Comparative Outcomes of All-Inside Versus Inside-Out Repair of Bucket-Handle Meniscal Tears

A Propensity-Matched Analysis

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Background: There are limited data comparing the outcomes of all-inside versus inside-out meniscal repair techniques.

Purpose: To assess failure rates and clinical outcomes after the surgical repair of bucket-handle meniscal tears utilizing either an all-inside or inside-out technique.

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

Methods: Patients with bucket-handle meniscal tears undergoing all-inside or inside-out repair at a single institution between 2003 and 2013 were analyzed. A total of 28 mensici repaired utilizing second-generation all-inside suturing devices and 42 menisci repaired using an inside-out technique were eligible for inclusion. Rigorous propensity matching was performed on the basis of age, sex, tear laterality, rim width, and concomitant anterior cruciate ligament reconstruction (ACLR), resulting in a total of 40 patients equally distributed between the 2 repair techniques for comparison. Retear-free survival as well as preoperative and postoperative International Knee Documentation Committee (IKDC) and Tegner scores and physical examination findings were subsequently analyzed.

Results: Twenty patients who underwent all-inside repair (14 male; mean age, 23.7 ± 6.7 years) were successfully propensity matched to 20 patients who underwent inside-out meniscal repair (15 male; mean age, 22.5 ± 7.6 years), with a mean retear-free follow-up of 4.4 years (range, 2.5-7.4 years). Four (20%) all-inside repairs and 4 (20%) inside-out repairs failed over the course of follow-up ($P > .999$), with a mean time to failure of 2.7 years (range, 1.3-4.4 years) and 5.0 years (range, 0.8-7.5 years), respectively ($P = .25$). Increasing patient age trended toward a decreased clinical retear rate, independent of the repair technique (hazard ratio, 0.86; $P = .056$). There were no significant differences in the Tegner scores, IKDC scores, or range of motion between the groups as a whole or when subcategorizing by age, sex, body mass index, tear complexity, rim width, isolated versus concomitant ACLR, or medial- versus lateral-sided repair. There were no complications in the all-inside group, while there was a 10% rate of minor complications in the inside-out group ($P = .49$).

Conclusion: Overall, satisfactory clinical outcomes are achievable at short-term to midterm follow-up with both inside-out and all-inside repair techniques of bucket-handle meniscal tears in rigorously matched patients with similar meniscal tear patterns.

Keywords: knee; meniscal tear; surgical repair; arthroscopic surgery

Bucket-handle meniscal tears are common, especially in the young, active patient population, and they represent a significant clinical challenge. In most cases, subtotal meniscectomy is not desirable secondary to the biomechanical imbalance created and the well-documented poor long-term outcomes.[3,12,18,20,26,28,34,45] Therefore, meniscal repair is favored whenever possible, especially in the setting of concomitant anterior cruciate ligament reconstruction (ACLR), where the literature has demonstrated improved outcomes.[43,47,51]

The most commonly utilized meniscal repair techniques for bucket-handle tears are inside-out repair utilizing zone-specific cannulas and all-inside repair with suture-based devices. Arthroscopically assisted inside-out repair has long been considered the gold standard secondary to the increased ability to reduce the meniscal tear anatomically as well as to pass sutures in tight knee compartments and in a variety of meniscal zones.[13,16,17,50] Reported drawbacks

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include the need for an extra assistant for passing sutures, a separate medial or lateral incision, and concerns about complications.[4,5,16,23,52] The advent of all-inside suture devices offered the potential of decreased operative time and potentially lower complication rates, although early results were mixed.[2,36,40] Second-generation all-inside devices leave only suture inside the joint while the PEEK pledgets remain extracapsular. They have proven to be biomechanically similar to inside-out suture techniques.[8,9,11] Drawbacks include the increased up-front expense, the possibility of device breakage or misfire, and the potential for vascular injury when treating tears involving the posterior horn.[8,42]

The existing literature suggests that both methods are equivalent for the repair of vertical longitudinal tears, but there is a distinct lack of high-quality, direct comparative studies.[21,23] Although there are several systematic reviews on this topic, Fillingham et al[21] performed the only review comparing second-generation all-inside devices with inside-out repair. However, their study compares cohorts of patients treated with either the all-inside technique or inside-out technique at different institutions. Furthermore, their study was limited by heterogeneous patient demographics, tear types, surgical techniques, follow-up intervals, and outcomes reported, making a direct comparison of data impossible.[21,23] There are no studies that assess displaced bucket-handle tears in isolation, and previous studies are limited because of significant selection bias. Additionally, the current data provide minimal guidance on which specific tear characteristics lend themselves to all-inside versus inside-out repair.

We reviewed the results of patients who underwent bucket-handle meniscal repair utilizing either the all-inside technique or inside-out technique at our institution in a rigorously matched propensity model algorithm. The goals of the study were to (1) directly compare clinical outcomes after the surgical repair of bucket-handle meniscal tears utilizing each technique and (2) identify the risk factors for failure to aid clinicians in determining the most appropriate repair type based on patient demographics and/or tear characteristics. We hypothesized that there would be no significant difference in failure rates or clinical outcomes between the repair techniques.

METHODS

We utilized our institution's electronic medical record database, after obtaining approval from the institutional review board, to review the charts of all patients who had undergone the repair of bucket-handle meniscal tears between 2003 and 2013. These dates were chosen because they reflect the timeline after which the senior authors (B.A.L., D.L.D., M.J.S., A.J.K.) began to utilize second-generation all-inside suture devices. Bucket-handle tears were defined as predominantly vertical, longitudinal tears in the posterior horn and body segments that could be displaced anteriorly into the notch.

Inclusion criteria consisted of patients with documented bucket-handle tears who underwent repair and consented for research participation. Indications for repair included a reducible full-thickness tear within 3 mm of the meniscosynovial junction, and the repair technique was at the discretion of the surgeon. Patients who underwent ACLR as a concomitant procedure were eligible for inclusion. Patients were categorized as having undergone all-inside repair if they had exclusively all-inside devices placed, and patients were categorized as having undergone inside-out repair if they either had only inside-out sutures placed or if they had 1 all-inside device in addition to a predominantly inside-out suturing technique.

Exclusion criteria consisted of (1) less than 2 years of follow-up, (2) prior meniscal repair on the same side, (3) multiligament injuries, (4) concomitant periarticular fractures, (5) full-thickness (grade 4) osteochondral lesions, or (6) fixation with meniscal arrows (a first-generation all-inside device).

Surgical Technique

All surgical procedures were carried out at an academic institution by 1 of 4 sports medicine fellowship–trained orthopaedic surgeons (B.A.L., D.L.D., M.J.S., A.J.K.). Standard arthroscopic portals were utilized, and all tears underwent preparation in the form of rasping or debriding the tear site and adjacent synovium, followed by anatomic reduction. There was no biologic augmentation utilized in isolated repairs (ie, no fibrin clot or marrow venting). The inside-out repair technique included a standard medial- or lateral-sided incision made before suture passing as well as zone-specific cannulas and 2-0 nonabsorbable (Ethibond; Ethicon) suture in a vertical mattress fashion.[49] All-inside repair was also performed in a vertical mattress configuration and in accordance with the guidelines for the specific device used. Of the 20 all-inside repairs, 19 utilized anchors (Fast-Fix 360; Smith & Nephew), and 1 utilized a meniscal cinch (Arthrex).

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Ethical approval for this study was obtained from the Mayo Clinic Institutional Review Board (No. 15-000601).

Tear Characteristics

Meniscal tear and repair characteristics were collected at the time of arthroscopic surgery. These included repair type (inside-out or all-inside), medial or lateral side of the knee, rim width as measured with a probe, number of sutures/devices utilized, tear complexity, and concomitant abnormalities (ie, ACL rupture, chondromalacia). Simple tears were defined as those with a single vertical tear with a displaced bucket-handle fragment, while complex tears were those involving multiple planes or consisting of ≥2 tear types.[32,33]

Patient Evaluation

Data were collected by both a retrospective chart review and direct patient contact via telephone interviews conducted by the study investigators. Data collection included the clinical success rate, length of survival free of clinical retears, and preoperative and postoperative pain and range of motion. Clinical success was determined by return to prior activity levels and the absence of joint-line tenderness, pain, swelling, mechanical symptoms, and subsequent surgical procedures.[32,33] Functional outcomes were collected in the form of preoperative and postoperative Tegner scores as well as preoperative and postoperative International Knee Documentation Committee (IKDC) subjective scores. All outcome scores were collected postoperatively.

Rehabilitation

Postoperative rehabilitation for isolated repairs included partial weightbearing in full extension and knee flexion limited to 90° for 4 weeks and then weightbearing as tolerated and full range of motion. Sports activities were permitted at 4 to 6 months postoperatively for isolated repairs, depending on the clinical progress. In the setting of concomitant ACLR, the postoperative protocol was dictated by the ACL, with the exception of the weightbearing limitations described above. Return to sports varied between 6 and 9 months during the time period of the study.

Statistical Analysis

Propensity score matching was undertaken to compare retear rates and clinical outcomes in a subset of matched patients undergoing all-inside or inside-out meniscal repair. Patients were matched on the basis of both demographic factors and meniscal tear characteristics. Twenty patients from each group were successfully matched to each other on the basis of the above criteria. A maximum caliper distance of 0.2 of the logit was chosen to ensure rigorous matching criteria between the 2 groups, as previous literature has suggested that this caliper distance eliminates >98% of the bias due to measured confounders.[6,7,46]

Potential risk factors such as patient demographics and repair type were evaluated using Cox proportional hazards analysis to determine their relationship to the failure (retear) rate. The failure rate was analyzed over time using Kaplan-Meier curves. The Wilcoxon rank-sum test was used to compare nominal values, including preoperative and postoperative IKDC and Tegner scores for those patients without operative failure. The Fisher exact test was used for proportions.

For the 20 patients obtained for each group after propensity matching, the post hoc power was 39.8% for detecting a difference of 1 point in the Tegner score and >99.9% for detecting a difference of 10 points in the IKDC score, a change that falls within the accepted range of estimates for the mean minimal clinically important difference for the IKDC score.[14,15,29,30,35,38] P values <.05 were considered significant. Analyses were conducted in R 3.4.1 (R Core Team) and G*Power 3.1.9.3 (G*Power Team).[19]

RESULTS

Propensity Score Matching and Demographics

A total of 88 repairs in 87 patients were identified for possible inclusion in the study, with 1 patient undergoing staged repair of bilateral bucket-handle tears related to separate injuries. Eighteen patients were excluded for less than 2 years of follow-up, resulting in 70 patients (80% 2-year follow-up rate) available for study. Twenty patients who underwent all-inside repair were successfully matched to 20 patients who underwent inside-out repair on the basis of age, sex, tear laterality, rim width, and concurrent ACLR. Matching was successful, as all match variables were statistically similar between the 2 groups (Table 1). A mean of 5.1 ± 1.3 suture devices were used in all-inside repairs, and 10.9 ± 3.2 sutures were used in inside-out repairs ($P < .01$).

Survival Free of Clinical Retears

The mean retear-free follow-up was 4.4 years (range, 2.5-7.4 years). There were a total of 4 failures (20%) in the all-inside group and 4 failures (20%) in the inside-out group; the mean time to a retear was 2.7 years (range, 1.3-4.4 years) and 5.0 years (range, 0.8-7.5 years), respectively ($P = .25$). Kaplan-Meier analysis showed no significant difference in clinical retear rates between the rigorously matched inside-out and all-inside groups ($P = .824$) (Figure 1).

Per history and the temporal onset of new knee pain, 3 patients in the all-inside group experienced retears during sporting activities (basketball, baseball, tubing), and 1 experienced a retear while stepping off a curb. In the inside-out group, retears occurred during basketball, lifting a heavy item, squatting, and while standing up from a seated position. All patients with clinical suspicion of a retear underwent magnetic resonance imaging, followed by repeat arthroscopic surgery. Three patients in each group were treated with partial meniscectomy and 1 patient in each group with re-repair.

Cumulative incidence values for failure were determined along with their 95% CIs for the various demographic predictors analyzed during Cox proportional hazards regression (Table 2). No single variable was found to predict increased failure incidence over time ($P \geq .10$).

TABLE 1
Patient Demographics and Meniscal Tear Characteristics[a]

	Inside-Out Repair (n = 20)	All-Inside Repair (n = 20)	P Value
Age at surgery, y	22.5 ± 7.6	23.7 ± 6.7	.42
Sex, n (%)			>.999
Male	15 (75)	14 (70)	
Female	5 (25)	6 (30)	
Body mass index, kg/m^2	24.9 ± 3.9	26.5 ± 3.6	.17
Smoker, n (%)	2 (10)	2 (10)	>.999
Preoperative Tegner score	1.8 ± 0.6	2.3 ± 1.4	.47
Preoperative IKDC score	37.5 ± 16.1	35.1 ± 10.5	.78
Laterality, n (%)			>.999
Lateral	10 (50)	11 (55)	
Medial	10 (50)	9 (45)	
Rim width, n (%)			>.999
<3 mm	11 (55)	12 (60)	
≥3 mm	9 (45)	8 (40)	
Concurrent ACLR, n (%)			>.999
No	12 (60)	13 (65)	
Yes	8 (40)	7 (35)	

[a]Data are expressed as mean ± SD unless otherwise indicated. ACLR, anterior cruciate ligament reconstruction; IKDC, International Knee Documentation Committee.

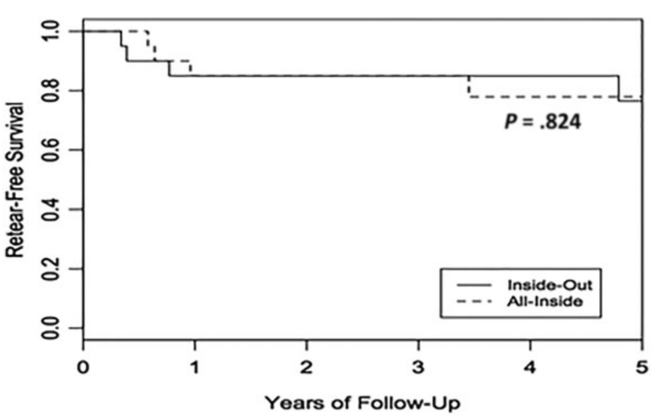

Figure 1. Kaplan-Meier survivorship curve demonstrating the overall proportion of patients free from retears at given time points for the propensity-matched inside-out and all-inside groups.

Univariate Cox proportional hazards analysis suggested that increased patient age at the time of surgery trended toward a decreasing risk of retears (hazard ratio, 0.86; P = .056) (Table 3). All retears in the inside-out (n = 4) and all-inside groups (n = 4) occurred in patients aged <28 years, with a mean age of 19.2 ± 5.4 years.

Complications

There were 2 minor complications associated with inside-out repair (10%) and no complications in the all-inside group (P = .49). The complications in the inside-out group included 1 wound dehiscence treated with superficial irrigation 1 week after surgery and one 2-cm parameniscal cyst that appeared 7 months after surgery, which resolved spontaneously 1 month later. There were no major complications in either group.

Outcome Measures

No significant difference existed between the propensity-matched inside-out and all-inside groups in terms of the preoperative Tegner score (P = .47) or IKDC score (P = .78) (Table 1). Postoperative Tegner scores were statistically similar for the inside-out (6.6 ± 1.5) and all-inside (6.5 ± 2.0) groups (P = .77). Additionally, no significant difference was observed in the postoperative IKDC scores of the 2 groups (inside-out: 94.0 ± 4.0; all-inside: 93.6 ± 5.4) (P = .62).

DISCUSSION

Bucket-handle meniscal tears continue to represent a significant challenge, and meniscal preservation with repair is the preferred option over total or subtotal meniscectomy.[55] It has been suggested that bucket-handle tear types fare worse than smaller, vertical longitudinal tears after meniscal repair,[32,47,48] so the optimal repair technique is of critical importance. In this direct comparison of repair techniques, in a rigorously propensity-matched cohort at midterm follow-up, we demonstrated no significant difference between inside-out and all-inside repairs of bucket-handle meniscal tears in terms of survival rates or clinical outcomes.[21,23] Both groups demonstrated significant improvements in their clinical outcome scores, and no major complications were observed in either group.

The clinical results observed in the current study are comparable with those reported in a recent systematic review by Fillingham et al,[21] although with a higher percentage of failures. The mean failure rate for both all-inside and inside-out repairs in our study was 20%, compared with 11% for all-inside repair and 10% for inside-out repair reported by Fillingham et al.[21] The increased failure rate observed in the current study may be because the included tears were all large, displaced bucket-handle tears, while Fillingham et al[21] included vertical longitudinal tears of all sizes. This size difference is highlighted if we utilize the number of sutures or devices as a proxy for tear size. Inside-out repairs in our propensity-matched cohort used an average of 10.9 ± 3.2 sutures and all-inside repairs averaged 5.1 ± 1.3 devices, as compared with 3 sutures and 2 devices in the study by Fillingham et al.[21] These observations also demonstrate that it is possible to place a higher volume of sutures with inside-out repair than all-inside repair, given the ease of suture passage and the smaller holes created in the meniscus.

The literature generally supports the concept that displaced bucket-handle tears have higher failure rates irrespective of the repair technique[32,41,47,48]; however, Moatshe

TABLE 2
Univariate Analysis for Incidence of Failure, Over Time[a]

	1 Year	2 Years	4 Years
Repair type			
Inside-out	0.15 (–0.01 to 0.31)	0.15 (–0.01 to 0.31)	0.15 (–0.01 to 0.31)
All-inside	0.15 (–0.01 to 0.31)	0.15 (–0.01 to 0.31)	0.15 (0.02 to 0.42)
Age			
≤25 y	0.21 (0.04 to 0.37)	0.21 (0.04 to 0.37)	0.21 (0.04 to 0.37)
>25 y	0.06 (–0.06 to 0.18)	0.06 (–0.06 to 0.18)	0.14 (–0.05 to 0.33)
Sex			
Female	0.09 (–0.09 to 0.27)	0.09 (–0.09 to 0.27)	0.09 (–0.09 to 0.27)
Male	0.17 (0.03 to 0.31)	0.17 (0.03 to 0.31)	0.22 (0.06 to 0.38)
Body mass index			
≤30 kg/m^2	0.14 (0.03 to 0.26)	0.14 (0.03 to 0.26)	0.18 (0.05 to 0.32)
>30 kg/m^2	0.33 (–0.32 to 0.99)	0.33 (–0.32 to 0.99)	0.33 (–0.32 to 0.99)
Laterality			
Lateral	0.10 (–0.03 to 0.22)	0.10 (–0.03 to 0.22)	0.10 (–0.03 to 0.22)
Medial	0.21 (0.02 to 0.40)	0.21 (0.02 to 0.40)	0.28 (0.06 to 0.50)
Rim width			
<3 mm	0.09 (–0.03 to 0.20)	0.09 (–0.03 to 0.20)	0.15 (–0.01 to 0.31)
≥3 mm	0.24 (0.03 to 0.44)	0.24 (0.03 to 0.44)	0.24 (0.03 to 0.44)
Concurrent ACLR			
No	0.20 (0.04 to 0.36)	0.20 (0.04 to 0.36)	0.25 (0.07 to 0.43)
Yes	0.07 (–0.06 to 0.20)	0.07 (–0.06 to 0.20)	0.07 (–0.06 to 0.20)

[a]Failure was defined as meniscal retear. Data are expressed as cumulative failure incidence (95% CI). ACLR, anterior cruciate ligament reconstruction.

TABLE 3
Univariate Cox Proportional Hazards Model for Failure[a]

	Hazard Ratio (95% CI)	*P* Value
Repair type		.818
Inside-out	Reference	
All-inside	1.18 (0.30-4.64)	
Age at surgery[b]	0.86 (0.74-1.00)	.056
Sex		.359
Female	Reference	
Male	2.64 (0.33-21.00)	
Body mass index		.467
≤30 kg/m^2	Reference	
>30 kg/m^2	2.29 (0.24-21.47)	
Laterality		.124
Lateral	Reference	
Medial	3.56 (0.71-17.95)	
Rim width		.531
<3 mm	Reference	
≥3 mm	1.54 (0.40-5.93)	
Concurrent ACLR		.318
No	Reference	
Yes	0.48 (0.11-2.05)	

[a]Failure was defined as meniscal retear. ACLR, anterior cruciate ligament reconstruction.
[b]Change in hazard ratio for per-year increase in age.

et al[39] recently reported comparable outcomes between large, vertical longitudinal (mean, 7 sutures) and bucket-handle tears (mean, 11 sutures) repaired utilizing an inside-out technique. It may be that the overall length of a vertical longitudinal tear is less important than other factors such as rim width and host variables.

In our study, increasing age at the time of surgery trended toward predicting a lower failure rate, with each additional year of age estimated to decrease the failure rate by 14% (hazard ratio, 0.86; $P = .056$). The reason for this trend may be the increased demand placed on meniscal repair by younger patients, although this has not been frequently described in other series. Krych et al[32] did report high failure rates in pediatric patients after the repair of complex and bucket-handle meniscal tears, although they did not compare their pediatric patients to a cohort of older patients. Other reported risk factors for failure include medial-sided repair,[32] isolated repair as opposed to repair with concomitant ACLR,[1,24,31,37] and rim width greater than 3 mm.[25,32,50] None of these factors reached statistical significance in the current study. However, this study was designed to evaluate differences between demographically matched meniscal repair techniques as opposed to overall predictors of outcomes, which are better evaluated using general, unmatched patient populations.

The mean postoperative Tegner scores in the current study were 6.5 ± 2.0 and 6.6 ± 1.5 for all-inside and inside-out repair techniques, compared with 6.3 ± 1.3 and 5.3 ± 1.2, respectively, in the Fillingham et al[21] study. The mean postoperative IKDC scores in our study were 93.6 ± 5.4 for all-inside repair and 94.0 ± 4.0 for inside-out repair. This compares favorably with IKDC scores reported in other studies.[10,22,27,44,53]

The current study did not identify a significantly increased risk for minor complications between groups, and there were no major complications in either group. The risk of nerve irritation will never be eliminated, given the nature of the inside-out technique, but careful posterior dissection can certainly mitigate this risk to an acceptable level. In their systematic review, Grant et al[23] found a 9% rate of nerve irritation and a 1% infection rate after inside-out repair. Fillingham et al[21] reported overall similar complication rates of 4.6% for all-inside repair and 5.1% for inside-out repair.

The lack of difference in clinical success rates, clinical outcome scores, or complication rates between repair methods in the current study contributes to the body of evidence challenging the dogma of inside-out repair as the gold standard for large, vertical longitudinal tears.[21,23] Biomechanical studies support the increased use of all-inside devices, demonstrating similar loads to failure when comparing second-generation all-inside suture devices with traditional vertical mattress suture configurations.[8,9,11] It is likely that anatomic reduction and biologic preparation/augmentation are equally as important as the suture device chosen.[54]

The current study does have some limitations. First, the strict inclusion criteria meant that the cohort sizes were fairly small, although post hoc power analysis demonstrated adequate power to detect differences in clinical outcomes between techniques. Larger sample sizes would be required to match patients based on additional criteria such as number of sutures or to evenly divide the 2 repair techniques between each surgeon. Second, the study was retrospective in nature, and thus, analysis was limited to the data available in the medical record database. The retrospective, nonrandomized nature of the study introduced selection bias, although we attempted to offset this through the propensity-matched study design. Third, magnetic resonance imaging and second-look arthroscopic surgery were not utilized to identify the true healing rate, which may have resulted in the underreporting of failures. However, clinical healing is the more important metric for overall knee function. Last, multiple surgeons performed the meniscal repairs, but the overall technique was similar, and this may suggest that these results are more generalizable.

CONCLUSION

The clinical success rate observed in this series of propensity-matched large bucket-handle meniscal tears was 80% for both all-inside repair and inside-out repair. This demonstrates that satisfactory clinical outcomes are achievable at short-term to midterm follow-up with both inside-out and all-inside repair of bucket-handle meniscal tears in rigorously matched patients with similar meniscal tear patterns. Increasing patient age trended toward a decreased clinical retear rate, independent of the repair technique. Given the similar biomechanical profile between the repair methods, surgeons should utilize the device or technique that allows them to most reliably obtain anatomic reduction. Randomized clinical trials or prospective cohort studies are needed to more completely evaluate the clinical and survival differences between the 2 repair types for bucket-handle meniscal tears.

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