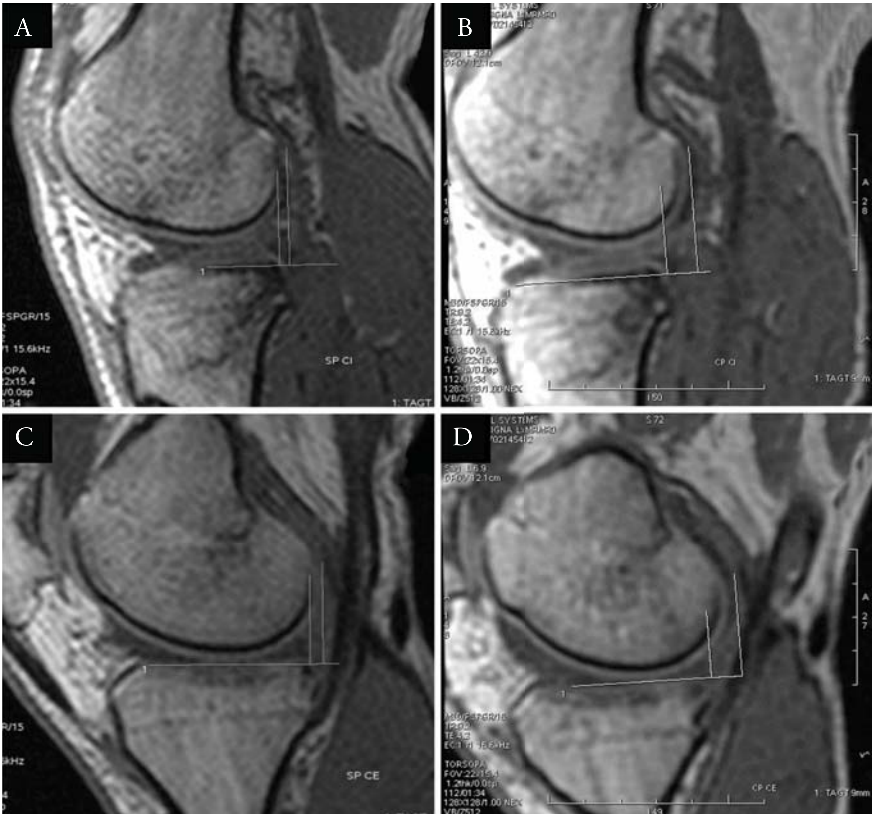

Figure 3. MRI images of injured knee obtained using the PKTD: medial compartment without (A) and with pressure (B); and lateral compartment without (C) and with pressure (D).

cal precision or effectiveness nor to assist surgeons in intra-operative decision making.

Surgical computer-assisted navigation may not only refine the evaluation of knee instability during surgery but also help clinicians understand the role of different ACL bundles during anatomical reconstruction.[45] It has been stated that navigation can make it possible to quantify knee laxity examination.[46] It also enables the testing of pathologic multiplanar or coupled knee motions, particularly in the setting of complex rotatory instability patterns.[47]

The repeatability of load application during clinical stability testing is still an issue to be considered, [48] in the same way as any type of manual clinical testing.

Furthermore, the invasive profile of some of these systems and inherent costs, which are not yet reflected in the outcome, represent obstacles to the widespread application of these tools.

2 Final remarks

Manual testing during clinical examination is still useful and relevant, but mechanised and objective evaluation devices are now essential. It has been shown that the reliability of mechanised testing is better than manual examination. By better identifying patients with higher rotatory laxity after ACL rupture, clinicians will be able to distinguish the patients will benefit more from double-bundle reconstruction from those who can expect an effective result from single-bundle or augmentation procedures. Furthermore, methods that make it possible to detect risk factors might improve prevention strategies. The PKTD, which permits assessment of antero-posterior and rotatory laxity of the knee during MRI exams, proves to be a valuable option both in pre- and post-operative settings. It expands MRI evaluation, enabling it to assess morphology and biomechanical features of cruciate ligaments including partial ruptures. Tools suited to intra-operative application, such as "navigation", may make valuable contributions towards improving technical issues in the near future.

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