

Systematic Review

Treatment of Meniscus Tears During Anterior Cruciate Ligament Reconstruction

Frank R. Noyes, M.D., and Sue D. Barber-Westin, B.S.

Purpose: To define the incidence of meniscectomy, meniscus repair, and meniscus tears left in situ during anterior cruciate ligament (ACL) reconstruction. **Methods:** A systematic search of PubMed and 7 sports medicine journal databases was performed to determine the treatment of meniscus tears during ACL reconstruction. Inclusion criteria were English language, publication in the last 10 years, clinical trials, all evidence levels, and skeletally mature or immature knees. Exclusion criteria were revision ACL reconstruction, concomitant ligament reconstruction, and studies with exclusion or inclusion criteria regarding meniscus surgery during ACL reconstruction. **Results:** Of 634 articles identified, 159 met the inclusion criteria, encompassing 19,531 patients. There were 11,711 meniscus tears; they were treated by meniscectomy in 65% (7,621 tears), treated by repair in 26% (3,022 tears), or left in situ in 9% (1,068 tears). Only 19 studies analyzed the treatment of meniscus tears according to the tibiofemoral compartment. These reported medial compartment tears were treated by meniscectomy in 63%, treated by repair in 27%, and left in situ in 9%. Lateral compartment tears were treated by meniscectomy in 71%, treated by repair in 14%, and left in situ in 14%. Only 24 studies identified the type of meniscus repair procedure performed. In 33 studies (21%) repair was performed more frequently than meniscectomy. **Conclusions:** Meniscectomy is performed 2 to 3 times more frequently than meniscus repair during ACL reconstruction. We were unable to analyze the effect of the location and type of meniscus tear, sex, age, or chronicity of injury on the treatment of meniscus tears. The number of potentially repairable meniscus tears that were treated by resection could not be identified. **Clinical Relevance:** This study found that meniscectomy was performed in 65% of meniscus tears. This is concerning because studies have shown that, regardless of knee stability obtained after ACL reconstruction, meniscectomy accelerates degenerative joint changes. **Level of Evidence:** Level IV, systematic review of Level I to IV studies.

The importance of the menisci for normal function in the human knee is well understood, especially in younger patients who are athletically active or involved in strenuous occupations. The menisci pro-

vide several vital mechanical functions in the knee joint, and loss of meniscal function leads to instability, symptoms of pain and swelling, loss of tibiofemoral joint space, and articular cartilage degeneration.¹⁻⁶ Unacceptable long-term clinical results after partial and total meniscectomy have been reported by many investigations.⁷⁻¹⁰

A common injury in younger active patients is a combined anterior cruciate ligament (ACL) rupture and meniscus tear. An estimated 200,000 individuals in the United States incur an ACL rupture each year, and approximately 40% to 60% of these also sustain meniscus tears.^{11,12} Studies have shown that, regardless of the outcome of ACL reconstruction in terms of restoration of knee stability, meniscectomy (performed

From the Cincinnati Sportsmedicine Research and Education Foundation, Cincinnati, Ohio, U.S.A.

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Address correspondence to Sue D. Barber-Westin, B.S., c/o Cincinnati Sportsmedicine Research and Education Foundation, 10663 Montgomery Road, Cincinnati, OH 45242, U.S.A. E-mail: sbwestin@csmref.org.

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before, during, or after ACL surgery) accelerates degenerative joint changes.¹³⁻¹⁸ Therefore preservation of meniscal tissue and function in addition to restoration of normal knee stability is critical for long-term knee joint function.

Since early reports of arthroscopic meniscus repair appeared in the 1980s,^{19,20} this procedure has been described and the results presented in well over 100 publications.²¹ Encouraging success rates have been reported for tears located in both the periphery (or outer one-third region) and the central avascular region.^{21,22} However, it remains unclear how many meniscus tears are repaired, excised, or left in situ during ACL reconstruction in the modern literature. The purpose of this systematic review was to define the incidence of meniscectomy, meniscus repair, and tears left in situ during ACL reconstruction over the last decade. Our hypothesis was that there would be a higher incidence of meniscectomies compared with meniscus repairs and tears left in situ.

METHODS

Literature Search

We searched Medline for all published literature from April 2001 to April 2011 using the following key words: anterior cruciate ligament reconstruction, ACL reconstruction, meniscus repair, ACL, and meniscus. We also conducted manual searches of the following journals published during this time period: *The American Journal of Sports Medicine*, *Arthroscopy*, *The Journal of Bone and Joint Surgery* (both the American and British volumes), *The Knee*, *Clinical Orthopaedics and Related Research*, and *Knee Surgery Sports Traumatology Arthroscopy*.

Inclusion criteria were English language, clinical trials, original research reports, Level I to IV evidence, skeletally mature and immature knees, and primary ACL reconstruction (any graft type). Exclusion criteria were revision ACL reconstructions; dislocated knees; major concomitant procedures such as high tibial osteotomy, meniscus allograft, or other knee ligament reconstruction; and other types of publications such as reviews, case reports, abstracts, and technical notes. We also excluded studies that specifically excluded patients with concomitant meniscus repairs or concomitant meniscectomy (partial or total) or that only focused on combined ACL reconstruction–meniscus procedures.

Data Abstraction

Each study that met the inclusion criteria was abstracted for information regarding (1) the number of all patients, sorted according to sex when provided; (2) patient age at ACL reconstruction (mean and range); (3) the amount of time from the initial injury to the ACL reconstruction (acute, chronic, or both combined); (4) grafts used for ACL reconstruction; (5) skeletally mature or immature population; and (6) country of first author. The articles were reviewed for information regarding meniscus tears and treatment during the ACL reconstruction, including (1) number of meniscus tears, (2) location of meniscus tears, (3) type of meniscus tears, (4) number and tibiofemoral compartment of meniscectomies, (5) number and tibiofemoral compartment of meniscus repairs, (6) type of meniscus repairs, and (7) number and tibiofemoral compartment of meniscus tears left in situ.

RESULTS

Literature Search

Our search initially identified 634 articles, of which 328 were excluded according to our study criteria. We reviewed 306 articles, of which 147 also had to be excluded because they failed to provide data regarding meniscus pathology or meniscus procedures performed or because they combined numbers of meniscectomies and repairs together (Fig 1). This left 159 articles that met our inclusion criteria and were included in this investigation.

Patient and Study Characteristics

There were a total of 19,531 patients in the 159 studies. Of these, 143 studies stratified the cohort according to sex and comprised 10,744 male and 6,921 female patients. The mean age in the 154 studies of skeletally mature patients was 29 ± 6 years (range, 13 to 66 years). Five articles focused on skeletally immature patients aged 3 to 17 years (Tanner stages 1 to 4). The chronicity of the ACL injury was designated as acute in 5 studies, chronic in 20, and a combination of both acute and chronic in 124, whereas it was not provided in 10 studies. The ACL grafts included allografts (patellar tendon, Achilles tendon, tibialis tendon), autografts (patellar tendon, quadriceps tendon, semitendinosus-gracilis tendons), double-bundle autografts and allografts, and synthetic grafts. There were 26 countries of origin, with the

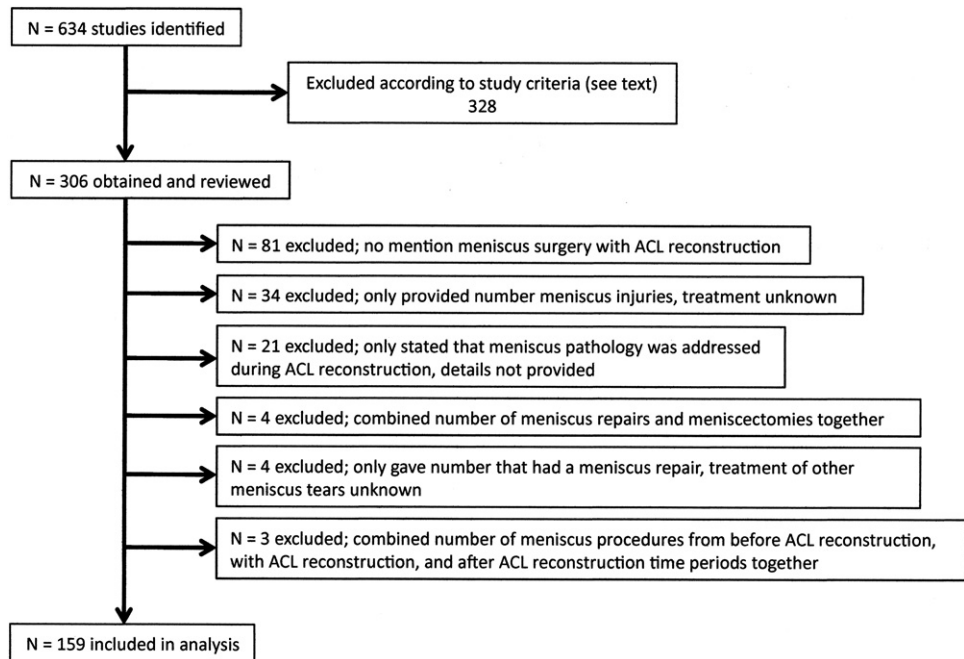


FIGURE 1. Flowchart of number of studies reviewed.

most common being the United States, in 43 studies; Japan, in 17 studies; and Italy, in 16 studies.

Treatment of Meniscus Tears

Partial or total meniscectomy was used in all 159 studies; meniscus repair, 122 studies; and tears left in situ, 32 studies. There were a total of 11,711 meniscus tears in the 159 studies. These were treated by meniscectomy in 65% (7,621 tears), treated by repair in 26% (3,022 tears), or left in situ in 9% (1,068 tears). Nineteen studies described the treatment of meniscus tears according to the involved tibiofemoral compartment. In the medial compartment, meniscus tears were treated by meniscectomy in 63%, treated by repair in 27%, and left in situ in 9%. In the lateral compartment, meniscus tears were treated by meniscectomy in 71%, treated by repair in 14%, and left in situ in 14%.

Insufficient data from the studies analyzed precluded an analysis of the effect of the location and type of meniscus tear, sex, age, or chronicity of the injury on the treatment of meniscus tears during ACL reconstruction. Twenty-four studies identified the type of meniscus repair procedure performed. These included inside-out suture repair in 12 studies, suture repair (exact type unknown) in 7, all-inside repair in 2, arrows and suture repair in 2, and arrows in 1. A high rate of meniscus repairs was found in the studies from countries most commonly analyzed in this review, the United States and Japan (Table 1).

Of the studies, 5 reported results on 160 skeletally immature patients, in whom 100 meniscus tears were sustained. Of these, 31% were partially removed, 55% were repaired, and 14% were left in situ. The 154 studies on 19,371 skeletally mature patients with

TABLE 1. Trends for Meniscus Repair With ACL Reconstruction According to Country of Study Origin

Country	Total No. of Studies	No. of Studies With Meniscus Repair	No. of Studies With No Meniscus Repair
United States	43	41 (95%)	2
Japan	17	16 (94%)	1
Italy	16	9 (56%)	7
Finland	9	9 (100%)	0
Germany	9	7 (78%)	2
Sweden	8	4 (50%)	4
China	7	6 (86%)	1
France	7	3 (43%)	4
Australia	6	4 (67%)	2
South Korea	4	4 (100%)	0
Turkey	4	2 (50%)	2
United Kingdom	4	1 (25%)	3
Switzerland	3	3 (100%)	0
Canada	3	3 (100%)	0
Austria	3	2 (67%)	1
Norway	3	1 (33%)	2

NOTE. Countries with 3 or more studies were included in this analysis.

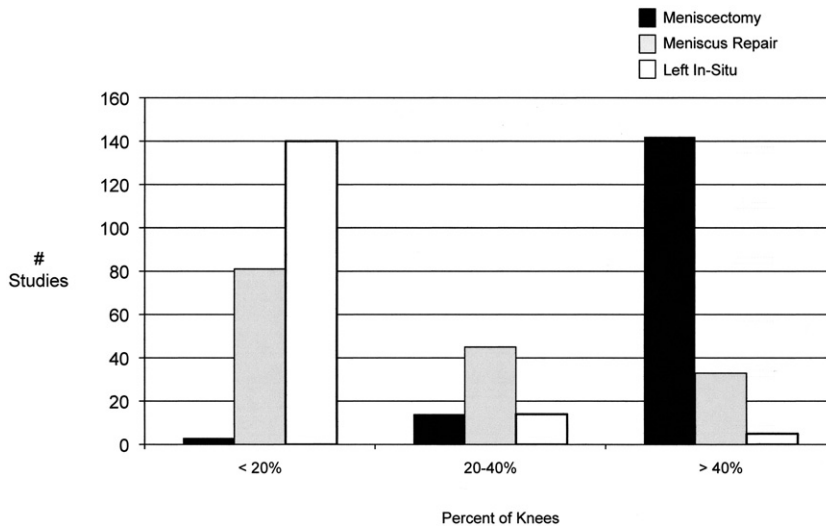


FIGURE 2. Treatment of meniscus tears during ACL reconstruction. Fewer than 20% of knees with meniscus tears underwent repair in 80 of the 159 studies analyzed. More than 40% of knees with meniscus tears underwent meniscectomy in 141 studies.

11,611 meniscus tears showed that 65% underwent meniscectomy, 25% had a meniscus repair, and 9% were left in situ.

There were 33 studies in which more than 40% of the meniscus tears were treated with repair (Fig 2). These studies involved 3,056 patients who had 1,969 meniscus tears. Of these, 58% (1,146 tears) had meniscus repairs, 40% (787 tears) had meniscectomies, and 2% (36 tears) had the tears left in situ. In comparison, meniscus tears in the other 126 studies (encompassing 16,475 patients with 9,766 meniscus tears) were treated with meniscectomy in 70% (6,834 tears), treated with meniscus repair in 19% (1,876 tears), or left in situ in 11% (1,056 tears).

DISCUSSION

This systematic review summarized data from 159 studies over the last 10 years to determine the treatment of meniscus tears during ACL reconstruction. The evidence showed that meniscectomy was the most common method of treatment, performed overall in 65% of the meniscus tears. This is concerning because studies have shown that, regardless of the outcome of ACL reconstruction in terms of restoration of knee stability, meniscectomy accelerates degenerative joint changes.¹³⁻¹⁸ Lubowitz and Poehling²³ recently stressed to “save the meniscus” and pointed out that arthroscopic partial meniscectomy is the most common orthopaedic procedure performed in the United States. Our review was unable to determine the effects of sex, age, chronicity of the injury, and type or location of meniscus tears on the ensuing treatment during ACL reconstruction.

Other authors have reviewed large cohorts and provided recent data regarding the treatment of meniscus tears during ACL reconstruction (Table 2). Fetzer et al.¹¹ analyzed the Multicenter Orthopaedic Outcomes Network (MOON) prospective cohort regarding the incidence and treatment of meniscus tears during ACL reconstruction in a group of 1,104 knees operated on between January 2002 and December 2003. Medial meniscus tears were recorded in 352 knees, of which 55% were excised, 31% were repaired, and 14% were left alone. Lateral meniscus tears were documented in 433 knees, of which 67% were excised, 12% were repaired, and 21% were left alone. The authors estimated that, given the 200,000 ACL reconstructions performed in the United States annually, a potential market exists in approximately 160,000 knees for either advanced meniscus repair techniques, tissue engineering strategies with implants, or scaffold replacements. They noted that many supporting data exist that suggest that preservation of meniscus function is a key factor in the successful long-term outcome of ACL reconstruction.

Magnussen et al.²⁴ compared data on primary isolated ACL reconstructed knees from the MOON database (from January 1 to December 31, 2002, and June 2007 to May 31, 2008) and the Norwegian National Knee Ligament Registry (NKLR) (from June 7, 2004, to December 31, 2007) to determine differences between these cohorts regarding patient demographics, initial treatment of the injury, associated injuries, and ACL graft selection. A total of 713 patients were selected from the MOON database and 4,928 from the NKLR. There were 2,824 meniscus procedures in the

TABLE 2. Comparison of Study Results With Published Data of Treatment of Meniscus Tears During ACL Reconstructions Performed in Last 10 Years

Study	Medial Compartment				Lateral Compartment			
	No. of Meniscus Tears	Meniscectomy	Meniscus Repair	Left In Situ	No. of Meniscus Tears	Meniscectomy	Meniscus Repair	Left In Situ
Current study	2,654	1,683 (63%)	724 (27%)	247 (9%)	2,260	1,600 (71%)	314 (14%)	319 (14%)
Fetzer et al. ¹¹ (2009)	352	192 (55%)	110 (31%)	50 (14%)	433	290 (67%)	51 (12%)	92 (21%)
Magnussen et al. ²⁴ (2010)*								
MOON database	273	123 (45%)	106 (39%)	33% (12%)	319	195 (61%)	45 (14%)	67 (21%)
NKLR	1,642	1,018 (62%)	361 (22%)	164 (10%)	1,235	865 (70%)	111 (9%)	160 (13%)

*Tears treated with trephination are not shown.

5,641 knees, which consisted of 2,201 meniscectomies (39% of knees) and 623 meniscus repairs (11% of knees). The authors noted that meniscectomy was more commonly performed in the NKLR population, whereas repair and no treatment (observation) were more frequently used in the MOON cohort ($P < .05$).

Musahl et al.²⁵ analyzed the American Board of Orthopaedic Surgery database to calculate the frequency of concomitant meniscectomy and meniscal repair in patients undergoing ACL reconstruction. From 2003 to 2007, there were 4,088 patients entered into the database who underwent ACL reconstruction and concomitant meniscus surgery. Of these, 2,836 (34%) underwent partial meniscectomy and 1,251 (15%) underwent meniscal repair. Meniscal repair was performed in 746 patients (18.6%) who were aged less than 25 years, 452 patients (13.8%) aged between 25 and 39 years, and 112 patients (8.1%) aged 40 years or older. The authors also reported that meniscal repair was more likely to be performed by a sports medicine fellowship-trained surgeon (16.6%) than a general orthopaedic surgeon (11.7%) or other fellowship-trained surgeon (12.0%) ($P < .001$). Sports medicine fellowship-trained surgeons performed partial meniscectomy twice as frequently as meniscal repair during ACL reconstruction (2,000 and 983 procedures, respectively), whereas other surgeons were nearly 3 times more likely to perform partial meniscectomy than repair (925 and 327 procedures, respectively). Still, the number of meniscus repairs reported to the American Board of Orthopaedic Surgery database was small compared with the overall incidence of meniscal tears that have historically been reported to occur with ACL injuries (55% to 65%).

Musahl et al.²⁵ speculated that 1 potential problem

with performing concomitant meniscal repair with ACL reconstruction may be financial compensation. According to calculations based on an urban academic medical center (University of Pittsburgh Medical Center, Pittsburgh, PA), these authors stated that concomitant coding of meniscal repair reimbursed an additional \$304 (to the \$882 for ACL reconstruction) compared with an additional \$281 for meniscectomy. The difference in net gain of only \$23 for meniscal repair represents potential problems with regard to the additional time of the surgeon and operating room staff and expense required for all-inside devices.

Studies have shown that, regardless of the outcome of ACL reconstruction in terms of restoration of knee stability, meniscectomy accelerates degenerative joint changes.¹³⁻¹⁸ Nakata et al.,¹⁶ in a 10-year follow-up of 61 patients who had undergone allograft ACL reconstruction, reported that radiographic degenerative changes were present in 13 of 15 knees that had undergone meniscectomy (87%) compared with 12 of 46 knees (26%) with intact menisci ($P < .05$). The failure rate of the ACL grafts was 7%. Cohen et al.¹⁷ found a significant association ($P < .0001$) between meniscectomy and radiographic joint deterioration in a group of 62 patients followed up for 10 to 15 years after ACL reconstruction. The presence of bilateral meniscal tears was associated with arthrosis in both the medial and lateral tibiofemoral compartments. Hart et al.¹⁸ used both radiographs and single photon emission computed tomography in 31 patients 9 to 13 years after ACL patellar tendon autograft reconstruction. By use of weight-bearing radiographs, the incidence of joint degeneration was 13% in knees with intact menisci and 44% in knees that had undergone meniscectomy. When data from the single photon

emission computed tomography scans were considered, the incidence of arthrosis was 7% in knees with intact menisci and 31% in knees that had undergone meniscectomy. Salmon et al.¹³ reviewed 43 patients at 13 years after ACL patellar tendon autograft reconstruction and reported a significant association between poor joint degeneration grades and medial meniscectomy ($P = .006$). Patients who had undergone meniscectomy also had increased laxity with time ($P = .03$) and greater odds of graft rupture by a factor of 6 ($P = .05$). ACL graft rupture occurred in 21% of knees that had undergone meniscectomy compared with 8% of those with intact menisci.

Of the studies in our review, 33 (21%) had a higher rate of meniscus repair compared with meniscectomy. Regarding the meniscus procedures performed in these studies and those in the other 126 articles, repair was performed in 59% and 19%, respectively, and meniscectomy was performed in 40% and 70%, respectively. The type of meniscus repair was only discussed in 9 of the 33 studies, and none provided information regarding the location of the tears. Three of these investigations focused on skeletally immature athletes. These data show tremendous disparity among authors in their approach to treating meniscus tears.

Data from the studies reviewed on 160 skeletally immature patients showed higher rates of meniscus repair compared with those of skeletally mature athletes (55% v 25%) and lower rates of meniscectomy (31% v 65%). This is encouraging, because loss of meniscus tissue in children carries a poor prognosis for future joint arthrosis.²⁶

Only 19 studies analyzed the treatment of meniscus tears according to the tibiofemoral compartment. These showed a higher rate of meniscus repairs performed in the medial compartment compared with the lateral compartment (27% v 14%). This discrepancy was also found in the investigations by Fetzer et al.¹¹ and Magnussen et al.²⁴ (Table 2). Other studies that focused on meniscus repair have reported satisfactory success rates with lateral meniscus repairs, which in some cases were higher than those with medial repairs.²⁷⁻²⁹ Techniques for performing lateral meniscus repairs have been reported in detail elsewhere.²¹

We found that 1,068 of the 11,711 meniscus tears (9%) were left in situ. Pujol and Beaufilets³⁰ conducted a systematic review of clinical studies that treated stable peripheral meniscus tears with this method at the time of ACL reconstruction to determine the outcome. Overall, in the 10 studies included, residual pain or subsequent meniscectomy occurred in 10% to 66% of medial menisci and 0% to 22% of lateral

menisci. Healing assessed with follow-up arthroscopy or arthrography was documented in 3 studies. Complete healing occurred in 50% to 61% of medial menisci and in 55% to 74% of lateral menisci. The authors concluded that the high prevalence of failures of medial menisci left in situ was concerning and that repair was the preferable treatment option.

Repair of meniscus tears located in the periphery (outer third) is associated with a well-known high success rate. In addition, studies have shown satisfactory outcome of repair of complex multiplanar tears that extend into the central-third avascular region.^{7,21,22,29,31,32} Inside-out vertical mattress suture repair remains the gold standard because of the superior biomechanical properties of mean load to failure, stiffness, and lower displacement during cyclic loading compared with horizontal sutures and all-inside devices. Even so, all-inside meniscus repairs have become common due in part to simpler surgical technique, reduction of operating room time, and avoidance of the accessory incisions. Lozano et al.³³ conducted a systematic review of all-inside meniscus repair devices that involved 31 clinical studies. The lack of randomization and short-term clinical follow-up did not allow for conclusions to be reached regarding the various repair devices assessed. High failure rates were found with increasing passage of time for meniscus arrows and T-fix (Acufex Microsurgical, Inc, Mansfield, MA) devices. Long-term studies have shown that successful meniscus suture repairs provide a chondroprotective effect to the involved tibiofemoral compartment.^{7,29} Stein et al.⁷ reported no radiographic evidence of joint arthritis (Fairbank grade 0) at a mean of 8.8 years postoperatively in 81% of patients who underwent isolated meniscus repair compared with 40% of those who had meniscectomy. Noyes et al.²⁹ reported no significant difference in the mean articular cartilage scores obtained from T2 magnetic resonance imaging between the involved and contralateral tibiofemoral compartments in the same knee in patients with healed red-white longitudinal meniscus repairs examined at a mean of 16.8 years postoperatively.

No standard currently exists in the orthopaedic and sports medicine literature for terminology and classification of meniscus tears. A reliable and validated documentation system would be helpful and allow pooling of resources from different institutions to better report the treatment of meniscus tears and determine outcomes according to tear pattern, location, quality of tissue, and other variables. In this manner, the International Society of Arthroscopy, Knee Sur-

TABLE 3. Portions of the ISAKOS Meniscus Classification System³⁴

Factor	Possible Responses
Location: rim width (see diagram in original article for description)	Zone 1 Zone 2 Zone 3
Tear pattern	Longitudinal-vertical; extension is a bucket-handle tear Horizontal Radial Vertical flap Horizontal flap Complex
Quality of tissue	Nondegenerative Degenerative Undetermined
Length of tear	— mm
Percentage of meniscus excised	— %

gery & Orthopaedic Sports Medicine knee committee recently developed a meniscus classification system.³⁴ A portion of this system is shown in Table 3. A recent pilot study determined that this system has sufficient interobserver reliability, with 87% agreement among 8 committee members (based on grading of arthroscopic videotapes) for anterior-posterior location of tear, 79% agreement for tear pattern, and 88% agreement for tear depth. Consideration of use of this system would be appropriate for future studies.

The limitations to this review were the inability to determine the effects of sex, age, chronicity of the original injury, and type or location of meniscus tears on the treatment of these tears during ACL reconstruction. We could not determine how many of the meniscus tears that were resected could have possibly been repaired. Whether the percentage of meniscectomies that were performed represented that actual number of unreparable tears is unknown.

SUMMARY

We reviewed 159 studies published from April 2001 to April 2011 to determine the treatment of meniscus tears during ACL reconstruction. There were a total of 11,711 meniscus tears in the 19,531 patients included in these studies. The meniscus tears were treated by meniscectomy in 65%, treated by repair in 26%, and left in situ in 9%. Disparity exists among surgeons and institutions regarding the frequency of the use of meniscus repair during ACL reconstruction. Of the studies, 33 (21%) performed

repair more frequently than meniscectomy (repair in 59% and 19%, respectively, and meniscectomy in 40% and 70%, respectively.) There appears to be a higher rate of medial meniscus repairs performed compared with lateral meniscus repairs for unknown reasons. An analysis could not be performed of the effect of the location and type of meniscus tear, sex, age, or chronicity of the injury on the treatment of meniscus tears during ACL reconstruction.

CONCLUSIONS

Meniscectomy is performed 2 to 3 times more frequently than meniscus repair during ACL reconstruction. Insufficient data precluded an analysis of the effect of the location and type of meniscus tear, sex, age, or chronicity of the injury on the treatment of meniscus tears during ACL reconstruction. The number of potentially repairable meniscus tears that were treated by resection could not be identified.

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