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Range of motion and complications following primary repair versus reconstruction of the anterior cruciate ligament

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ABSTRACT

Introduction: Recently, there has been a resurgence of interest in primary anterior cruciate ligament (ACL) repair. The procedure is less invasive than ACL reconstruction, yet studies assessing early postoperative course are lacking. Goal therefore was to assess postoperative range of motion (ROM), complications and operative times following primary repair and compare this to the gold standard of reconstruction.
Methods: A retrospective study was performed for which 52 repair and 90 reconstruction patients could be included. Patients were examined at one week and one, three and six months. Rehabilitation protocol consisted of early ROM and was equal for both groups. Outcomes were compared using independent t-tests and chi-square tests, and reported in mean ± standard deviation.
Results: Repair had more ROM than reconstruction patients at one week (89° ± 18 vs. 61° ± 21, $p < 0.01$) and one month (125° ± 14 vs. 116° ± 18, $p < 0.01$) postoperatively. Fewer repair patients had 90° ROM at one week (23% vs. 84%, $p < 0.01$), and more repair patients had full ROM at one month (57% vs. 30%, $p < 0.01$). Treatment of meniscal lesions, but not chondral lesions, influenced ROM. Trends towards fewer complications (2% vs. 9%, $p = 0.19$) and infections (0% vs. 6%, $p = 0.20$) were noted following primary repair, and the procedure was significantly shorter. Conclusions: Following primary repair, patients had better ROM, and trends towards fewer complications than reconstruction. Primary repair is a safe, brief procedure with early ROM and low complication rates.

1. Introduction

The first surgical treatment of an anterior cruciate ligament (ACL) injury was performed by Mayo Robson in 1895 using open primary repair [1]. Over the following decades, Ivar Palmer [2,3] and Don O'Donoghue [4,5] further popularized the treatment of open primary ACL repair, and this technique became the most commonly used treatment in the 1970s and 1980s [6–11]. However, because no appropriate patient selection was applied, surgery consisted of an invasive arthrotomy and postoperative management consisted of joint immobilization with a cast for five or six weeks, problems such as decreased range of motion (ROM), intraoperative and postoperative complications, and deterioration of outcomes at mid-term follow-up were frequently reported [11–15]. Ultimately, open primary repair was abandoned and ACL reconstruction became the gold standard [16].

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In recent years, a resurgence of interest has been noted regarding primary repair. With the modern-day understanding of only repairing patients with proximal (type I) tears [14,18–20] (using a recently modified Sherman classification [20,21]), utilizing rehabilitation protocols that stress early ROM [16,19,22], and with the modern advancements of arthroscopic technology [23,24], better results of primary repair could be expected. Indeed, DiFelice et al. were the first to report a case series of 11 patients treated with arthroscopic primary ACL repair of proximal type I tears using suture anchors [25]. They reported excellent outcomes at a mean short-term follow-up of 3.5 years. More recently, Achtnich et al. compared arthroscopic primary repair to the gold standard of single-bundle ACL reconstruction in patients with proximal type I tears, and found equivalent outcomes regarding stability, and patient reported outcomes [26]. More recently, Mackay et al. reported on the addition of an internal brace to the primary repair in order to protect healing of the repaired ligament during early rehabilitation [27].

Arthroscopic primary ACL repair is a conservative and minimally invasive approach when compared to reconstructive surgery, as no tunnels are drilled, no grafts are harvested and revision surgery, when necessary may be less complicated [20]. Furthermore, the native nerve-endings, blood supply and ligament are preserved, and thus proprioception is maintained [28]. With the less invasive nature of this surgery, one could expect a more benign postoperative course with regard to ROM and complications when compared to ACL reconstruction, but studies assessing this are lacking.

Therefore, we aimed to assess the intraoperative and early postoperative course of arthroscopic primary ACL repair patients and compare this to the gold standard of single-bundle ACL reconstruction. The hypotheses were that (I) patients undergoing primary repair had earlier return of ROM and (II) less complications when compared to reconstruction surgery, and (III) primary repair was a shorter surgical procedure than reconstruction surgery.

2. Methods

2.1. Patient selection

Following Institutional Review Board approval (Hospital for Special Surgery IRB 2016-285), a retrospective search was performed in the database of the senior author (GSD) for patients who underwent arthroscopic primary ACL repair and ACL reconstruction between April 2009 and April 2016. In the practice of the senior author, patients with type I ACL tears are treated with arthroscopic primary repair, while patients with non-repairable tears undergo ACL reconstruction. A total of 66 patients underwent primary repair and 109 patients underwent ACL reconstruction. Patients in the repair group were excluded because they had multiligamentous injuries ($n = 6$), distal avulsion tears ($n = 4$), or simultaneously conservatively treated medial collateral ligament (MCL) injuries ($n = 4$), since the focus of the study was to assess primary repair of isolated proximal ACL tears, and since MCL injuries influence postoperative ROM [29,30]. Patients in the reconstruction group were excluded because they had multiligamentous injuries ($n = 17$), or simultaneously conservatively treated MCL injuries ($n = 2$), since the focus of the study was to assess reconstruction of isolated ACL injuries, and since MCL injuries influence postoperative ROM [29,30]. No patients were excluded for meniscus tears or chondral lesions. This resulted in the inclusion of a total of 52 patients that underwent primary repair and 90 patients that underwent ACL reconstruction without any other ligamentous injuries.

2.2. Surgical techniques

Preoperatively, the senior author discussed with all patients that they would undergo primary repair when a proximal (type I) tear was present, and that they would undergo single-bundle ACL reconstruction when the tear was non-repairable. The senior author performed all surgeries. All patients had full ROM (i.e. 0 to ≥130°) preoperatively. Arthroscopic primary ACL repair was performed with suture anchor fixation of the anteromedial and posterolateral bundle as has been previously described [23,24]. An InternalBrace (Arthrex, Naples, FL, USA) was added to the repair in 52% of patients since the availability of this internal brace, as this was thought to protect the ligament with early ROM [19,27,31]. Single-bundle anatomic ACL reconstruction with anteromedial drilling of the femoral tunnel was performed in all patients without repairable tears using either soft tissue allograft tissue (55%) or autograft tissue with bone-patellar tendon-bone (BPTB) (43%) or hamstring autografts (3%). BPTB was fixed using interference screws, while soft tissue grafts were fixed proximally with a button or interference screw, and distally with an interference screw. The specific drilling technique (retrograde versus antegrade) differed throughout the study period.

2.3. Rehabilitation protocol

The rehabilitation protocol was the same for patients undergoing primary repair (with and without internal brace) and reconstruction with an early ROM protocol. A brace is worn in the first four weeks with weight bearing as tolerated. The brace is locked in extension until volitional quadriceps control has returned and is then unlocked for ambulation. Swelling control and ROM exercises are initiated in the first few days after surgery in a controlled fashion. Formal physical therapy is started at four weeks. After four to six weeks, the patient is advanced to gentle strengthening and a standard ACL rehabilitation protocol. Return to sports is generally based upon sport specific assessment between six and nine months postoperatively.

2.4. Data collection

As part of the standard postoperative protocol, all patients presented in the clinic at one week, one month, three months and six months postoperatively. Data collected were information on operative procedures, age, gender, body mass index (BMI), side of injury, time of injury to surgery, other ligamentous injuries, status of meniscus and meniscus procedures, time of surgery (defined as time from incision to closure), status of cartilage and chondroplasty procedures, passive ROM, complications, reoperations and revisions. ROM was measured with a goniometer and defined as the arc of ROM (flexion–extension) and was categorized as limited (<90°), mildly limited (90–130°) and full ROM (≥130°). Additionally, extension deficits were reported separately.

2.5. Statistical analysis

Statistical analysis was performed using SPSS Version 21 (SPSS Inc., Armonk, NY, USA). Independent *t*-tests were used to compare continuous data, whereas chi-square tests and Fisher's exact tests (in case one of the cells was less than 5) were used to compare nominal data. Microsoft Excel 2011 (Microsoft Corp., Redmond, WA, USA) was used to plot ROM graphs with standard deviation (SD) as the error bars. All tests were two-sided and a difference of $p < 0.05$ was considered statistically significant.

3. Results

3.1. Baseline characteristics

Mean age in the primary repair group was higher (33 ± 11 years, range 14–57) than in the reconstruction group (29 ± 9 years, range 14–51) ($p = 0.03$). Mean time from injury to surgery was shorter in the primary repair group (48 ± 39 days, range 5–155) than in the reconstruction group (412 ± 1037 days, range 3–5479) ($p = 0.02$), although three patients in the repair group had chronic ACL tears with a range from injury to surgery of four to 11 years. No significant differences between both groups were noted in gender, side, BMI, or how many days postoperatively patients came in for visits (Table 1). Patients in the reconstruction group had more often meniscal injuries when compared to the repair group ($p < 0.01$). No differences in cartilage damage were noted between both groups ($p = 0.27$) (Table 1).

3.2. ROM

Patients who underwent primary repair had significantly more ROM when compared to patients who underwent reconstruction at one week (89° ± 18 vs. 61° ± 21, $p < 0.01$) and one month postoperatively (125° ± 14 vs. 116° ± 18, $p < 0.01$). This was

Table 1
Patient demographics of patients undergoing primary repair or reconstruction of the anterior cruciate ligament.

	Primary repair n = 52		Reconstruction n = 90		*t*-Test or χ^{2a}
	Mean ± SD	Range	Mean ± SD	Range	*p*-Value
Age (years)	33 ± 11	14–57	29 ± 9	14–51	0.03
BMI (kg/m^2)	25 ± 4	19–35	26 ± 5	18–47	0.11
Delay (days injury – surgery)	48 ± 39[b]	5–155	412 ± 1037	3–5479	0.02
Gender (M:F)	30:22		65:35		0.08
Side (R:L)	29:23		42:48		0.30
First visit (days postop.)	5 ± 2	2–11	5 ± 2	2–10	0.58
Second visit (days postop.)	35 ± 7	20–46	34 ± 7	20–45	0.19
Third visit (days postop.)	93 ± 24	64–129	89 ± 21	59–128	0.35
Fourth visit (days postop.)	190 ± 38	143–224	188 ± 38	148–219	0.81
Concomitant injuries	n (%)		n (%)		*p*-Value
Meniscus					
No meniscal tears	35 (67%)		37 (41%)		<0.01
Meniscal Repair	5 (10%)		19 (21%)		0.08
Meniscectomy	12 (23%)		34 (38%)		0.07
Cartilage					
No damage	40 (77%)		73 (81%)		0.27
TF chondroplasty	5 (10%)		13 (14%)		0.40
Pat. chondroplasty	6 (12%)		2 (2%)		0.02
TF + pat. chondroplasty	1 (2%)		2 (2%)		0.90

BMI indicates body mass index; M, males; F, females; R, right; L, left; n, number of patients; TF, tibiofemoral; pat., patellar.
[a] Independent *t*-test was used to compare repair vs. reconstruction with continuous data and chi-square test (χ^2) was used for nominal or categorical data (i.e. groups).
[b] Three patients had a chronic ACL tear but were excluded for the calculation of delay, as they were outliers. These three patients underwent repair four to 11 years following injury.

Table 2
Range of motion, range of motion groups (very limited vs. limited vs. full range of motion), and extension deficits in patients treated with primary repair and reconstruction.

	Primary Repair	Reconstruction	Independent *t*-test
	Mean ± SD	Mean ± SD	*p*-Value
One week	89° ± 18°	61° ± 21°	<0.01
One month	125° ± 14°	116° ± 18°	<0.01
Three months	137° ± 4°	134° ± 10°	0.03
Six months	138° ± 3°	128° ± 3°	0.91

	Primary repair			Reconstruction			Chi-square test	
	<90°	90–130°	≥130°	<90°	90–130°	≥130°	<90°	≥130°
One week	23%	75%	2%	84%	16%	0%	<0.01	0.79
One month	0%	43%	57%	7%	63%	30%	0.11	<0.01
Three months	0%	0%	100%	1%	9%	90%	>0.99	0.18
Six months	0%	0%	100%	0%	0%	100%	>0.99	>0.99

	Primary repair			Reconstruction			Chi-square test	
Extension deficit	<5°	5–10°	>10°	<5°	5–10°	>10°	<5°	<10°
One week	0%	0%	0%	0%	0%	0%	>0.99	>0.99
One month	4%	4%	0%	4%	3%	0%	>0.99	>0.99
Three months	2%	0%	0%	1%	1%	0%	>0.99	>0.99
Six months	2%	0%	0%	2%	0%	0%	>0.99	>0.99

SD indicates standard deviation.

also seen at three months postoperatively (137° ± 4 vs. 134° ± 10, $p = 0.03$), but this was not clinically relevant. At six months follow-up, all patients had full ROM (Table 2, Figure 1). Furthermore, fewer repair patients had limited ROM when compared to reconstruction patients at one week (23% vs. 84%, $p < 0.01$), and more repair patients had full ROM at one month (57% vs. 30%, $p < 0.01$) (Table 2 and Figure 2). No differences in extension deficits were noted between both groups at all visits (all $p > 0.99$) (Table 2).

In patients without meniscus injury, it was noted that primary repair patients had more ROM at one week (88° ± 16 vs. 57° ± 21, $p < 0.01$) compared to reconstruction patients, but not at other visits. In patients with meniscectomy, patients with primary repair had more ROM at one week (93° ± 23 vs. 60° ± 23, $p < 0.01$) and at one month (129° ± 10 vs. 115° ± 19, $p = 0.02$) compared to reconstruction patients. Similarly, repair patients with meniscal repair had more ROM at one week and one month than reconstruction patients but this was not significant due to the small number of patients in the primary repair group (n = 5) (Table 3). The presence of cartilage injuries and subsequent chondroplasty did not influence ROM in both groups (Table 3, Figure 3).

No differences in ROM were noted between patients treated with primary repair and patients treated with primary repair with the addition of an internal brace (Figure 4). Finally, no differences in ROM were noted between reconstruction with autograft and allograft tissue (Figure 5).

3.3. Complications

When comparing repair with reconstruction, trends towards fewer complications (2% vs. 9%, respectively, $p = 0.19$) and infections (0% vs. 6%, respectively, $p = 0.20$) were noted (Table 4). In the primary repair group, one reinjury (2%) occurred within six months while descending stairs and one technical operative complication (2%) occurred when the tip of the scorpion device broke off and was lost in the ACL ligament, which was treated conservatively without further problems.

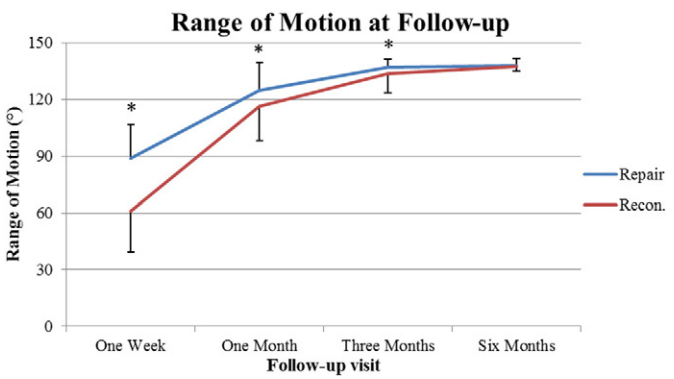

Figure 1. Graph shows mean range of motion in patients that underwent repair versus reconstruction at postoperative visits. The error bars represent standard deviation. Asterix (*) indicates significant differences at one week, one month and three month visits.

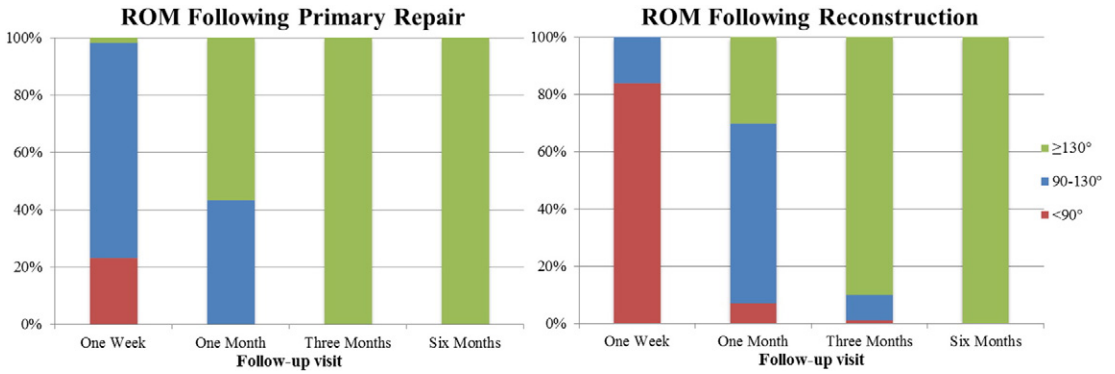

Figure 2. Graph shows the distribution of the range of motion of patients following primary repair (on the left) and reconstruction (on the right) at all visits, stratified by limited (<90°), mildly limited (90–130°) and full (≥130°) range of motion. Repair patients had significantly less often limited ROM at one week and significantly more often full ROM at one month.

In the reconstruction group, one reinjury (1%) (BPTB autograft) occurred while playing soccer, while he was not cleared for return to sports. One patient (1%) who underwent BPTB autograft reconstruction had a patella fracture during physical therapy, and one patient (1%) with a BPTB autograft had a tibial stress fracture. Both were successfully treated conservatively. One technical complication (1%) of a graft-tunnel mismatch occurred intraoperatively (BPTB autograft).

Two patients (2%) developed septic arthritis at one week (hamstring autograft) and two weeks (BPTB autograft) postoperatively, respectively. One patient (1%) had a stitch abscess (BPTB autograft) and two patients (2%) developed superficial infection at the graft-harvesting site (BPTB autograft) and the incision site (soft tissue allograft), respectively. The first three patients all required reoperation, with one of the patients with a deep infection (1%) requiring revision surgery because the graft was damaged and non-functioning and the patients with superficial infections were successfully treated with oral antibiotics.

3.4. Operation time

The operation time of the repair procedure was 74 ± 14 min, and this was faster when compared to repair with internal brace 95 ± 15 min ($p < 0.01$), compared to autograft BPTB reconstruction 129 ± 32 min ($p < 0.01$), and compared to reconstruction

Table 3
Range of motion (mean ± SD) of primary repair vs. reconstruction in different meniscus/cartilage status.

	Primary repair	Reconstruction	*t*-Test
Patients without meniscus injury			
One week	88° ± 16°	57° ± 21°	<0.01
One month	124° ± 16°	121° ± 17°	0.54
Three months	137° ± 4°	133° ± 14°	0.10
Six months	138° ± 4°	138° ± 3°	0.86
Patients with meniscectomy			
One week	93° ± 23°	60° ± 23°	<0.01
One month	129° ± 10°	115° ± 19°	0.02
Three months	136° ± 4°	133° ± 7°	0.23
Six months	137° ± 3°	137° ± 3°	0.75
Patients with meniscus repair			
One week	82° ± 21°	69° ± 19°	0.19
One month	120° ± 17°	110° ± 17°	0.23
Three months	136° ± 3°	135° ± 4°	0.48
Six months	136° ± 3°	138° ± 3°	0.24
Patients without chondroplasty			
One week	88° ± 21°	60° ± 21°	<0.01
One month	125° ± 14°	116° ± 19°	0.01
Three months	137° ± 4°	134° ± 11°	0.11
Six months	137° ± 3°	138° ± 3°	0.51
Patients with chondroplasty			
One week	90° ± 5°	63° ± 23°	<0.01
One month	125° ± 16°	119° ± 14°	0.29
Three months	136° ± 5°	132° ± 6°	0.04
Six months	138° ± 4°	136° ± 2°	0.12

SD indicates standard deviation.

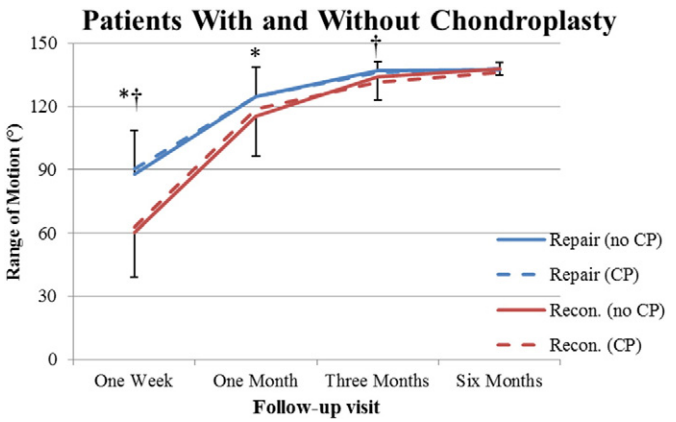

Figure 3. Graph shows mean range of motion in patients that underwent repair versus reconstruction with and without chondroplasty at all visits. The error bars represent standard deviation. Asterix (*) indicates statistical significant difference between repair and reconstruction without chondroplasty, and dagger (†) indicates statistical significant difference between repair and reconstruction in patients with chondroplasty. CP indicates chondroplasty.

allograft 103 ± 20 min ($p < 0.01$). Meniscus treatment did not significantly influence the differences in operation times between the groups (Table 5).

4. Discussion

The main findings of this study were that patients undergoing primary repair had more ROM in the early phases of rehabilitation, and earlier return to full ROM when compared to patients who underwent reconstruction. Furthermore, trends towards fewer complications and infections were noted following primary repair when compared to reconstruction, and it was noted that the primary repair procedure had significantly shorter operative times than reconstruction surgery.

The first hypothesis of this study was that patients undergoing primary repair would have earlier return of ROM when compared to patients undergoing reconstruction surgery. Data in our study indeed showed that patients undergoing primary repair had approximately 30° more ROM in the first week when compared to reconstruction patients, which can likely be explained by less invasive nature of primary repair surgery. Furthermore, it was noted that after one month patients with primary repair had more ROM and twice as many primary repair patients had full ROM (57%) when compared to reconstruction patients (30%). It was also noted that the differences were significant at three months follow-up, but these differences were not considered clinically relevant (137° vs. 134°). At three months follow-up, however, it was noted that 10% of patients undergoing ACL reconstruction had not achieved full ROM while all patients in the repair group had regained full ROM (Figure 2 and Table 2). At six months follow-up, no differences were noted between both patient groups and all patients had regained full ROM without significant extension deficits. It is likely that the more invasive surgery of ACL reconstruction with the drilling of tunnels and graft harvesting (especially BPTB) plays a role in these differences. It should be noted that patients in the reconstruction group were four years younger than patients in the primary repair group but this was not considered clinically relevant.

This is the first study assessing postoperative ROM following arthroscopic primary ACL repair. Comparing these results with studies performing open primary repair in the historical literature is difficult for several reasons. First of all, primary repair in the historical literature was performed via an arthrotomy, which is a significantly more invasive surgery when compared to

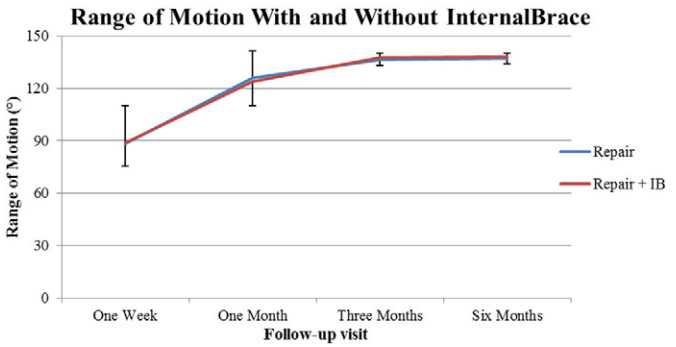

Figure 4. Graph shows mean range of motion in patients that underwent repair with internal brace versus without internal brace at all visits. The error bars represent standard deviation. Differences were not significant at all visits. IB indicates internal brace.

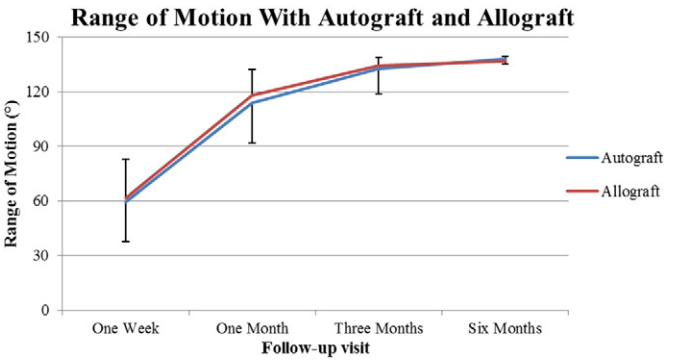

Figure 5. Graph shows mean range of motion in patients that underwent reconstruction with autograft or allograft tissue at different visits. The error bars represent standard deviation. Differences were not significant at all visits.

the current standard of arthroscopic surgery. Secondly, ROM exercises are currently started early (first few days in our study), while patients historically were placed in a cast and immobilized for four to six weeks [10]. Interestingly, Noyes et al. assessed postoperative ROM following ACL reconstruction and compared arthroscopic surgery with arthrotomy and divided patients in these groups in early and delayed motion postoperatively [32]. The authors concluded that there were correlations of better ROM in the early motion group and better ROM in the arthroscopic group when compared to the arthrotomy and delayed motion groups. When reviewing the complications following open primary repair in the historical literature, problems with ROM have been reported up to 77% [33]. In contrast, when reviewing the two recent publications on arthroscopic primary repair [25,26] and the results of this current study, no complications with regard to ROM were noted in the cohorts. It seems that the difference between ROM problems in the historical literature of open primary repair and the excellent ROM in this current study of arthroscopic primary repair can be explained by the minimally invasive procedure and early ROM protocols during rehabilitation. Recently, Murray et al. reported the short-term postoperative course of primary repair using a biological scaffold using an arthrotomy approach [34]. They found an average flexion of approximately 90° at six weeks, which is significantly less when compared to this current study. This might be explained by their arthrotomy approach, and the fact that patients were not allowed to flex their knee beyond 90° for six weeks. It seems that their approach might be midway between the historic arthrotomy and casting approach versus our early ROM approach.

It was further noted that adding an internal brace to the repair did not have an influence on ROM (Figure 4). It should be emphasized that an internal brace, which is practically the addition of a doubled length of stout suture that runs in the anterior third of the ligament that is tensioned with suture anchors [27,35], is different from the recently published technique of the dynamic intraligamentary stabilization (DIS) device [36,37]. With the DIS device, a spring mechanism is placed in the tibia and a braid is placed through the ligament and is fixed proximally on the femoral cortex with a fixation button. With this design, however, many problems have been reported with a 79% complication rate, and a 33% extension deficit rate that required additional reoperation (mostly cyclops lesions) [36], while 60% of the tibial spring mechanisms needed to be removed [37]. This is not surprising as complications with synthetic augmentation devices were frequently reported in the historical literature [38,39]. The internal brace, however, is a minimalist variation of the repair procedure that is only slightly more invasive, and ROM data was not different when compared to primary repair without internal brace in this study. Furthermore, no complications with this technique

Table 4
Complications, reoperations and indicated revisions following primary repair and reconstruction.

	Primary repair n = 52	Reconstruction n = 90	Chi-square test
Reinjury	1 (2%)	1 (1%)	>0.99
Meniscal repair failures	0/5 (0%)	2/19 (11%)	>0.99
Complications	1 (2%)	8 (9%)	0.19
Technical	1 (2%)	1 (1%)	>0.99
Patella fracture	0 (0%)	1 (1%)	>0.99
Tibial stress fracture	0 (0%)	1 (1%)	>0.99
Infections	0 (0%)	5 (6%)	0.20
Deep infection	0 (0%)	2 (2%)	
Stitch abscess	0 (0%)	1 (1%)	
Superficial infection	0 (0%)	2 (2%)	
Total revisions indicated[a]	1 (2%)	2 (2%)	>0.99
Total reoperations[b]	0 (0%)	5 (6%)	0.20

n indicates number of patients.
[a] Revisions indicated means that the anterior cruciate ligament was not functioning and revision surgery was indicated. One patient with a deep infection had a nonfunctioning ligament after treatment and underwent revision.
[b] Two patients with meniscus repair failure, two patients with deep infection and one patients with stitch abscess underwent reoperation.

Table 5
Operation times in minutes of the different procedures.

	All patients		Isolated ACL tear		ACL + meniscus[a]		*t*-Test[b]
	Mn ± SD	Range	Mn ± SD	Range	Mn ± SD	Range	
Repair	74 ± 14	54–98	76 ± 17	54–98	72 ± 7	64–82	0.63
Repair + internal brace	97 ± 15	76–129	98 ± 17	76–129	97 ± 11	84–115	0.95
t-Test	<0.01		0.01		<0.01		
Reconstruction (autograft)	129 ± 32	83–210	124 ± 24	84–161	133 ± 37	83–210	0.42
Reconstruction (allograft)	103 ± 20	64–157	99 ± 20	64–123	105 ± 21	76–157	0.49
t-Test	<0.01		0.02		0.01		

Mn indicates mean; SD, standard deviation; ACL, anterior cruciate ligament; IB, internal brace; Recon, reconstruction.
[a] Meniscus treatment indicates any meniscus treatment (partial meniscectomy and meniscal repair).
[b] Independent *t*-tests compare the operation times between isolated ACL tears and ACL tears with meniscus treatments.

were noted during the first six months postoperatively. Future studies are needed to further assess if the internal brace indeed protects the ligament and decreases reinjury rates.

Taking a close look at the results in this study, it was noted that the meniscus status played a role on ROM. Because the numbers in the subgroups were small (e.g., n = 5 in meniscus repair group of primary repair patients), outcomes were not significantly different in the meniscus repair analysis. It was noted that ROM differences existed between repair and reconstruction in all meniscus groups at one week postoperatively, but that this depended on the meniscus status at one month postoperatively. Interestingly, Herbst et al. recently assessed the postoperative ROM following ACL reconstruction and noted that the incidence of extension deficits was different in patients with and without meniscus injuries [40]. Although no large extension deficits were present in our study, we similarly noted that ROM was influenced by the meniscus status. Studies with larger number of patients are necessary to compare ROM in these meniscus subgroups. Finally, chondroplasty and the use of autograft versus allograft tissue did not seem to play a role on postoperative ROM, which can be expected when comparing these results with studies in the literature [41,42].

With regard to our second hypothesis, low incidences of complications (2%) and infections (0%) were found in the cohort of primary repair patients, and there was a trend that this was lower when compared to reconstruction surgery (9% and 6%, respectively). The low complication rate in the primary repair is likely to be multifactorial with the minimally invasive nature of the procedure, (no drilling of tunnels, graft harvesting or use of allograft tissue), and the shorter operation time with repair procedure compared to the reconstruction procedure (Table 5). This was the first study reporting operative times of arthroscopic primary ACL repair, and comparison with the literature was therefore not possible. Some complications of reconstruction surgery can be contributed to graft harvesting, such as the patella fracture, superficial wound infections around the graft harvesting skin or a graft-tunnel mismatch. Furthermore, the risk for infections is generally increased with a longer surgery time that occurs when graft are harvested or when allograft tissue is prepared for graft placement [43]. Although the incidence of infections and deep infections was high following reconstruction (6% and 2%, respectively), others recent studies have reported similar rates or slightly lower rates when stratifying by type of infection (superficial versus deep) when compared to the literature regarding infections following ACL reconstruction [44,45]. One patient had a tibial stress fracture following ACL reconstruction, which may be explained by the fact that abnormal contact stresses occur following ACL reconstruction [46]. It is currently not known if primary repair restores normal kinematics and contact stresses, and studies are necessary to compare the contact stresses following repair vs. reconstruction. Results in this study, nonetheless, showed that complications and infections are rare following arthroscopic primary ACL repair and that this procedure is both safe and relatively expeditious when compared to ACL reconstruction. Larger studies are necessary to assess if the differences between reconstruction and repair are also statistically significant.

Limitations in this study existed. First of all, due to the retrospective design it was not possible to assess if individual adjustments were made during the rehabilitation, despite the fact that the same protocol was used for all patients. Similarly, differences in delay of injury to surgery were present in both groups, which could have led to altered kinematics in the reconstruction group [47]. We believe, however, that this study simulates the clinical setting of acutely treating the subgroup of patients that are repairable [20,26], while reconstruction patients that are not repairable in a delayed stage. Similarly, differences in age and BMI were noted in both groups, which should be considered when reviewing the outcome sin this study, although we believe these differences are small with regards to clinical relevance. Furthermore, baseline characteristics, such as smoking status, were not available and the study cohort was too small to perform multivariate analysis to correct for BMI or graft type, as these factors can increase the risk for infections. Also, the operative times of the procedures were relatively long. This could be explained that no residents or fellows were present at the surgeries, and that the senior author therefore had to prepare the graft himself. However, when comparing the operative times of primary repair with the operative times of ACL reconstruction in the literature, it can be noted that the primary repair procedure is still shorter [48]. Furthermore, the primary repair procedure in this study included the learning curve for the senior author, and a trend was noted towards shorter operative times as the learning curve was passed, which if included in this analysis, would show a greater difference between both procedures. Also, the numbers of patients were relatively small in this cohort, but we believe that this represents a typical volume for a general orthopaedic surgeon performing ACL surgery, and that the results are therefore generalizable to the average volume orthopaedic surgeon. Finally, the numbers of patients for comparing complication rates were too small to show significance and larger studies or registry studies are necessary to compare complication rates between primary repair and reconstruction surgery. We, however, believe that, based on this data, it can be concluded that primary repair is a safe and minimally invasive procedure.

5. Conclusion

Patients undergoing arthroscopic primary repair for proximal (type I) tears had more ROM and regained earlier full ROM in the early phases of rehabilitation when compared to patients undergoing ACL reconstruction. Furthermore, a trend of lower complications and fewer infections was seen following primary repair compared to reconstruction, which may be explained by the less invasive nature of the surgery and shorter surgery time. Based on these results, primary repair appears to be a relatively quick and safe procedure with early return of ROM and a low complication rate.

Disclosures

Author JPL declares he has no conflict of interest. Author GSD declares he is a paid consultant for Arthrex (Naples, FL, USA) but this has not conflicted this study.

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