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ORIGINAL PAPERS

Relationship between mechanism of injury and associated lesions in anterior cruciate ligament tears

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Abstract
Purpose: To analyze joint and bone alterations occurring in patients diagnosed with anterior cruciate ligament (ACL) tears and their relationship with the mechanism of injury.
Materials and Methods: Over one year, 127 patients were selected that had been diagnosed with an ACL rupture. The mechanism of injury was analyzed, i.e. whether the lesions had been caused by valgus tress or by forced varus. Forty-five patients fulfilled the inclusion criteria. We assessed intra-articular lesions by means of MRi and direct arthroscopic visualization and found 33 patients with forced valgus lesions and 12 patients with forced varus injuries. A comparison was made between the intra-articular lesions found in both groups.
Results: Indirect or non-contact injuries were the most frequent, without any differences being identified as regards the appearance of meniscus or ligament lesions seen in the MRi scans or the meniscus and tibiofemoral and patellar cartilage lesions seen arthroscopically. Nonetheless, we identified 24 patients with subchondral bone lesions in the valgus injury group and only 2 in the varus group, with the difference between both groups reaching statistical significance (p=0,002).
Conclusion: There exists a relationship between the forced valgus mechanism of injury and the presence of subchondral bone lesions. This relationship could not be demonstrated for varus injuries.

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PALABRAS CLAVE
Ligamento cruzado anterior;
Edema óseo;
Contusión ósea;
RM

Relación entre el mecanismo de producción y las lesiones concomitantes en las roturas del ligamento cruzado anterior

Resumen
Objetivo: Comprobar las alteraciones articulares y óseas que se producen en pacientes diagnosticados de rotura del ligamento cruzado anterior (LCA) y su relación con el mecanismo de producción.
Material y método: Se seleccionó a 127 pacientes diagnosticados de rotura del LCA durante 1 año. Se evaluó el mecanismo de acción de la lesión según fuesen en valgo o varo forzado; 45 pacientes cumplieron los criterios de inclusión. Evaluamos las lesiones intraarticulares mediante resonancia magnética (RM) y visualización artroscópica directa; 33 pacientes tenían lesiones en valgo forzado y 12, en varo forzado. Se compararon las lesiones intraarticulares observadas en ambos grupos.
Resultados: Las lesiones indirectas o sin contacto fueron más frecuentes, sin diferencias en cuanto a la aparición de lesiones meniscales o ligamentosas, vistas en RM, ni de lesiones meniscales, condrales femorotibiales y rotulianas, vistas por artroscopia. Sin embargo, detectamos 24 pacientes con lesiones óseas subcondrales en el grupo de valgo y sólo 2 en el grupo de varo; la diferencia entre ambos grupos fue significativa (p = 0,002).
Conclusiones: Hay relación entre el mecanismo de valgo forzado y las lesiones óseas subcondrales, que no se demostró en las lesiones en varo.

Introduction

Several theories have been proposed to explain the mechanisms that may lead to anterior cruciate ligament (ACL) injury. Nonetheless, the causes of ACL tears are not well-defined[1-10], which has prompted a renewed interest in the biomechanical characteristics of such injuries[11].

The ACL Study Group classifies ACL tears into indirect or non contact injuries and direct or contact injuries[10]; the most usual mechanisms of injury are those that result in non contact or indirect injuries to the knee. They are movements that entail a sudden deceleration force, while the knee is extended and there are valgus or varus moments and rotation of the leg[2,9-11]. Contact lesions normally occur either in sports or road accidents and are caused by forces acting directly on the affected limb. Differences have been established between males and females in terms of the risk factors related to the mechanism of injury[6,11-13].

Injuries sustained while he leg is externally rotated give the patient the impression that the knee has moved inward. A knee valgus moment, together with the external rotation, is the most usual mechanism of ACL injuries, which tend to be accompanies by other lesions as well[2,10,11]. In lesions sustained when the limb is internally rotated, the leg turns inward and the subject has the feeling that the knee has moved outward, a movement similar to a varus thrust even if the internal rotation may also be accompanied by a knee valgus moment. Hyperextension or hyperflexion injuries are less frequent, but also more serious[10,14].

Intraarticular lesions may be at the origin of the ACL injury, they may be previous to it or they may occur as a degeneration of an unstable knee. Different patterns have been established on the basis of arthroscopic and imaging technique findings[15-20]. Time to injury repair may also have a role to play[18,19]. Assessment is normally performed by some imaging method, especially magnetic resonance (MR) and arthroscopy[21,22].

Biomechanic, environmental, hormonal and anatomic circumstances have been cites as risk factors for ACL injury. An understanding of these factors could help establish preventive strategies[11]. Identification of the right mechanisms of action is especially important to be able to establish preventive strategies based on proprioceptive or neuromuscular training that may prevent injury in persons at risk and thereby produce a set of guidelines for treatment and prognosis[1,4,12,15].

It is not easy to obtain specific evidence on the exact movements the knee made when sustaining an ACL injury. Video analysis of the injury could help in sports lesions. However, in everyday life or occupational situations conclusions are hard to draw[2,12]. Moreover, even if intraarticular lesions have been related to different parameters, such as age, gender or activity, few studies have been published on their mechanism of action. We believe that the most objective information furnished by patients following their lesion is precisely a description of the movements of their knee at the time of sustaining the injury. This has assisted us in analyzing the differences among the knee joint lesions occurring in patients diagnosed with and operated for an ACL rupture and relating these differences to the mechanism that caused the injury in the first place.

Materials and methods

127 patients were selected with a main diagnosis of ACL rupture who were due to be subjected to arthroscopic repair surgery. To be included in the study patients had to submit MR images and a magnetic resonance report for their

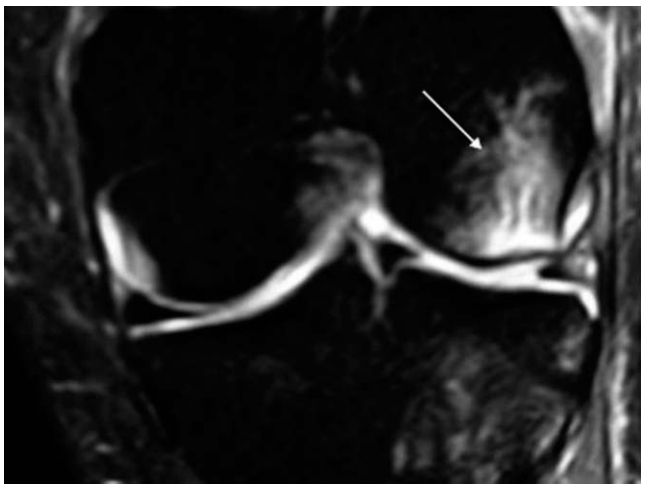

Figure 1 Coronal T2 view showing bone contusion in the lateral condyle (arrow) and bucket handle tear of the lateral meniscus in a patient with an ACL tear.

Figure 2 Sagittal T2 view. Bone contusion in the lateral condyle (arrow) and tibial plateau in a patient with an ACL tear.

affected knee. We assessed intraartiuclar injuries by MR (figs. 1, 2 & 3) and direct arthroscopic visualization. On the MR we evaluated alterations in the menisci, the ligaments, the cartilage and the bone. Arthroscopically we analyzed meniscus, ligament and chondral lesions. Assessment of the lesions was quantitative, without establishing any sort of Trading, except for chondral lesions, where we used Outerbridge's classification. Injuries diagnosed on Imaging studies were taken from the report, without adding any new findings, in order to preserve the observer's independence.

Patients who fulfilled these requirement were given a questionnaire made up of 5 questions:

— Do you remember how you sustained the injury? Please describe it.
— What activity were you performing?
— What direction did your knee take?

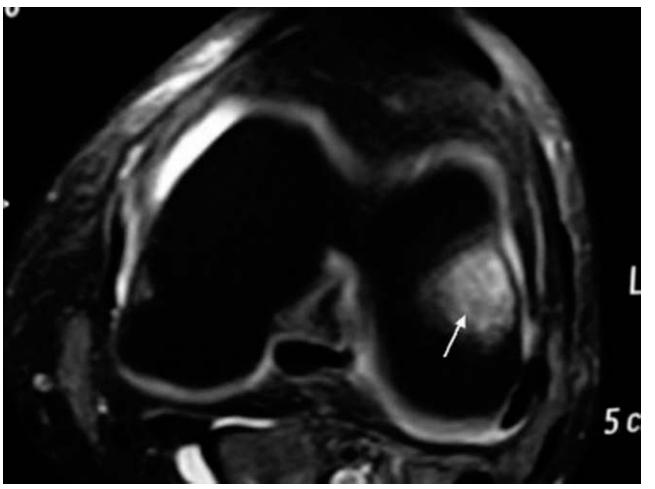

Figure 3 Axial T2 view showing bone contusion in the weight-bearing area of the lateral condyle (arrow) in a patient with an ACL tear.

— Do you remember hearing any popping sound?
— Had you sustained any prior injuries in your knee?

A negative response to any of the first 3 questions was considered an exclusion criterion and answers of the type "I don't know" or "I don't remember" were taken as negative.

The first 2 questions focused on the activity the patient was engaged in at the time of sustaining the injury. Activities were classified into occupational, sports-related, road accident or incidental. The next question was intended to find out whether the knee injury was direct or indirect (non contact). On many occasions we recorded the movement of the affected limb in accordance with the description provided by the patient. Answers to the third question allowed us to classify mechanisms of injury into forceful valgus and forceful varus. We excluded patients who reported mechanisms combining hyperfiexion and hyperextension since they were both infrequent and difficult to interpret. The questionnaire was processed by 2 independent specialists.

Of all the patients interviewed, only 47 met the inclusion criteria; 33 patients attributed their ACL tear to valgus stress; 12 to varus stress and 2 to combined movements. In 41 (87.2%) patients, the injury occurred with no contact, while only 6 reported that their injury had involved contact. We excluded the 2 patients with combined injuries, which is why we ended up with a final series of 45 cases: 33 with valgus stress and 12 with varus stress.

The SPSS 11.5 package was used for the statistical analysis. Yates' chi square test was used to compare the injuries found in both groups. Differences were deemed significant when $p<0.05$.

Results

Among patients sustaining valgus stress there were 31 males and 2 females, whereas in the varus stress group all patients were male. Mean age for the valgus stress patients was 32

years, whereas that for varus stress patients was 38 years. There were 25 right and 8 left knees affected by valgus stress, while 8 right and 4 left knees were affected by varus stress. Mean time to surgery was 4 months in patients sustaining valgus stress and 6 months in those with varus stress. Thirteen (39.3%) patients in the valgus stress group reported having had a previous injury in the affected knee; 9 (27.2%) of these injuries had been included in the patients' clinical records, with 5 (15.1%) patients having undergone a prior arthroscopic meniscectomy. Five (41.3%) patients in the varus stress group reported previous injury, of which 3 (25%) had been included in their clinical records, although none of them had had previous surgery.

Table 1 Activity carried out during ACL injury

	Valgus stress, n (%)	Varus stress, n (%)
Occupational or incidental	28 (84.8)	9 (75)
Sports-related	5 (15.1)	1 (8.3)
Road accident	1 (3)	2 (16.6)

Table 2 Injuries detected on Mri

Injury	Valgus stress (n = 33)	Varus stress (n = 12)
Meniscus	25 (75.7%)	8 (66.6%)
Medial	10	4
Lateral	7	1
Bilateral	8	3
Bone	24 (72.7%)	8 (66.6%)
Medial compartment	4	0
Lateral compartment	18	2
Bilateral	2	0
Ligament	13 (39.3%)	4 (33.3%)
Medial collateral	9	2
Lateral collateral	3	2
Posterior cruciate	1	0
Patellar chondropathy	1	0

Table 3 Injuries detected on knee arthroscopy

Injuries	Valgus stress (n = 33)	Varus stress (n = 12)
Meniscus	24 (72.7%)	8 (66.6%)
Medial	8	4
Lateral	7	2
Bilateral	9	2
Cartilage	17 (51.5%)	4 (33.3%)
Medial compartment		
I-II	4	2
II-IV	6	1
Lateral compartment		
I-II	3	1
II-IV	1	0
Bilateral		
I-II	3	0
II-IV	0	0
Patellar	9 (27.2%)	1 (8%)
I-II	6	1
III-IV	3	0

Table 4 Types of injuries found

Injuries	Valgus stress (n = 33)	Varus stress (n = 12)	p
Magnetic resonance diagnosis			
Meniscus	25 (75.7%)	8 (66.6%)	0.819
Bone	24 (72.7%)	2 (16.6%)	0.002
Ligament	13 (39.3%)	4 (33.3%)	0.982
Arthroscopy diagnosis			
Meniscus	24 (72.7%)	8 (66.6%)	0.98
Tibiofemoral chondral	17 (51.5%)	4 (33.3%)	0.457
Patellar chondral	9 (27.2%)	1 (8%)	0.34

Twenty-four (72.7%) patients in the valgus stress group and (66.6%) patients in the varus stress group remembered hearing a classical popping noise at the time of sustaining the injury.

The most frequent activity performed by patients in both groups at the time of sustaining the injury (table 1) was a common occupational one. Some patients reported incidental trauma such as slips, trips and falls from low heights (under 1.5 m)", although one patient sustained a fall from a height of 3 m.

Tables 2 and 3 include the intraarticular injuries detected on MR and during the arthroscopic procedure, respectively. The statistical analysis showed no differences regarding the appearance of the meniscus or ligament injuries detected on RM or regarding the meniscus and tibiofemoral and patellar chondral lesions found on arthroscopy (table 4).

We should underscore the high incidence of meniscus lesions in both groups and the low incidence of chondral lesions in the MR reports. Ligament lesions corresponded with the mechanism of injury; the most frequent ones were those of the medial collateral ligament in valgus stress injuries.

The bone lesions described in x-ray reports as contusion, edema or subchondral microfracture appeared in 24 patients in the valgus Group and only in 2 cases in the varus Group; the difference between both was statistically significant (p=0.002) (table 5).

Discussion

The main limitation of our study, which it shares with others, was trying to come up with an accurate description of mechanisms of injury on the basis of a clinical interview; patients' reports may be influences by all sorts of biases. The

Table 5 Location of bone lesions

	Valgus stress			Varus stress		
	Femur	Tibia	Both	Femur	Tibia	Both
Medial compartment	2	2	2	0	0	0
Lateral compartment	3	11	4	0	2	0

mechanisms of ACL injury remain a fruitful field of inquiry given the difficulty inherent in identifying them by asking patients or by analyzing clinical records[2,12]. These endeavors will only provide us with data furnished by the patient which, in the majority of cases, is biased or confusing. Our interviews were administered in an occupational accidents clinic and, for that reason, the questionnaire was focused on finding out the precise movement of the affected knee at the time of injury rather than the precise activity the subject was engaged in at that moment.

Indirect injuries caused by valgus stress are the most frequent ACL injuries[2,11]. In line with other reports in the literature, we found a higher percentage of injuries caused by valgus stress than by varus stress. However, in contrast to those reports[18,19], we found that time to surgery is not a determining factor for the appearance of more intraarticular lesions.

Meniscus lesions are often related with ACL tears and there is a highly significant correlation between image-based diagnosis and arthroscopic visualization. A previous meniscectomy was confirmed in 5 cases, all of them in the valgus stress group. This is a factor that increases the number of concomitant injuries because of its chronic nature. The patterns and implications of meniscal lesions in the context of an ACL tear have been well described and their relation to the development of osteoarthritis is a proven fact[17,23].

Ligament injury is less frequent and their characteristics tend to coincide with patient reports, according to the classical description of the injury[14].

We have found differences in terms of the presentation of bone injury, whose definitions vary as depending on the severity of the lesion: Some of the terms used are "bone contusion", "bone edema", "subchondral edema" and "subchondral microfracture". The English language literature uses the term "bone bruises" to describe them and a high incidence of these injuries has been resected in the context of ACL tears[24]. Valgus stress injuries have been constant in our study, especially in the lateral compartment, caused by a direct injury and affecting the tibial plateau.

The relation between bone edema and ACL tears has been documented in 71-85%of patients[25-30]. In the majority of these series the bone bruise could be seen in the distal groove of the lateral femoral condyle and was often accompanied by a lesion in the posterolateral region of the proximal tibia. It has been argued that it is related to the mechanism of ACL injury, which includes axial stress, valgus stress and anterior tibial subluxation with the nearly complete knee extension, as is the case in the pivot shift test[25,26,31]. Accordint to Mair et al[31], bone contusions are related to tears in all the ligaments around the knee Joint and always occur on the side opposite to the affected ligament.

The incidence of bone lesions in our study has been higher in the valgus stress than in the varus stress Group and the difference was statistically significant (p=0.002). The most frequently involved area was the lateral articular facet of the tibia. Other studies have established a relationship between bone and ligament injuries[32]. In the series by Viskontas et al[33], bone lesions related to ACL tears were more frequent and profound when caused by a non contact mechanism. In turn, Rosen et al[25] and Lahm et al[34,35] inferred that bone lesions caused damage to the articular cartilage and that, therefore, the management and prognosis of ACL injuries would depend on whether there was an associated bone injury or not.

The persistence and clinical implications of these lesions remain unclear[36]. Vincken et al[37] point out that patients with bone contusions present with greater functional limitations during the first 6 months from injury. However, a recent study[38] observes that all contusions had disappeared from MR studies after 12 years' follow-up and finds no clinical differences between patients who had had bone ACL-tear related bone contusions and those who had not.

To conclude, we have established a relationship between the valgus stress mechanism and bone lesions that is not so evident in injuries caused by varus stress. This may have consequences for premature knee degeneration in these patients and hence for the prevention and Management of this type of injury.

Conflict of interests

The authors have declared that they have no conflict of interests

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