Articular and Meniscal Pathology Associated with Primary Anterior Cruciate Ligament Reconstruction

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Abstract

Background The abnormal kinematics, contact pressures, and repeated episodes of instability observed in chronic anterior cruciate ligament (ACL) deficiency suggest that these patients may be predisposed to early degenerative changes and associated pathologies such as meniscal tears and chondral injury. Injury to the cartilage and associated structures at the time of ACL rupture, in combination with the inflammatory mediators released at the time of injury, may create irreversible damage to the knee despite restoration of normal knee kinematics with an ACL reconstruction.

Hypothesis Patients undergoing acute ACL reconstruction have a higher incidence of lateral meniscal tears and less severe chondral changes when compared with patients undergoing late ACL reconstruction. Older patients likely have a higher incidence of chondral and meniscal pathology compared with younger patients.

Methods A retrospective chart review of a single surgeon's ACL practice over 20 years was performed. A surgical data packet was used to record patient demographics, location, grade, and number of chondral injuries as well as location and pattern of meniscal injuries at the time of ACL reconstruction. Patients ($N = 709$) were divided into three subgroups according to their time from injury to surgery; acute (less than 4 weeks, $N = 121$), subacute (4 to 8 weeks, $N = 146$), and chronic (8 weeks or more, $N = 442$).

Results Older patients had a higher incidence of more severe chondral grade and number of chondral injuries at the time of ACL reconstruction. Patients undergoing surgery more than 8 weeks after injury had a statistically significant more severe chondral grade in the medial compartment when compared with those that had surgery less than 8 weeks after injury. A similar observation was not found in the lateral compartment. With regard to meniscal pathology, full-thickness medial meniscal tears were likely to be bucket-type tears regardless of the chronicity of the injury. Similarly,

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- cartilage
- ACL deficiency

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full-thickness lateral meniscal tears were more often flap-type tears independent of the time interval between injury and surgery. Partial-thickness tears were common both medially and laterally.

Conclusions Patient's age and chronicity of ACL tear greater than 8 weeks are both significant factors in medial compartment chondral pathology. Patients with delayed reconstruction may have greater associated pathology.

Reconstruction of the anterior cruciate ligament (ACL) is one of the most common orthopedic procedures performed annually. With over 300,000 ACL injuries per year, patients and their surgeons are increasingly aware of the need to restore the normal anatomy of this ligament in an effort to return patients to their desired activity level and prevent future injury.[1] Serial sectioning studies of the ACL have shown that in ACL deficiency, the major restraints to anterior tibial translation are the iliotibial band (24%), medial capsule (22%), lateral capsule (20%), medial collateral ligament (16%), and the lateral collateral ligament (12%). Several biomechanical and kinematic studies have evaluated the ACL-deficient knee to determine the secondary stabilizers against anterior tibial translation. Secondary stabilizers include the iliotibial band,[2] the lateral collateral ligament and posterolateral structures,[3,4] the medial collateral ligament,[5] the medial acapsule, and the medial and lateral menisci.[6] In the ACL-deficient knee, the in situ load imparted by the MCL and posterolateral structures to an anterior tibial translational load is 2 to 5 times higher than that of the ACL intact state.[5] In addition to abnormal load to the supporting knee structures, in vitro studies show ~40% increase in tibiofemoral contact pressures and double the force across the medial meniscus in the ACL-deficient knee.[7]

The abnormal kinematics, contact pressures, and repeated episodes of instability observed in chronic ACL deficiency suggest that these patients may be predisposed to early degenerative changes and associated pathologies such as meniscal tears and chondral injury.[8–14] However, patients that have an ACL reconstruction in the acute period (less than 4 weeks) may have progressive degenerative changes in their knee earlier than the noninjured knee.[15,16] These data suggest that the injury to the cartilage and associated structures at the time of ACL rupture, in combination with the inflammatory mediators released at the time of injury, may create irreversible damage to the knee despite restoration of normal knee kinematics with an ACL reconstruction.[17,18] Some authors have correlated this degeneration with the presence of an associated meniscal tear at the time of ACL reconstruction.[19–22]

There have been several reports describing the meniscal and chondral injuries associated with ACL injury.[18,23–25] In general, these reports have had a small sample size ($n = 44$ to 201) with a wide variation in results. The incidence of meniscal tears in the acutely ACL-deficient knee is between 16 and 82%, and as high as 96% for the chronically injured knee.[8,13,21,26–31] There is a trend toward more lateral meniscal tears in the acute ACL injuries and more medial meniscal injuries with chronic deficiency.[24] Chondral injury in the ACL-deficient knee has also been reported with some variation due to the complex interaction of knee kinematics, biologic mediators, and patient-activity level discussed previously (←**Fig. 1**).[32]

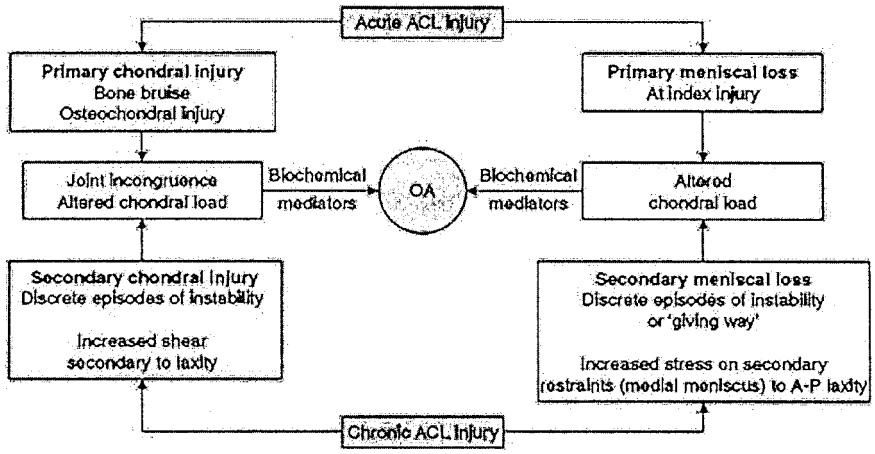

Fig. 1 The proposed mechanism of progressive injury to cartilage and meniscal structures in anterior cruciate ligament (ACL)-deficient knee with resultant joint degeneration. There is a complex relationship between damage to the associated structures at the time of injury, abnormal joint kinematics, and biomechanical mediators as represented by this schematic. A-P, anterior-posterior; OA, osteoarthritis. (Reproduced with permission from Jones HP, Appleyard RC, Mahajan S, Murrell GAC. Meniscal and chondral loss in the anterior cruciate ligament injured knee. Sports Med 2003;33(14):1075–1089.)

We hypothesized that patients undergoing acute ACL reconstruction would have a higher incidence of lateral meniscal tears and less severe chondral changes when compared with patients undergoing late ACL reconstruction. We also hypothesized that older patients would likely have a higher incidence of chondral and meniscal pathology compared with younger patients due to the physiologic process of joint degeneration with time.

Materials and Methods

Data Collection

After obtaining permission from the Institutional Review Board, we retrospectively reviewed all primary ACL reconstructions performed by the senior author (BRB) at Rush University Medical Center from 1986 to 2006. Indications for ACL reconstruction included ACL tears in patients of any age with the desire to return to cutting or pivoting types of activities and sports or multiple instability episodes without evidence of meniscal pathology. If patients were older and sedentary with an ACL tear and meniscal pathology they were offered knee arthroscopy to treat the meniscal tear without fixing the ACL, and were counseled on each with the ultimate decision given to the patient. 1,453 subjects were included in the initial chart review. Of these patients, 744 were excluded due to inability to retrieve charts kept in storage or incomplete preoperative or intraoperative data. Therefore, 709 patients were included in the final analysis. Demographic and surgical data were prospectively collected by the senior surgeon (BRB) at the time of reconstruction: patient's age, gender, injured side, time from injury to surgery (acute < 4 weeks, subacute 4 to 8 weeks, chronic > 8 weeks), preoperative exam (Lachman, anterior drawer, and pivot shift), previous history of knee injury, surgical technique (two-incision versus endoscopic), graft type (allograft versus autograft, bone–tendon–bone versus hamstring), and character of the ACL at the time of surgery. Knee instability on Lachman examination was numerically graded: Grade 1 (0 to 5 mm), Grade 2 (6 to 10 mm), Grade 3 (>10 mm). The pivot-shift test was graded as negative, 1+ (glide), 2+ (jump), and 3+ (transient lock) in the position of thigh abduction and tibial external rotation to maximize the pivot-shift sign.[8] The surgical worksheet was also used to map the location, size, and grade of the chondral injuries (←**Fig. 2**). The Outerbridge classification was used to grade the chondral damage.[33] All the reconstructions were performed by a single surgeon using an arthroscopically assisted technique.[34]

The presence of an associated meniscal tear was also recorded with respect to the location (anterior third, middle third, and posterior third), extent (full or partial-thickness), and type of tear (bucket, flap, radial, complex, and peripheral). Of note, peripheral tears were categorized separately and included bucket handle tears in which the meniscal flap had displaced within or in front of the tibiofemoral articulation. Finally, any additional pathology or surgery was also noted, including posterior cruciate ligament tear, medial collateral ligament injury, posterolateral structure injury, plica, or loose bodies.

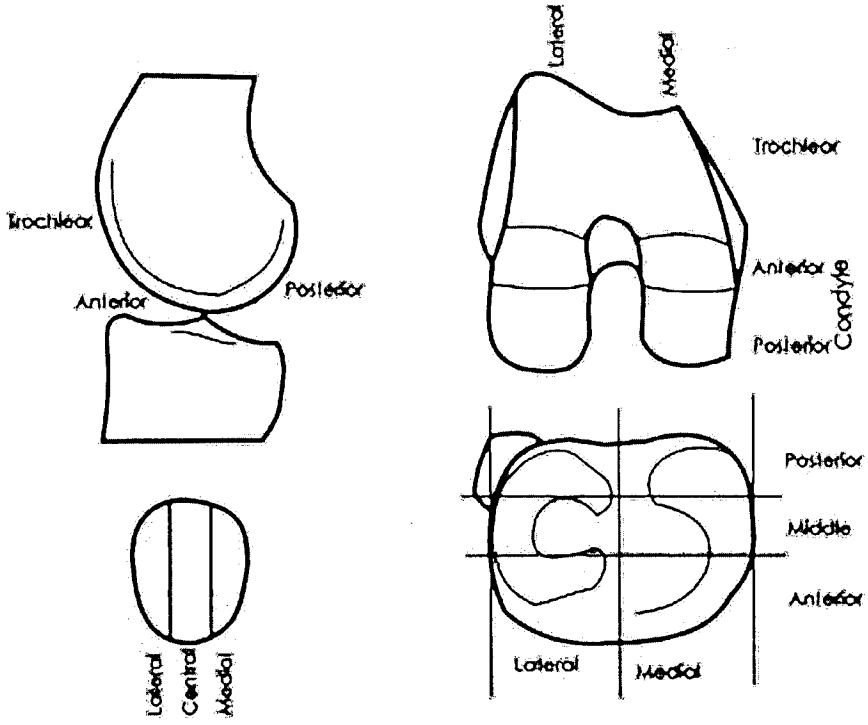

Fig. 2 Schematic of map used to diagram the location size and number of chondral injuries observed at the time of surgery. The condylar chondral surface is divided into anterior and posterior with respect to the sulcus terminalis on the lateral condyle. Similarly, the lateral and medial plateaus are divided into anterior, middle, and posterior thirds. The location and pattern of meniscal tear was also recorded on this schematic.

Statistical Analysis

The data were analyzed using standardized statistical methods and software (GraphPad Software, San Diego, CA). Comparison of the acute, subacute, and chronic subgroups was compared using ANOVA and Kruskall–Wallis test analysis with respect to meniscal and chondral pathology. Multiple regression analysis was used to analyze the correlation between the time from injury, age, and chondral or meniscal pathology. Statistical significance was established at $p < 0.05$.

Results

Demographics

There were 395 men and 314 women who underwent primary ACL reconstruction at a mean age of 28 (range 11 to 61, SD 10.1), 346 right knees and 363 left knees. The ACL autograft was used in 74% ($n = 527$) of patients and allograft in 26% ($n = 182$). Bone–tendon–bone was used in 97% ($n = 686$) of patients. The mean time from injury to surgery was 726 days (range 3 days to 32 years, SD 1,547 days) with a median of 88 days. One hundred and twenty-two patients (18%) underwent surgery between 3 and 28 days from the injury, 146 (20%) had surgery between 28 and 56 days, and 441 (62%) had surgery 8 weeks or more after their injury. There was no statistically significant difference between the demographics of patients having surgery in the acute, subacute, or chronic time period with respect to gender, surgical extremity, or graft type. However, there was a statistically significant difference in patient age between the acute and chronic subgroups ($p < 0.001$). The mean age for patients undergoing surgery within 4 weeks of injury was 25 (range 14 to 57, SD 10.5) while the mean age of patients undergoing surgery 8 weeks or more after the injury was 29 (range 12 to 61, SD 9.7). There was no statistically significant difference between the acute and subacute groups or the subacute and chronic groups with respect to patient age (►**Table 1**).

Preoperative Assessment

A preoperative assessment including an examination under anesthesia was performed at the time of ACL reconstruction surgery (►**Table 1**).

Table 1 Patient demographics

	Acute	Subacute	Chronic
Age (SD)	25 (10.5)	27 (10)	29 (9.7)
Gender (M/F)	56/65	66/79	271/170
Extremity (R/L)	53/68	72/74	221/221
Lachman (%)			
Negative	1 (0.8)	1 (0.6)	154 (34.9)
Grade 1	0 (0)	3 (2)	65 (14.5)
Grade 2	76 (62.8)	113 (78)	219 (49.5)
Grade 3	44 (36.4)	28 (19.4)	4 (0.1)
Pivot (%)			
Negative	0 (0)	1 (0.6)	65 (14)
Grade 1	21 (17.4)	35 (24.6)	128 (30)
Grade 2	42 (34.7)	88 (60.4)	171 (38)
Grade 3	72 (59.5)	21 (14.4)	78 (18)
Anterior drawer (%)			
Negative	42 (34.7)	49 (34)	208 (48.2)
Grade 1	72 (59.5)	95 (65.4)	202 (46.8)
Grade 2	6 (5)	1 (0.6)	28 (6.3)
Grade 3	1 (0.8)	0 (0)	3 (0.7)
Graft (auto/allo)	98/23	101/45	327/114
TFI days (SD)	19 (7)	42 (7)	1,146 (1,836)

Note: There was no statistically significant difference between patient groups with regard to patient gender, extremity, exam or graft type; there was a significant difference with regard to patient age and time from injury ($p < 0.001$). Abbreviations: Allo, allograft; auto, autograft; F, female; L, left; M, male; R, right; SD, standard deviation; TFI, time from injury.

Meniscus Tear

A medial or lateral meniscal tear was present in 474 (67%) of patients at the time of reconstruction (►**Fig. 3**). The relationship between timing of surgery and side of meniscal pathology is seen in ►**Fig. 4**. Twenty-three percent of patients had a tear in both the lateral and medial meniscus in the chronic subgroup ($n = 163$). The difference between medial and

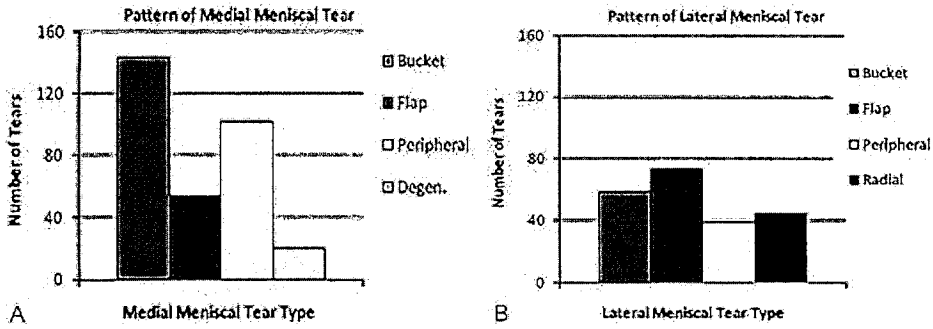

Fig. 3 Distribution of the type of medial meniscal tears observed among all patients undergoing anterior cruciate ligament reconstruction (A). Bucket handle tears of the medial meniscus were the most common. Within the lateral meniscus, flap type tears were the most commonly seen pattern (B). Degen., degenerative tear.

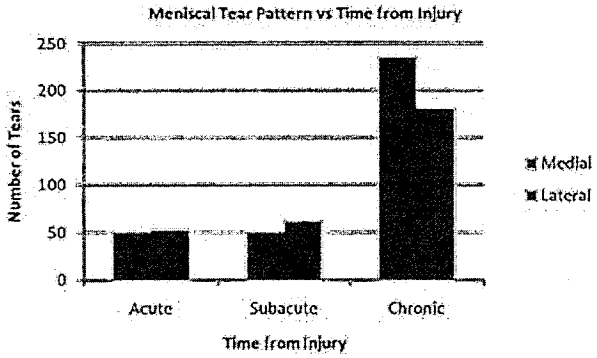

Fig. 4 The distribution of all meniscal tears observed according to the time from injury (acute, subacute, and chronic). Among acute and subacute patients there was a slightly higher incidence of lateral meniscal tears. In the chronic subgroup there was a higher incidence on medial meniscal tears.

lateral meniscus tears in each group was not significant. With the numbers available in this study, we had adequate power to show a 15% difference in the side of meniscal pathology between groups. Likewise, the location of the medial (►**Fig. 5A**) and lateral (►**Fig. 5B**) meniscal tears with respect to the time from injury to surgery demonstrated no significant difference between groups. With the numbers available in this study, we had adequate power to show a 25% difference in tear location between groups. The distribution of the type of meniscal tear as it relates to the time from injury to ACL is seen in ►**Fig. 6.** A high incidence of partial-thickness tears was noted at the time of surgery (►**Fig. 6**).

Chondral Injury

Among all patients undergoing ACL reconstruction there was a statistically significant increase in chondral grade among older patients ($p < 0.0001$). The average age of patients with Grade 0 chondral changes in the knee (tibiofemoral or patellofemoral) was 24 (range 11 to 54, SD 8.3), Grade 1 or 2 was 28 (range 14 to 57, SD 10.2), and Grade 3 or 4 was 34 (range 14 to 61, SD 10). There was a linear correlation between patient age and the grade of chondral injury ($r^2 = 0.07$, CI = 0.20 to 0.34, $p < 0.0001$). There was also a linear correlation between the time from injury to surgery and the grade of chondral injury observed at the time of surgery ($r^2 = 0.15$, CI = 0.32 to 0.45, $p < 0.0001$).

Similarly, there was a statistically significant difference in the number of chondral injuries and patient age at the time of reconstruction ($p < 0.0001$). The mean age of patients with no chondral defects was 24 (range 11 to 54, SD 8.3), with one defect was 29 (range 14 to 61, SD 10.5), and with multiple defects was 33 (range 14 to 59, SD 10). Overall, 45% ($n = 317$) of patients had no chondral injury at the time of surgery, 25% ($n = 177$) had one chondral lesion noted, and 30% ($n = 215$) had two or more lesions noted at the time of reconstruction (►**Fig. 7**).

The grade and location of the lesions were variable (►**Table 2**). Among all patients who underwent surgery within 3 to 28 days (acute) from the time of injury 86% had no identifiable chondral injury in the medial compartment (femoral condyle or tibial plateau) at the time of surgery (►**Fig. 8**).

Discussion

There have been several prospective studies evaluating the natural history of the acute, ACL-deficient knee.[10,12–14,20,22,35–39] Hawkins et al[11] prospectively evaluated the early outcomes of 40 active patients with a known ACL tear treated conservatively at a mean of 2 years of follow-up. Thirty percent of patients progressed to an ACL reconstruction due to repeated episodes of instability. Eighty-six percent of patients that did not have an ACL reconstruction experienced persistent episodes of "instability." Only 10% of this patient population was able to return to their previous level of sport without surgery.

The purpose of this study was to refine the incidence and severity of meniscal and chondral injury after ACL injury using a large patient cohort. The incidence of medial and lateral meniscal tears in this study in the acutely injured knee is 37 and 41%, respectively, with 17% of patients injuring both menisci. This contradicts previous reports of a higher incidence of lateral meniscal tears in the setting of acute ACL injury.[38,40,41] Conversely, among patients undergoing surgery more than 8 weeks after their injury 56% had a tear in the

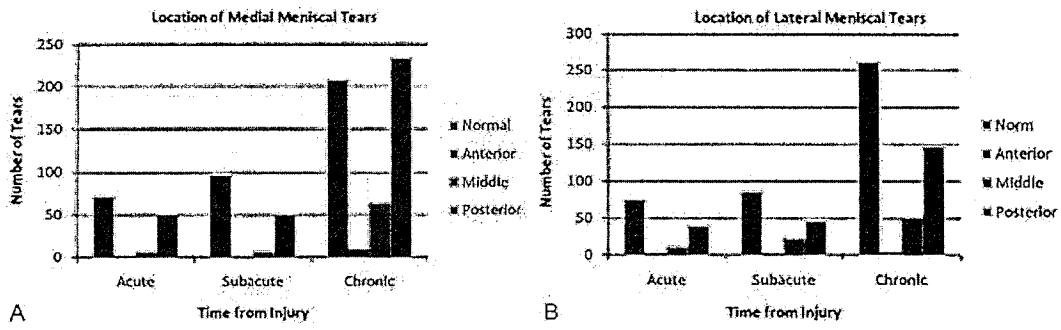

Fig. 5 Distribution of the location of medial meniscal tears according to the time from injury to surgery (acute, subacute, and chronic; A). The most common location for medial meniscal tears was in the posterior third. Similarly, lateral meniscal tears were most often in the posterior third of the meniscus (B).

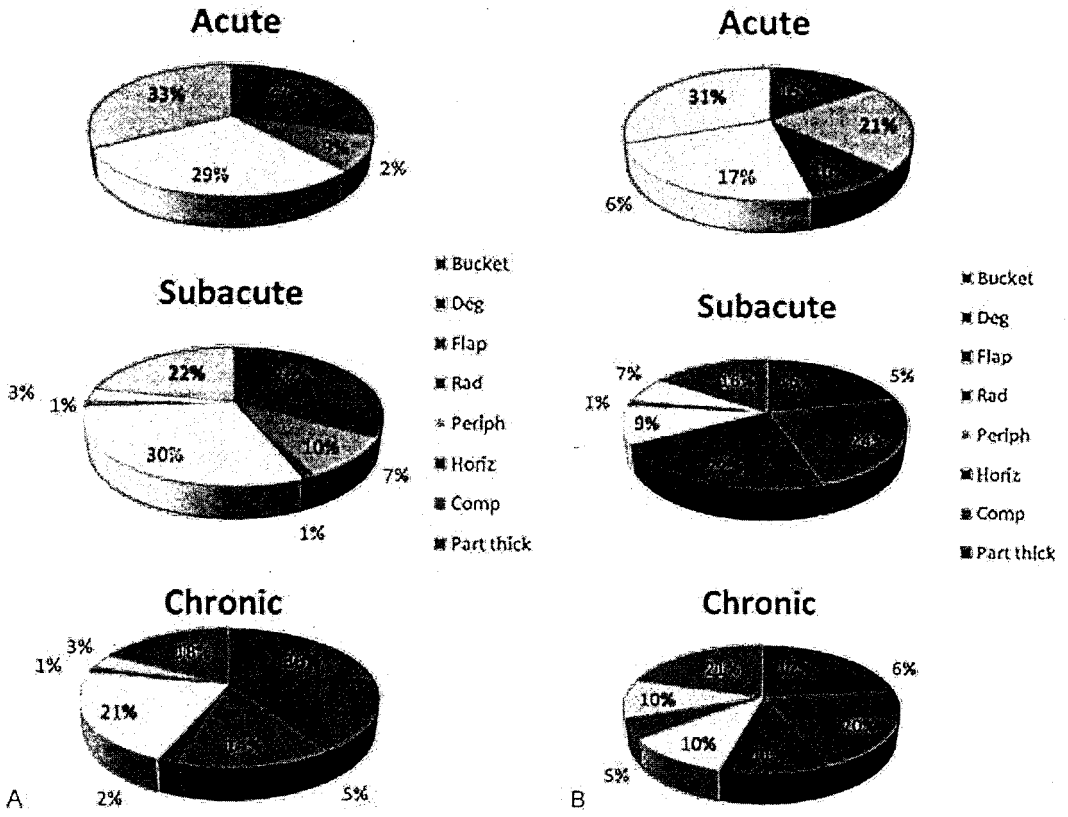

Fig. 6 Distribution of the type of medial meniscal tears observed among each subgroup of patient (acute, subacute, and chronic; A). Bucket handle tears were the most common full-thickness medial meniscal tear regardless of time from injury. Distribution of the type of lateral meniscal tears (B). Flap-type tears of the lateral meniscus were the most common full-thickness tear regardless of the chronicity of the anterior cruciate ligament deficiency. There was a high incidence of partial-thickness tears. Deg, degenerative; Rad, radial; Periph, peripheral; Horiz, horizontal cleavage; Comp, complex; Part thick, partial thickness.

medial meniscus, 44% had a tear in the lateral meniscus, and 23% had tears in both menisci. These findings correlate with reports from previous authors.[20,42,43] In addition, there was a high incidence of partial-thickness tears among our cohort of patients, ~16 to 32%.

The change in knee kinematics and repeated instability episodes observed in the ACL-deficient knee causes increased shear load on the cartilage surface, a change in joint congruence, and thus repetitive microtrauma to the cartilage surface.[44–47] Patients who have surgery within 4 weeks from the injury have less cartilage damage to the tibiofemoral compartments when compared with patients undergoing surgery more than 8 weeks from injury.[48] In addition to a more severe chondral grade with chronic injury, there was also a linear correlation between the number of chondral lesions observed and the time to reconstruction (►**Fig. 8**). While this study was not designed to determine the cause of these findings, we were able to demonstrate that chronically injured patients are more likely to have higher grade chondral injuries and multiple chondral lesions at the time of ACL reconstruction.

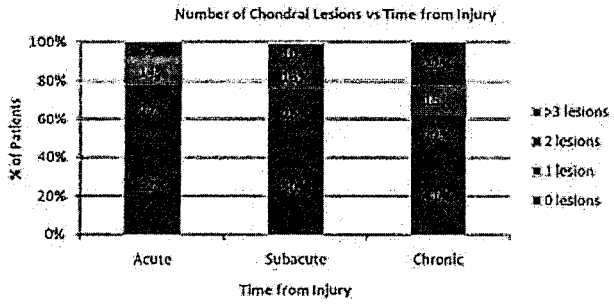

Fig. 7 The percentage of patients within each subgroup with no chondral lesions, one lesion, two lesions, and greater than three lesions noted at the time of surgery. The number of chondral lesions noted at the time of surgery increased with time from injury. Chronic patients were more likely to have three or more chondral lesions noted at the time of surgery.

There are several limitations to this study. There is selection bias in this cohort of patients as surgery was only performed on patients who presented with complaints of persistent instability, pain, etc. There is a subset of patients who may be ACL-deficient and continue to be asymptomatic. The incidence of meniscal and chondral pathology is reflective of the population of symptomatic patients as a result of their ACL deficiency. Also, there may be selection bias due to the unavailable charts of some patients. There was no independent validation of the surgical findings nor was reproducibility evaluated. The power analysis evaluating the statistical

Table 2 The distribution of the location of chondral injuries among all patients undergoing ACL reconstruction

		Patella	Trochlea	MFC	LFC	MTP	LTP
Normal							
	Acute	86	118	106	105	116	89
	Subacute	103	138	128	126	139	106
	Chronic	262	399	319	362	380	308
Grade 1							
	Acute	7	1	7	9	3	24
	Subacute	4	4	4	8	6	28
	Chronic	42	19	32	30	26	78
Grade 2							
	Acute	14	0	2	1	1	4
	Subacute	11	0	1	1	1	11
	Chronic	30	2	10	8	11	25
Grade 3							
	Acute	13	1	5	5	0	3
	Subacute	27	3	10	7	0	1
	Chronic	107	19	71	31	17	26
Grade 4							
	Acute	0	0	0	0	0	0
	Subacute	1	1	3	4	0	0
	Chronic	0	2	9	10	7	4

Note: The patients are stratified according to chondral grade (normal, Grades 1, 2, 3, 4) and time from injury (acute, subacute, chronic). Abbreviations: ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LTP, lateral tibial plateau; MFC, medial femoral condyle; MTP, medial tibial plateau.

comparisons of meniscal tear side and location were performed in a post hoc fashion. A priori power analysis is difficult in this situation due to the lack of a universally accepted minimal clinically important difference in number of tears. We feel that a 25% difference in location based on timing would be significant, however, this could be argued. We did not perform statistical analyses on the type of tear as a function of time from injury and chose to report this as descriptive data due to the large number of subgroups to be analyzed. This study was not powered to analyze this data statistically.

To our knowledge, this is the largest collection of patients reviewed to record the changes observed in the associated structures of the ACL-deficient knee. There has been little variation in surgical technique and the data collection has been consistently recorded by the senior author (B.R.B.) in

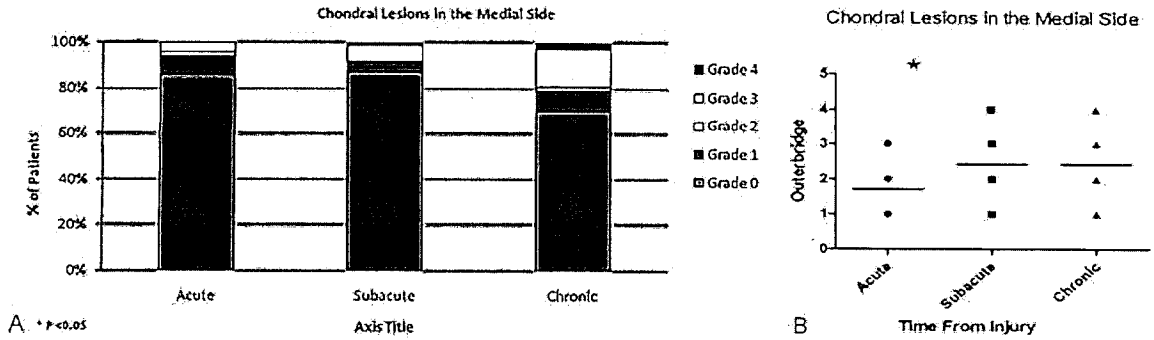

Fig. 8 The percentage of patients among each subgroup with Grade 0 (normal) to Grade 4 changes observed in the medial compartment (femoral condyle or tibial plateau) at the time of surgery (A). Chronically injured patients had a higher incidence of higher chondral grade. Stratification of the chondral grade in the medial compartment according to the time from injury (B). There was a statistically significant ($p = 0.02$)

every ACL reconstruction performed. This method of data collection is similar to those used in previous ACL follow-up studies.[49–54]

Summary

The ACL is vital to the normal kinematics of the knee and the ability for patients to satisfactorily compete in acceleration, deceleration, cutting, and pivoting sports. ACL deficiency has been shown to cause increased contact pressures on the tibiofemoral articular cartilage and produce abnormal stresses on the supporting structures, predisposing these structures to injury. There is an increased incidence of meniscal tears with time from injury to ACL reconstruction. There is also a time-related response to chondral injury after ACL injury with the lateral compartment more often affected acutely and the medial compartment developing injury more chronically.

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