Outcomes After Biologically Augmented Isolated Meniscal Repair With Marrow Venting Are Comparable With Those After Meniscal Repair With Concomitant Anterior Cruciate Ligament Reconstruction

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Background: Meniscal repair in the setting of anterior cruciate ligament (ACL) reconstruction has demonstrated superior outcomes compared with isolated meniscal repair. Limited evidence exists for the effects of biological augmentation in isolated meniscal repair, particularly as compared with meniscal repair with concomitant ACL reconstruction.

Purpose/Hypothesis: The purpose of this study was to compare the outcomes and survivorship of meniscal repair in 2 cohorts of patients: meniscal repair with biological augmentation using a marrow venting procedure (MVP) of the intercondylar notch, and meniscal repair with concomitant ACL reconstruction. We hypothesized that the clinical outcomes and survivorship of meniscal repair with concomitant ACL reconstruction would be improved compared with meniscal repair with biological augmentation.

Study Design: Cohort study; Level of evidence, 3.

Methods: Inclusion criteria were skeletally mature patients aged $\geq$16 years who underwent inside-out meniscal repair and either a concomitant MVP of the intercondylar notch or ACL reconstruction. Patients were excluded from this study if they were skeletally immature, underwent meniscus root or radial tear repair, or underwent meniscal repair with concurrent ligamentous reconstruction not limited to the ACL. At the preoperative evaluation and a minimum 2 years after the index meniscal repair procedure, patients were administered a subjective questionnaire. Differences in outcome scores, survivorship, and failure rates between the cohorts were assessed. Failure was defined as reoperation with meniscectomy or revision meniscal repair.

Results: There were 109 patients (52 female, 57 male) who met the inclusion criteria for this study. There were 37 knees in cohort 1 (isolated meniscal repair plus MVP) and 72 knees in cohort 2 (meniscal repair plus ACL reconstruction). The failure status was known in 95 patients, and patient-reported outcome scores were obtained in 89 (82%) patients. Both cohorts demonstrated a significant improvement in all outcome scores, and there was no significant difference in any of the preoperative or postoperative outcome measures. The overall failure rate was 9.5% (9/95). There were 4 (12.9%) failures in cohort 1 and 5 failures (7.8%) in cohort 2, with no significant difference in failures between the cohorts (P = .429). There was a significant association between failure and female sex (P = .001).

Conclusion: The most important finding in this study was that there was no difference in outcomes in meniscal repair performed with biological augmentation using an MVP versus that performed concomitantly with ACL reconstruction. The similar outcomes reported for meniscal repair with an MVP and meniscal repair with ACL reconstruction may be partly attributed to biological augmentation.

Keywords: meniscal repair; vertical mattress suture; inside-out repair; biological augmentation; marrow stimulation; ACL reconstruction; patient-reported outcomes

Meniscal repair procedures are increasingly performed because of an enhanced understanding of the long-term deleterious consequences of meniscectomy, the benefits of meniscal preservation, and the improved techniques and devices available for meniscal repair.[32] While meniscal repair has demonstrated a higher reoperation rate than meniscectomy,[32] recent studies have reported that meniscal repair results in improved long-term outcomes when compared with meniscectomy.[32] If the anatomic meniscal

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shape is not restored, the chondroprotective function of the meniscus is disrupted, predisposing the joint to early degenerative changes and increased morbidity.[14]

While the decision for meniscal repair or meniscectomy is typically determined based on the tear pattern and location, the ultimate surgical decision is based on the preference of the treating surgeon. When meniscal repair is indicated, several techniques can be utilized.[4,12] Of these, the inside-out technique allows for versatility and improved surgical precision, avoids leaving prominent intra-articular structures that could damage the articular cartilage,[19,30] and allows for a greater number of low-profile sutures that do not alter the meniscal structure. Further, most types of meniscal tears can be repaired with the inside-out technique.[12] There are, however, potential complications associated with inside-out techniques that are minimized or eliminated with all-inside techniques.

Meniscal tears repaired at the time of anterior cruciate ligament (ACL) reconstruction have demonstrated improved outcomes when compared with those repaired in isolation.[14,21,29] While the average failure rate was 23% in the overall population,[22] Westermann et al[30] reported a 14% failure rate at 6 years' follow-up in 235 patients with ACL reconstruction. Similarly, Feng et al[9] reported a 100% failure rate if the objective arthrometer-measured laxity was greater than 5 mm. It has been theorized that the reason behind these improved outcomes relates to a favorable healing environment created by biological augmentation of the repair from the intra-articular release of peptides, growth factors, and pluripotent cells from the bone marrow when drilling the ACL reconstruction tunnels.[14] In an attempt to re-create this favorable healing response, bone marrow stimulation procedures, such as venting of the intercondylar notch, have been performed in conjunction with isolated meniscal repair procedures as a potential option to enhance healing of the repair.[1,10] In this regard, several studies have reported that the introduction of bone marrow components has resulted in improved healing of meniscal tears.[2,15]

The purpose of this study was to compare the meniscal repair outcomes and survivorship in 2 cohorts of patients: meniscal repair with biological augmentation from a marrow venting procedure (MVP) of the intercondylar notch, and meniscal repair with concurrent ACL reconstruction. We hypothesized that the clinical outcomes and survivorship of meniscal repair with concomitant ACL reconstruction would be superior to meniscal repair with biological augmentation.

METHODS

This study was approved by our institutional review board. Inclusion criteria were skeletally mature patients aged ≥16 years with an isolated meniscal tear or a meniscal tear with an ACL rupture who underwent inside-out meniscal repair by a single surgeon (R.F.L.) between June 2010 to April 2014. Included patients underwent either isolated meniscal repair with a concomitant MVP of the intercondylar notch or meniscal repair performed concomitantly with ACL reconstruction. The age of inclusion (16 years old) was chosen to eliminate patients who were skeletally immature and to capture only those with closed physes. Patients were excluded from this study if they had a meniscus root[17] or radial tear or had undergone meniscal repair with concurrent ligamentous repair or reconstruction not limited to the ACL. Demographic data were documented at the initial clinical evaluation (Table 1).

TABLE 1
Patient Demographics by Cohort[a]

	Cohort 1: Meniscal Repair Plus MVP (n = 37)	Cohort 2: Meniscal Repair Plus ACLR (n = 72)	*P* Value
Sex, n			.888
Female	18	34	
Male	19	38	
Age, mean (range), y	37 (18-82)	33 (17-65)	.227
BMI, mean (range), kg/m^2	23.6 (16.7-33.3)	23.9 (18.6-32.3)	.443

[a]ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; MVP, marrow venting procedure.

Patients were categorized into 2 cohorts: inside-out meniscal repair with an MVP as biological augmentation (cohort 1), and inside-out meniscal repair with concomitant ACL reconstruction (cohort 2). Preoperatively and at a minimum 2 years after the index meniscal repair procedure, patients were administered a subjective questionnaire that included the following clinical outcome measures: Lysholm score, Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC) score, Short Form–12 (SF-12) physical component summary (PCS) and mental component summary (MCS), Tegner activity scale score, and patient satisfaction with outcomes. Patient satisfaction was measured on a 1-to-10 scale, with 1 being very unsatisfied and 10 being very satisfied. Demographic characteristics were also recorded. Failure was defined as reoperation with meniscectomy or revision meniscal repair.

Surgical Technique

All patients included in this study underwent inside-out meniscal repair with vertical mattress sutures. Before

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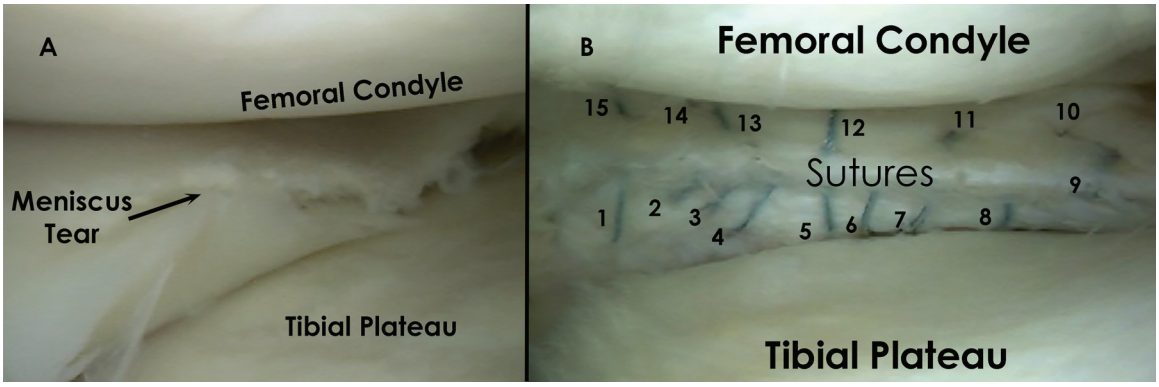

Figure 1. (A) Horizontal longitudinal tear of a lateral meniscus and (B) repair construct with 15 sutures on both the superior and inferior borders of the meniscus.

attempting the repair, a complete arthroscopic evaluation of the meniscal tear was performed, which included stability of the tissue and the presence, type, and zone of the lesion. A posterolateral or posteromedial approach was performed according to previously reported techniques[4] depending on whether the tear was located in the lateral or medial meniscus. A self-delivery gun fitted with a cannula (SharpShooter; Ivy Sports Medicine) was used to pass double-loaded nonabsorbable No. 2-0 sutures (Fiber Wire; Arthrex) into the meniscus. To pass the sutures, the knee was positioned in 30° of flexion, the meniscal needle was advanced through the superior or inferior aspect of the meniscus, and the knee was then flexed to 70° to 90° while the needle was further advanced to help an assistant retrieve the needle through the previously made incision. The same process was repeated adjacent to the previous suture, with the second needle penetrating the joint capsule such that the sutures were placed both in the superior and inferior borders of the meniscus at 3 to 4 mm apart. The needles were cut from the sutures, and the suture ends were clamped with numbered hemostats while maintaining slight tension. Multiple sutures were used to create a greater number of fixation points and mechanically potentiate the healing environment (Figure 1).

With the knee flexed to 90°, all sutures were tied with the meniscus tissue under direct arthroscopic visualization so as not to overtighten the tissue or entrap nearby soft tissue structures. A vertical suture pattern was used because it allowed for greater capture of the strong circumferential fibers of the meniscus. In addition, for isolated meniscal repair, an MVP was performed with 4 to 5 microfracture awl holes into the lateral aspect of the intercondylar notch to release bone marrow elements into the joint.[18]

Rehabilitation

Postoperatively, all patients who underwent meniscal repair plus biological augmentation remained nonweightbearing for 6 weeks. Physical therapy was initiated on postoperative day 1 and focused on early quadriceps muscle activation and assisted knee flexion from 0° to 90°. Starting at 2 weeks postoperatively, knee flexion was increased as tolerated. At 6 weeks postoperatively, weightbearing was initiated along with the utilization of a low-resistance stationary bicycle and one-quarter body weight leg presses to a maximum of 70° of knee flexion. Additional increases in low-impact knee exercises were permitted as tolerated starting at 12 weeks postoperatively. Patients were recommended to avoid deep squatting, sitting cross-legged, or performing any heavy lifting or squatting activities for a minimum of 4 months after surgery.

For those with concomitant ACL injuries, patients were allowed to bear weight as tolerated and to wean off of crutches when they could ambulate without a limp. A knee immobilizer was utilized until the patient could perform a straight-leg raise without an extension sag, usually at postoperative week 2, after which time the patient was transitioned to a functional sport brace. Immediate postoperative physical therapy focused on early quadriceps muscle activation and assisted knee flexion as much as tolerated. The advancement of rehabilitation at that point followed an ACL reconstruction rehabilitation protocol.

Statistical Analysis

Data were tested for normal distribution. Parametric methods were employed for comparisons between the cohorts for age and follow-up years. For comparisons of normally distributed continuous variables between cohorts, an independent *t* test was utilized. Nonparametric methods were employed for comparisons between the cohorts for the Lysholm score, Tegner activity scale score, WOMAC score, SF-12 PCS, SF-12 MCS, patient satisfaction with outcomes, number of sutures, and body mass index (BMI). For comparisons of nonnormally distributed continuous variables between cohorts, the Mann-Whitney *U* test was utilized. For preoperative and postoperative comparisons of dependent variables, the paired-samples *t* test was utilized for normally distributed data, and the Wilcoxon signed-rank test was utilized for nonnormally distributed data. Comparisons of categorical data were performed by using chi-square tests and Fisher exact tests. Survivorship data were calculated using the Kaplan-Meier method with the log-rank test to determine significant

TABLE 2
Preoperative and Postoperative Outcome Scores by Cohort[a]

	Cohort 1: Meniscal Repair Plus MVP			Cohort 2: Meniscal Repair Plus ACL Reconstruction		
	Preoperative	Postoperative	*P* Value	Preoperative	Postoperative	*P* Value
Lysholm	60	84	<.001	50	82	<.001
WOMAC total	30	9	<.001	36	9	<.001
SF-12 PCS	38.9	51.5	<.001	41.2	52.5	<.001
SF-12 MCS	52.2	55.0	.272	48.9	53.2	.037
Tegner activity scale[b]	3	5.5	.002	2	6	<.001

[a]Values are reported as the mean unless otherwise specified. ACL, anterior cruciate ligament; MCS, mental component summary; MVP, marrow venting procedure; PCS, physical component summary; SF-12, Short Form–12; WOMAC, Western Ontario & McMaster Universities Osteoarthritis Index.
[b]Values are reported as the median.

TABLE 3
Postoperative Outcome Measures by Cohort[a]

	Cohort 1: Meniscal Repair Plus MVP	Cohort 2: Meniscal Repair Plus ACL Reconstruction	*P* Value
Follow-up, y	2.9 (2.0-5.4)	3.0 (2.0-5.2)	.485
Lysholm score	84 (59-100)	82 (25-100)	.956
WOMAC total score	9 (0-55)	9 (0-49)	.433
SF-12 PCS	51.5 (26.7-59.0)	52.5 (25.7-60.9)	.059
SF-12 MCS	55.0 (30.7-64.2)	53.2 (29.7-68.1)	.152
Tegner activity scale score[b]	5.5 (1-9)	6 (0-10)	.382
Patient satisfaction[b]	7.5 (1-10)	7 (1-10)	.955

[a]Values are reported as the mean (range) unless otherwise specified. ACL, anterior cruciate ligament; MCS, mental component summary; MVP, marrow venting procedure; PCS, physical component summary; SF-12, Short Form–12; WOMAC, Western Ontario & McMaster Universities Osteoarthritis Index.
[b]Values are reported as the median.

differences in survivorship between the cohorts. All *P* values were 2-tailed, and *P* values <.05 were considered statistically significant. All statistical analyses were performed with SAS version 9.4 (SAS Institute).

RESULTS

Demographics

There were 111 patients who met the inclusion criteria for this study. Two patients refused to participate, leaving 109 patients (52 female, 57 male) who met the inclusion criteria for this study. There were 37 knees in cohort 1 (isolated meniscal repair plus biological augmentation) and 72 knees in cohort 2 (meniscal repair plus ACL reconstruction). Fourteen patients were lost to follow-up, and telephone or email contact with confirmation of the revision surgery status was achieved with 95 patients. Of the 95 patients contacted, follow-up consisting of patient-reported outcome scores was obtained in 82% (n = 89) of patients, with 6 patients being interviewed by telephone but choosing not to complete the follow-up questionnaire. The median number of sutures used for all meniscal repairs was 8 (range, 2-26). There were no significant differences in age, sex, or BMI between the cohorts (Table 1).

Outcomes

There were no significant differences in the baseline WOMAC total score, Tegner activity scale score, SF-12 PCS, or SF-12 MCS. There was a significant difference in the baseline Lysholm score, with cohort 2 (meniscal repair plus ACL reconstruction) having a 10-point deficit in the preoperative Lysholm score compared with cohort 1 (meniscal repair plus MVP) (*P* = .042). In each cohort, the Lysholm score, SF-12 PCS, WOMAC score, and Tegner activity scale score significantly improved from preoperatively to postoperatively (Table 2). There was no significant difference in any postoperative outcome measures between the 2 cohorts (Table 3).

Failure

Failure was defined as reoperation with meniscectomy or revision meniscal repair. Telephone or email contact was made with 95 patients, and the need for secondary surgery on the meniscus was known in each of these patients. Of the contacted patients, 89 completed the full questionnaire as noted above, and 6 patients only reported whether they underwent additional surgery on the index meniscus. The overall failure rate for the entire contacted sample was 9.5% (9/95). There were 4 of 31 (12.9%) failures in cohort 1 and 5 of 64 (7.8%) failures in cohort 2, with no significant

TABLE 4
Descriptive Findings of Meniscal Repair Failures by Cohort[a]

	Cohort 1: Meniscal Repair Plus MVP (n = 37)	Cohort 2: Meniscal Repair Plus ACL Reconstruction (n = 72)
Failures (knees), n (%)	4/31 (12.9)	5/64 (7.8)
Female sex, n	4	5
Age, mean (range), y	24.2 (18.2-25.8)	29.5 (17.6-44.1)
Meniscal repair, n	5	5
Medial	2	4
Lateral	1	1
Medial and lateral	1 (2 suture repairs within same knee)	0
No. of sutures, mean (range)	8 (4-10)	7.5 (5-10)
Medial tear type, n	3	4
Horizontal	2	0
Longitudinal/vertical	0	2
Flap/bucket/complex	1	2
Lateral tear type, n	2	1
Horizontal	0	0
Longitudinal/vertical	2	0
Flap/bucket/complex	0	1
Medial tear zone, n	3	4
Red/red	1	1
Red/white	2	3
White/white	0	0
Lateral tear zone, n	2	1
Red/red	1	1
Red/white	1	0
White/white	0	0

[a]ACL, anterior cruciate ligament; MVP, marrow venting procedure.

difference in failures between the cohorts (P = .429). There was a significant association between failure and female sex (P = .001). All patients who were failures were female (odds ratio, 12.9). Descriptive meniscus findings for failures by cohort are documented in Table 4. For cohort 1, survivorship was 86% at 2 years, 86% at 3 years, and 86% at 5 years. For cohort 2, survivorship was 94% at 2 years, 94% at 3 years, and 87% at 5 years. There was no significant difference in survivorship between the cohorts (P = .379) (Figure 2).

Medial and Lateral Meniscal Repairs

There was no significant difference in the proportion of medial and lateral meniscal repairs, meniscal tear type, meniscal tear zone, or number of sutures between cohort 1 and cohort 2. Detailed intraoperative findings were documented at the time of surgery (Table 5).

Complications

There were 4 complications, which all occurred in cohort 2. Three patients who underwent repair for a bucket-handle medial meniscal tear had postoperative arthrofibrosis that required lysis of adhesions. One patient had deep vein thrombosis that was successfully treated with medications with no further complications.

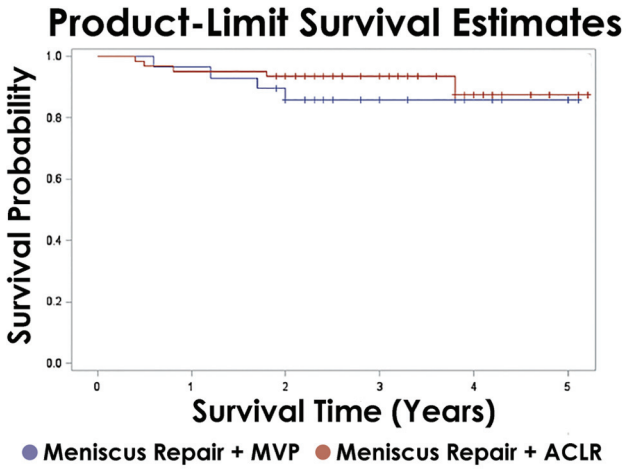

Figure 2. Kaplan-Meier survivorship curve for each cohort. MVP, marrow venting procedure.

DISCUSSION

The most important finding of this study was that there was no significant difference in outcomes in isolated meniscal repair performed with biological augmentation with an MVP versus meniscal repair performed concomitantly with ACL reconstruction. These results also provide new information regarding the potential for healing in meniscal repair performed in the white/white zone as well as in complex meniscal tears. Previous literature reported on the higher prevalence of lateral-sided meniscal injuries when compared with medial meniscal tears. We theorize that the discrepancy on the laterality in this study might be caused by the injury mechanism of our cohort of patients. Moreover, although not significant, cohort 2 had more longitudinal/vertical tears, which are more amenable to repair than the increased number of horizontal and complex tears seen in cohort 1. Regardless of this fact, no differences in outcomes or failure rates were found.

Biological augmentation of meniscal repair by the release of bone marrow elements from the intercondylar notch has been previously referred to in various ways, including microfracture and notch picking.[18] To eliminate the confusion created between those patients who undergo concurrent microfracture for articular cartilage defects, we propose that this biological augmentation be called the MVP. In this study, inside-out meniscal repair resulted in an overall failure rate of 9.5%. The failure rate was 12.9% in cohort 1 and 7.8% in cohort 2. Two studies on the long-term outcomes of isolated inside-out meniscal repair have reported failure rates of 23.7%[16] and 26.9%,[8] while another study[28] demonstrated signs of mucoid degeneration or scar tissue in 46% of the patients. A systematic review reported that the overall reoperation rate

TABLE 5
Intraoperative Data by Cohort[a]

	Cohort 1: Meniscal Repair Plus MVP	Cohort 2: Meniscal Repair Plus ACL Reconstruction	*P* Value
Meniscal repair, n (%)	37	72	.451
Medial	32 (86)	55 (76)	
Lateral	4 (11)	10 (14)	
Medial and lateral	1 (3)	7 (10)	
No. of sutures, mean (range)			
Medial	8 (2-21)	8 (2-26)	.210
Lateral	6 (4-10)	6 (2-16)	.575
Medial tear type, n (%)	33	62	.388
Horizontal	9 (27)	11 (18)	
Longitudinal/vertical	13 (39)	33 (53)	
Flap/bucket/complex	11 (33)	18 (29)	
Lateral tear type, n (%)	5	17	.772
Horizontal	0 (0)	2 (12)	
Longitudinal/vertical	3 (60)	11 (65)	
Flap/bucket/complex	2 (40)	4 (23)	
Medial tear zone, n (%)	33	62	.801
Red/red	6 (18)	14 (23)	
Red/white	19 (58)	36 (58)	
White/white	8 (24)	12 (19)	
Lateral tear zone, n (%)	5	17	.433
Red/red	1 (20)	4 (24)	
Red/white	4 (80)	9 (53)	
White/white	0 (0)	4 (23)	

[a]ACL, anterior cruciate ligament; MVP, marrow venting procedure.

after all meniscal repairs was 24% compared with a 14% reoperation rate for ACL reconstruction with meniscal repair.[23] Nepple et al[22] performed a systematic review of the literature and a meta-analysis of meniscal repair outcomes that demonstrated an overall failure rate of 22.3% with inside-out repair, regardless of whether it was isolated meniscal repair or with concomitant ACL reconstruction. The rate of failure was similar for patients with an intact ACL and a reconstructed ACL. However, a multicenter study by Westermann et al[31] reported that patients who underwent meniscal repair with concurrent ACL reconstruction had a 14% failure rate, with failure defined as the need for reoperation.

The comparable results found between the 2 cohorts in this study may be partially attributed to the use of biological augmentation. Current literature supports the theory that the lower failure rate and higher clinical outcomes of the cohort with meniscal repair plus an MVP compared with previously reported isolated meniscal repair may be partially explained by biological augmentation. For example, de Girolamo et al[6] reported that the joint fluid concentration of platelet-derived growth factor (PDGF) was significantly higher after ACL reconstruction when compared with arthroscopic partial meniscectomy alone. This biological component has been reported to play a key role in the early phases of the meniscal healing process by inducing angiogenesis and the stimulation of other growth factors such as insulin-like growth factor 1 (IGF-1)[5] and inducing fibroblast proliferation and differentiation and collagen deposition.[24,25] In a similar study, Galliera et al[11] reported that angiogenesis-promoting vascular endothelial growth factor (VEGF) and vascular endothelial growth factor receptor 2 (VEGFR-2) concentrations were significantly higher in the knee joint fluid of an ACL reconstruction group. In addition, recent animal models have demonstrated improved meniscal healing with marrow stimulation procedures.[7,13] A recent study using a goat model reported complete healing at 6 months after injury in 65% of meniscal tears when marrow stimulation was performed compared with 12% of menisci that demonstrated complete healing without marrow stimulation ($P < .001$).[13]

The overall improvement in functional patient-reported outcomes in the present study surpassed the minimum detectable change for the Lysholm score, which has been reported to be 10.1 points (29 points increased, on average, for this study), and the Tegner activity scale score, which is set at 1 point (increased 3.6 points, on average, for this study).[3] Recently, it was reported that patients who underwent meniscal repair had high function and high patient satisfaction at an average of 16 years after meniscal repair,[27] reinforcing the concept of long-term survivorship of meniscal repair surgery.[24,26] Additionally, the current study demonstrated high survivorship in both cohorts, with no significant difference between the groups. Furthermore, data from the current study demonstrated that the majority of patients who met survivorship criteria at 2 years postoperatively (94%) also survived to 5 years postoperatively (87%). Meniscal root repair was not included

in this study because it utilizes sutures passed through transtibial tunnels.

In the present study, there was a significant association between failure and female sex, with female patients being 12.9 times more likely to fail the index meniscus surgery than male patients. A recent study by Lyman et al[20] reported no difference in the need for meniscectomy after meniscal repair between sexes. Presently, it is unclear why female patients had a higher association with failure in this study. Further studies are necessary to elucidate the reasons behind this relationship.

We acknowledge some limitations in this study. While patient outcome data were collected prospectively, postoperative data were reviewed retrospectively. In addition, it is recognized that the inside-out meniscal repair technique with multiple vertical mattress sutures requires a trained assistant to effectively protect the soft tissue when passing the sutures. The superior mechanical strength provided by the increased number of sutures utilized in this study may have also resulted in improved outcomes reported when compared with previous literature. Another limitation was that an MVP was performed in all isolated meniscal repairs and not specifically controlled for. There was no a priori power analysis performed because of the nature of the study, which was a retrospective comparative cohort design. This type of design and sample size may increase the chance of a type II error. Moreover, it is still unknown which of the factors or group of factors are truly responsible for the improved outcomes in cohort 1. The initial postoperative rehabilitation program differed between studies, which could be a factor between the similar outcomes. Therefore, more studies are necessary to determine the basic science and long-term outcomes of the MVP performed concomitantly with isolated inside-out meniscal repair. Additionally, differences in rehabilitation protocols between cohorts may induce a confounding variable in outcomes.

CONCLUSION

The most important finding of this study was that there was no difference in outcomes in isolated meniscal repair performed with biological augmentation with an MVP versus meniscal repair performed concomitantly with ACL reconstruction. In this study, inside-out meniscal repair was utilized in all patients and had an overall failure rate of 9.5%. The similar outcomes reported between isolated meniscal repair with an MVP and meniscal repair with ACL reconstruction may be partly attributed to biological augmentation.

REFERENCES

1. Ahn JH, Kwon OJ, Nam TS. Arthroscopic repair of horizontal meniscal cleavage tears with marrow-stimulating technique. *Arthroscopy*. 2015;31(1):92-98.
2. Arnoczky SP, Warren RF, Spivak JM. Meniscal repair using an exogenous fibrin clot: an experimental study in dogs. *J Bone Joint Surg Am*. 1988;70:1209-1217.
3. Briggs KK, Lysholm J, Tegner Y, Rodkey WG, Kocher MS, Steadman JR. The reliability, validity, and responsiveness of the Lysholm score and Tegner activity scale for anterior cruciate ligament injuries of the knee: 25 years later. *Am J Sports Med*. 2009;37(5):890-897.
4. Chahla J, Serra Cruz R, Cram TR, Dean SC, LaPrade RF. Inside-out meniscal repair: medial and lateral approach. *Arthrosc Tech*. 2016;5(1):e163-e168.
5. Creaney L, Hamilton B. Growth factor delivery methods in the management of sports injuries: the state of play. *Br J Sports Med*. 2008;42(5):314-320.
6. de Girolamo L, Galliera E, Volpi P, et al. Why menisci show higher healing rate when repaired during ACL reconstruction? Growth factors release can be the explanation. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(1):90-96.
7. Driscoll MD, Robin BN, Horie M, et al. Marrow stimulation improves meniscal healing at early endpoints in a rabbit meniscal injury model. *Arthroscopy*. 2013;29(1):113-121.
8. Eggli S, Wegmuller H, Kosina J, Huckell C, Jakob RP. Long-term results of arthroscopic meniscal repair: an analysis of isolated tears. *Am J Sports Med*. 1995;23(6):715-720.
9. Feng H, Hong L, Geng XS, Zhang H, Wang XS, Jiang XY. Second-look arthroscopic evaluation of bucket-handle meniscus tear repairs with anterior cruciate ligament reconstruction: 67 consecutive cases. *Arthroscopy*. 2008;24(12):1358-1366.
10. Freedman KB, Nho SJ, Cole BJ. Marrow stimulating technique to augment meniscus repair. *Arthroscopy*. 2003;19(7):794-798.
11. Galliera E, De Girolamo L, Randelli P, et al. High articular levels of the angiogenetic factors VEGF and VEGF-receptor 2 as tissue healing biomarkers after single bundle anterior cruciate ligament reconstruction. *J Biol Regul Homeost Agents*. 2011;25(1):85-91.
12. Goodwillie AD, Myers K, Sgaglione NA. Current strategies and approaches to meniscal repair. *J Knee Surg*. 2014;27(6):423-434.
13. Howarth WR, Brochard K, Campbell SE, Grogan BF. Effect of microfracture on meniscal tear healing in a goat (Capra hircus) model. *Orthopedics*. 2016;39(2):105-110.
14. Hutchinson ID, Moran CJ, Potter HG, Warren RF, Rodeo SA. Restoration of the meniscus: form and function. *Am J Sports Med*. 2014;42(4):987-998.
15. Ishimura M, Ohgushi H, Habata T. Arthroscopic meniscal repair using fibrin glue, part I: experimental study. *Arthroscopy*. 1997;13:551-557.
16. Johnson MJ, Lucas GL, Dusek JK, Henning CE. Isolated arthroscopic meniscal repair: a long-term outcome study (more than 10 years). *Am J Sports Med*. 1999;27(1):44-49.
17. LaPrade CM, James EW, Cram TR, Feagin JA, Engebretsen L, LaPrade RF. Meniscal root tears: a classification system based on tear morphology. *Am J Sports Med*. 2015;43:363-369.
18. LaPrade CM, James EW, LaPrade RF, Engebretsen L. How should we evaluate outcomes for use of biologics in the knee? *J Knee Surg*. 2015;28(1):35-44.
19. LaPrade RF, Wills NJ. Kissing cartilage lesions of the knee caused by a bioabsorbable meniscal repair device: a case report. *Am J Sports Med*. 2004;32(7):1751-1754.
20. Lyman S, Hidaka C, Valdez AS, et al. Risk factors for meniscectomy after meniscal repair. *Am J Sports Med*. 2013;41(12):2772-2778.
21. Melton JT, Murray JR, Karim A, Pandit H, Wandless F, Thomas NP. Meniscal repair in anterior cruciate ligament reconstruction: a long-term outcome study. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(10):1729-1734.
22. Nepple JJ, Dunn WR, Wright RW. Meniscal repair outcomes at greater than five years: a systematic literature review and meta-analysis. *J Bone Joint Surg Am*. 2012;94(24):2222-2227.
23. Paxton ES, Stock MV, Brophy RH. Meniscal repair versus partial meniscectomy: a systematic review comparing reoperation rates and clinical outcomes. *Arthroscopy*. 2011;27(9):1275-1288.
24. Rochcongar G, Cucurulo T, Ameline T, et al. Meniscal survival rate after anterior cruciate ligament reconstruction. *Orthop Traumatol Surg Res*. 2015;101(8 Suppl):S323-S326.
25. Ronnstrand L, Heldin CH. Mechanisms of platelet-derived growth factor-induced chemotaxis. *Int J Cancer*. 2001;91(6):757-762.

26. Salle de Chou E, Pujol N, Rochcongar G, et al. Analysis of short and long-term results of horizontal meniscal tears in young adults. *Orthop Traumatol Surg Res*. 2015;101(8 Suppl):S317-S322.
27. Steadman JR, Matheny LM, Singleton SB, et al. Meniscus suture repair: minimum 10-year outcomes in patients younger than 40 years compared with patients 40 and older. *Am J Sports Med*. 2015;43(9):2222-2227.
28. Steenbrugge F, Verdonk R, Verstraete K. Long-term assessment of arthroscopic meniscus repair: a 13-year follow-up study. *Knee*. 2002;9:181-187.
29. Wasserstein D, Dwyer T, Gandhi R, Austin PC, Mahomed N, Ogilvie-Harris D. A matched-cohort population study of reoperation after meniscal repair with and without concomitant anterior cruciate ligament reconstruction. *Am J Sports Med*. 2013;41(2):349-355.
30. Westermann RW, Duchman KR, Amendola A, Glass N, Wolf BR. All-inside versus inside-out meniscal repair with concurrent anterior cruciate ligament reconstruction: a meta-regression analysis [published online April 25, 2016]. *Am J Sports Med*. doi:10.1177/0363546516642220.
31. Westermann RW, Wright RW, Spindler KP, Huston LJ, MOON Knee Group, Wolf BR. Meniscal repair with concurrent anterior cruciate ligament reconstruction: operative success and patient outcomes at 6-year follow-up. *Am J Sports Med*. 2014;42(9):2184-2192.
32. Xu C, Zhao J. A meta-analysis comparing meniscal repair with meniscectomy in the treatment of meniscal tears: the more meniscus, the better outcome? *Knee Surg Sports Traumatol Arthrosc*. 2015;23(1):164-170.