Comparison of Inside-Out and All-Inside Techniques for the Repair of Isolated Meniscal Tears

CME

A Systematic Review

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Background: Arthroscopic meniscal repair techniques are continuing to evolve. Most studies to date comparing the healing rate of inside-out to all-inside meniscal repair techniques are confounded by associated anterior cruciate ligament reconstruction or deficiency.

Purpose: This review was conducted to compare the effectiveness and complications of the inside-out repair technique to that of the all-inside repair technique in isolated unstable peripheral longitudinal (''bucket-handle'') meniscal tears.

Study Design: Systematic review.

Methods: Computerized keyword searches of MEDLINE, EMBASE, CINAHL, ACP Journal Club, the Cochrane Central Register of Controlled Trials, and the Cochrane Database of Systematic Reviews were performed. Two reviewers independently performed searches and article reduction. Studies that included stratified data for isolated unstable longitudinal meniscal tears in stable knees, repaired with either an inside-out or all-inside repair technique, were selected. Data on clinical failure, subjective outcome measures, and complications were summarized.

Results: Nineteen studies included data specific to isolated meniscal tears. The rate of clinical failure was 17% for inside-out repairs and 19% for all-inside repairs. Lysholm scores and Tegner activity scores were similar between the 2 repair methods (87.8 vs 90.2 and 5.6 vs 5.5, respectively). The prevalence of nerve injury/irritation was higher with the inside-out technique (9% vs 2%). All-inside techniques had a higher rate of local soft tissue irritation, swelling, and implant migration or breakage. The use of older generation, rigid, all-inside implants is associated with chondral injury.

Conclusion: There are no differences in clinical failure rate or subjective outcome between inside-out and all-inside meniscus repair techniques. Complications are associated with both techniques. More nerve symptoms are associated with the inside-out repair and more implant-related complications are associated with the all-inside technique.

Clinical Relevance: Rates of structural healing and complications are comparable for inside-out and all-inside repair techniques for isolated meniscal injury. Differences in observed healing rates after meniscal repair may be more dependent on tear pattern and associated anterior cruciate ligament reconstruction rather than an inside-out versus all-inside surgical approach.

Keywords: meniscus repair; all-inside; inside-out; arthroscopic meniscal repair; complications

The increased use of the arthroscope in the 1980s was expected to present significant advantages to meniscus surgery and patient outcomes. The arthroscopic approach was designed to allow the surgeon better visualization of the meniscus, allow repair of more complex and difficult-to-access tears, decrease surgical morbidity, and do so with a much more cosmetic result than the standard open repair.[10,12,13] This new arthroscopically assisted inside-out technique,[38] however, was subsequently found to have a concerning rate of injuries to the saphenous and peroneal nerves, as well as the popliteal vasculature.[11] Given these findings, this minimally invasive procedure was modified with an additional incision and dissection, not unlike that used for an open repair, to protect the neurovascular structures from the exiting suture needles.[39]

While the inside-out suture repair technique remains the current gold standard of meniscal repair, arthroscopists and

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One or more of the authors has declared the following potential conflict of interest or source of funding: Dr Bedi has received a royalty for an educational consult from Smith & Nephew.

The American Journal of Sports Medicine, Vol. 40, No. 2
DOI: 10.1177/0363546511411701

medical device companies alike have continued to strive for a successful and completely (all-inside) arthroscopic technique for meniscal repair. In 1991, Morgan[31] reported that the inside-out technique required suturing to the posterior capsule, which could precipitate flexion contractures. Additionally, he believed that this technique lacked the ability to optimally manage the frequent tears to the posterior horns of the menisci. He published a new "all-inside" technique utilizing a posterior cannulated portal, a 70° arthroscope, and a new suture hook device to perform an all-inside suture repair of the posterior horn.[31] In 1993 and 1997, Albrecht-Olsen et al[2,3] published their work with a new all-inside meniscus arrow technique. This new polylactic acid implant was designed to shorten operative time and minimize risk to the neurovascular structures, while allowing repair with a standard 30° arthroscope through standard anterior arthroscopy portals.[3] Since this publication, there have been many more all-inside implants developed and reported, including arrow, screw, staple, and suture-based implants.

In a recent systematic review of all-inside meniscal repair devices, Lozano et al[26] were unable to draw any conclusions regarding which devices had the lowest failure rate. They did, however, identify a consistent confounder in most of the published literature on meniscal healing—the concomitant anterior cruciate ligament (ACL) injury/reconstruction. Previous studies have consistently demonstrated the improved healing capacity of the meniscus when associated with a concomitant ACL reconstruction.[9,38,44] Conversely, multiple authors have demonstrated an increased failure rate of meniscal repairs in ACL-deficient individuals.[6,22,40] Studying the effectiveness of meniscal repair techniques with heterogeneous sample populations (ie, including isolated meniscal tears and those associated with ACL injury/reconstruction) limits the utility of these study outcomes, especially because the majority of studies have a higher proportion of patients with concomitant ACL reconstructions.[26]

Given the relatively large body of literature on meniscal repair techniques that includes the confounding variable of ACL injury/reconstruction, the purpose of this systematic review was to compare the effectiveness and complications of the inside-out repair technique to that of the all-inside repair technique in isolated, unstable peripheral longitudinal ("bucket-handle") meniscal tears.

METHODS

Literature searches of the following computerized databases were performed: MEDLINE (1950 to September week 1, 2010), EBSCO CINAHL (searched on October 5, 2010), EMBASE (1980 to 2010 week 39), ACP Journal Club (1991 to August 2010), Cochrane Central Register of Controlled Trials (CCRCT) (3rd quarter, 2010), and the Cochrane Database of Systematic Reviews (CDSR) (2005 to August 2010). The following keywords were used for the MEDLINE, EMBASE, and CINAHL searches: all-inside meniscus repair, all-inside meniscal repair, inside-out meniscus repair, inside-out meniscal repair, bucket handle tear, bucket handle meniscal tear, and bucket handle meniscus repair. In MEDLINE, the use of a hyphen (eg, all-inside vs all inside) produced different results and as such separate searches were run. Because of the more limited nature of ACP Journal Club, CCRCT, and CDSR, the following more sensitive keywords were used for the searches: meniscus repair, meniscal repair. The reference lists of the included articles and previous (systematic) reviews related to meniscal repair were also hand searched for additional studies.[§]

The initial searches were completed separately by 2 reviewers. The 2 lists were then compared and collated into 1 complete list. This article list was then reduced by applying the inclusion and exclusion criteria that follow. Inclusion criteria were (1) isolated bucket-handle tears or isolated unstable vertical longitudinal tears of $\geq$10 mm in length, (2) tears located in the red-on-red or red-on-white zones,[33] (3) surgical repair of the meniscus by either the all-inside technique (all variations of implants included) or the inside-out technique, (4) $\geq$3 months' follow-up, (5) age $\geq$18 years, (6) original data, (7) English language, (8) human subjects, and (9) all study designs with levels of evidence I through IV.[48] Exclusion criteria were (1) concomitant or staged ACL reconstruction; (2) cruciate ligament deficiency or otherwise diagnosed instability; (3) radial, horizontal, or degenerative tears, or the lack of stratification to allow for extraction of vertical/bucket-handle tear–specific data; (4) biomechanical studies; (5) technical notes; (6) letters to the editor; and (7) review articles.

Many articles included both isolated tears and those with concomitant ACL injuries.[‖] An article was excluded if the data were not stratified sufficiently to allow for the extraction of data relevant to isolated meniscal tears. The 2 reviewers manually searched all articles by title and abstract to determine their fit with the inclusion and exclusion criteria. This process was done separately by the same 2 reviewers and the results were compared after the title review, and again after the abstract review, to compile a list of relevant articles. If abstracts were not available, the complete article was reviewed. The methods and results sections of potentially relevant articles were then retrieved in their entirety to identify the studies that met the predetermined inclusion and exclusion criteria. A high sensitivity for the detection of relevant articles was maintained until the full-text review stage.

Outcomes of interest included the following: (1) clinical failure rate, (2) subjective outcome scores (eg, Lysholm,[27] Tegner activity scores[43]), (3) operative time, (4) healing on second-look arthroscopy, (5) healing on MRI or CT, and (6) complications.

RESULTS

The initial hit rates for each of the search terms in MEDLINE, EMBASE, and CINAHL are included in Table 1. The ACP Journal Club search yielded no hits for either search term. The CCRCT search resulted in 7 hits for

[§]References 1, 4, 7, 9, 14-19, 21, 22, 24-26, 34, 35, 37, 41, 45.

[‖]References 1, 7, 9, 14, 16-19, 21, 22, 24, 25, 34, 35, 37, 41, 45.

"meniscus repair," with only 4 relevant to our subject of interest; and 4 hits for the term "meniscal repair," with only 1 relevant study. The CDSR search resulted in 2 hits for "meniscus repair," with only 1 relevant to the study, and 0 hits for "meniscal repair."

After consideration of the inclusion/exclusion criteria and cross-referencing, the inclusion list was reduced to 19 articles. None of the articles identified demonstrated level I evidence.[48] There were 2 level II randomized controlled trials,[1,16] 1 level III retrospective cohort study,[41] and the remaining 16 studies were level IV case series.[¶] The study summaries are included in Table 2.

Only 2 of the 19 selected studies were restricted to isolated meniscal tears.[4,15] The ages and other demographic data were rarely given for the isolated meniscal tear patients and are therefore not reported here. Eight studies utilized the inside-out suture technique.[1,4,9,15,17,18,34,41] The all-inside implants included the meniscal arrow (8 studies),[#] the meniscal screw (2 studies),[16,45] the FasT-Fix (Smith & Nephew, Andover, Massachusetts) suture device (3 studies),[7,14,21] and the meniscal staple (1 study).[25] These studies included a total of 311 relevant patients—139 patients with inside-out suture fixation and 172 patients with all-inside repairs. Because of the heterogeneous inclusion criteria of these studies (isolated meniscal tears and concomitant ACL injuries), the sample sizes of isolated meniscal tears were small (mean, 16.6 patients per study; range, 2-35). Mean follow-up time was 38.1 months (range, 3.5-156 months).

TABLE 1
Initial Search Results for MEDLINE, EMBASE, and CINAHL

Keyword Search Term(s)	MEDLINE	EMBASE	CINAHL
Meniscus repair and *all-inside*	73	27	1
Meniscus repair and *all inside*	73	27	1
Meniscal repair and *all-inside*	86	81	6
Meniscal repair and *all inside*	86	81	6
Meniscus repair and *inside-out*	58	26	2
Meniscus repair and *inside out*	71	26	2
Meniscal repair and *inside-out*	64	70	4
Meniscal repair and *inside out*	74	70	4
Bucket handle tear	201	94	18
Bucket handle meniscal tear	126	42	1
Bucket handle meniscus tear	130	9	11

Clinical Failures

Five of the 8 studies involving inside-out suture repair reported their clinical failure rate. The failure rate varied from 0% to 30%.[4,9,15,17,18] Albrecht-Olsen and Bak[4] reported that 8 of their 27 patients (30%) had symptomatic retears and underwent meniscectomy after a mean of 18 months. Four of these patients had an identifiable injury while the other 4 patients had a spontaneous onset of symptoms. Conversely, Johannsen et al[18] found no clinical symptoms in 18 patients over a postoperative period of 3 to 20 months. Horibe et al[15] performed second-look arthroscopies on 35 patients a mean of 5 months (range, 2-10 months) after inside-out repair. While 4 of these patients (11%) had clinical symptoms, during arthroscopy there was incomplete healing found in 4 menisci and no healing in 5 menisci (26%). Cannon and Vittori[9] used multiple modalities to evaluate failure. They found a >50% cleft remaining in 5 of the 12 patients (42%) on which they performed a second-look arthroscopy and they found contrast traversing the meniscal tear in 6 of the 10 patients (60%) who underwent a CT arthrogram. Clinically, however, only 6 of the 22 patients were symptomatic, resulting in a failure rate of 27%. Finally, Jensen et al[17] reported clinical failures in 2 of their 22 patients (9%). Using a combination of clinical and second-look arthroscopy findings, the pooled failure rate for inside-out suture repair was therefore 21 of 124 patients (17%).

Seven studies involving meniscus arrows, FasT-Fix, staples, and screws reported failures.[7,14,19,22,24,25,45] The failure rate with meniscus arrows ranged from 6% to 42%.[19,22,24] Jones et al[19] had 2 of their 16 patients fail (13%, with failure = need for second surgery and partial meniscectomy) at 17 and 18 months. While 1 patient had an identifiable injury at 7 months, the other was diagnosed with a white-on-white tear and therefore should have originally been excluded from their study. This exclusion would lower the failure rate to 6%, which is concordant with Koukoulias et al,[22] who had 1 of 17 patients (6%) with continued pain/swelling up to 12 months after repair. This patient underwent a repeat arthroscopy and partial meniscectomy. In contradiction to this low failure rate, Kurzweil et al[24] reported symptoms of locking, buckling, swelling, pain, or joint-line tenderness in 5 of 12 isolated meniscal repair patients (42%). It is difficult to definitively explain this dichotomy in failure rate. Kurzweil et al, however, stated that patients at the beginning of the study followed an accelerated rehabilitation program, including immediate full weightbearing as tolerated. This rehabilitation program was modified to restricted weightbearing with crutches for 4 weeks and restriction of squatting for 4 months, after a number of early failures. The authors do not report how many failures occurred before the rehabilitation modification.

Using a variety of failure definitions, studies involving the FasT-Fix, meniscal staple, and meniscal screw reported failure rates in the range of 17% to 29%.[7,14,25,45] Laprell et al[25] used a meniscal staple device (Mitek Meniscal Repair System; Mitek, Ethicon, Norderstedt, Germany) and found that 4 of the 20 patients (20%) had continued clinical symptoms that included locking, joint-line pain, and kneeling pain. Hoffelner et al[14] implanted the FasT-Fix and used MRI to diagnose 2 of 7 patients (29%) with a failure of healing (ie, hyperintense signal uptake representing fluid tracking through the meniscus and continuous with the meniscal base). Conversely, Barber et al[7] reported a failure rate of 17% (2 of 12 patients) with the FasT-Fix based on either clinical symptoms or second-look arthroscopy. The Clearfix meniscal screw (Mitek

[¶]References 4, 7, 9, 14, 15, 17-19, 21, 22, 24, 25, 34, 35, 37, 45.

[#]References 1, 16, 19, 22, 24, 35, 37, 41.

TABLE 2
Study Data[a]

Authors, Year	Level of Evidence and Type of Study	Groups	Patients: Total (Isolated Meniscus)	Outcome Measure(s)	Results	**Mean Follow-up**
Albrecht-Olsen et al,[1] 1999	Level II RCT	(1) Inside-out suture (2) Meniscus arrow	Suture: 32 (15) Arrow: 33 (15)	OR time, healing on second scope	OR time: suture = 60min, arrow = 30 min; $P < .001$ Healing: no difference, $P = 1.0$	3-4 months
Jarvela et al,[16] 2010	Level II RCT	(1) Meniscal screw (2) Meniscal arrow	Screw: 21 (12) Arrow: 21 (16)	Failure	10 of 28 (36%) failed	2 years
Steenbrugge et al,[41] 2004[b]	Level III Retrospective cohort	(1) Inside-out suture (2) Biofix meniscus arrow	Inside-out: 20(13, **3**) All-inside: 35(26, **4**)	mHSS	For >6-mm tears: Inside-out: 3 good mHSS All-inside: 3 excellent, 1 poor	Inside-out: 13 years All-inside: 6.5 years
Albrecht-Olsen and Bak,[4] 1993	Level IV Case series	Inside-out suture	Total: 27 Lysholm: 19 All isolated	Failure, Lysholm	8 of 27 failures 16 of 19 (84%) good-to-excellent Lysholm	18 months
Barber et al,[7] 2008	Level IV Case series	FasT-Fix	41 (12)	Clinical failure	2 of 12 (16.7%)	31 (12-58) months
Cannon and Vittori,[9] 1992	Level IV Case series	Inside-out suture	80 (22)	Failure on clinical, arthroscopic, or arthrogram exam	5 of 12 (42%) failed arthroscopically 6 of 10 (60%) failed on arthrogram 6 of 22 (27%) failed clinically	7 (5-12) months
Hoffelner et al,[14] 2011	Level IV Case series	FasT-Fix	27 (7)	Failure, Lysholm, Tegner, MRI healing	Lysholm = 85 ± 8 Tegner = 5.6 2 of 7 failed on MRI	4.5 ± 1.7 years
Horibe et al,[15] 1996	Level IV Case series	Inside-out suture	36 tears in 35 patients All isolated	Clinical failure and second-look arthroscopy	31 no symptoms Scope: 27 complete healing, 4 incomplete healing, 5 no healing	5 (2-10) months
Jensen et al,[17] 1994	Level IV Case series	Inside-out suture	36 (22)	Lysholm, Tegner, clinical failure	Lysholm = 88 Tegner = 5.7 2 of 22 (9%) clinically failed	4.5 (1–6.3) years
Johannsen et al,[18] 1988	Level IV Case series	Inside-out suture	29 (10)	Lysholm, clinical failure	Lysholm = 92 (81-98) 100% clinically healed	12 (6-20) months
Jones et al,[19] 2002	Level IV Case series	Meniscal arrow	38 (16)	Lysholm, clinical failure	Clinical failure 2 of 16 (12.5%) Lysholm = 94.8	29.7 months
Kotsovolos et al,[21] 2006	Level IV Case series	FasT-Fix	58 (22)	Lysholm, Tegner, OR time	Lysholm = 86.8 (61-100) Tegner = 5.9 (5-7) OR time = 11 min 9.1% clinically symptomatic	18(14-28) months
Koukoulias et al,[22] 2007	Level IV Case series	Bionx meniscus arrow	45 (17)	Clinical failure, Lysholm, Tegner	1 failure (5.9%)	73 (49-96) months
Kurzweil et al,[24] 2005	Level IV Case series	Meniscus arrow	57 (12)	Clinical failure	5 of 12 (42%) failed	54 (36-70) months
Laprell et al,[25] 2002	Level IV Case series	Mitek meniscus staple	37 (20)	Lysholm, Tegner, OR time	OR time: 29.3 (18-39) min; Lysholm = 93 Tegner = 3.8	Min 1 year
Perdue et al,[34] 1996	Level IV Case series	Inside-out suture	63 (13)	Lysholm, Tegner	Lysholm = 83.4 ± 16.2 Tegner = 5.4 ± 1.7	29.6 (18-51) months
Petsche et al,[35] 2002	Level IV Case series	Meniscus arrow	29 (2)	Lysholm, Tegner	Lysholm = 95.5 Tegner = 6.5	24 (12-42) months
Sarimo et al,[37] 2005	Level IV Case series	Bionx meniscus arrow	20 (8)	Lysholm, Tegner	Lysholm = 92.4 Tegner = 6.4 Healed on 5 of 5 second-look scopes	26 (6-38) months
Tsai et al,[45] 2004	Level IV Case series	Mitek Clearfix screw	18 (9)	Clinical failure, Lysholm, Tegner	Lysholm = 84 (52-100) Tegner = 5 (3-10) 2 of 9 clinical failures	106 (70 – 189) weeks

[a]RCT, randomized controlled trial; OR, operating room; HSS, Hospital for Special Surgery; mHSS, modified HSS.

[b]Steenbrugge et al included patients with concomitant anterior cruciate ligament reconstructions and isolated meniscal repairs. The tear size was divided into 3 categories: 1-3 mm, 3-6 mm, and >6 mm in length. Given the inclusion criteria for this study, only those patients with tears >6 mm were included. The number of study patients is therefore listed as: total patients (all isolated meniscus tear patients, included patients with isolated meniscus tears >6 mm).

Products, Norwood, Massachusetts) was implanted by Tsai et al[45] in 13 knees that did not undergo ACL reconstruction (2 of these were ACL-deficient). They were able to follow up with 9 patients but did not report whether the 2 ACL-deficient patients were in this group. Two of the 9 patients were reported as failures (ie, requirement for subsequent surgery). Given the unfortunate ambiguity with respect to the ACL-deficient patients, the failure rate of the meniscal screw in isolated meniscal tears with stable knees could be 0% to 28%. Apart from this study, the pooled failure rate for all-inside devices was 19% (16 of 84 patients).

The preoperative duration of symptoms may relate to the success of repair. Nine studies stated the duration of symptoms.[**] Five of these had a duration of symptoms of less than 8 months.[16,19,21,22,37] The others included patients with symptoms up to 12 years.[1,2,9,15] All of the studies with a short duration of symptoms that reported clinical failure rates used all-inside techniques. The pooled failure rate was 9.1% (6 of 66 patients).[7,19,21,22] Studies with a wide range of symptom duration demonstrated a failure rate of 17.5% (10 of 57 patients) for inside-out repair[9,15] and 29.6% (8 of 27 patients) for all-inside repairs.[2]

The number of studies utilizing each of the different all-inside implants was small. The failure rate for the FasT-Fix was 14.6% (6 of 41 patients).[7,14,21] Three studies demonstrated a failure rate of 15.9% (7 of 44 patients) for the meniscus arrow.[19,22,24] The failure rates of the meniscal staple (20%) and meniscal screw (0%-28%) were previously discussed.[25,45]

Given the limitations of combining the various methods used to report clinical failure, the pooled failure rates for inside-out and all-inside meniscal repair techniques were similar—17% versus 19%, respectively. There were 116 inside-out patients contained in the studies that reported clinical failures[2,9,15,17,18] and there were 105 patients in the all-inside studies that reported clinical failures.[14,19,21,22,24,25,45] The pooled odds ratio for the comparison of clinical failure in the inside-out studies to the all-inside studies was 0.92 (95% confidence interval = 0.45, 1.86).

Subjective Outcomes

The most common patient-oriented outcomes reported were the Lysholm scale and the Tegner activity scale.[27,43] Unfortunately, none of the 3 comparative studies included in this review used[1,41] or reported[16] these scores for isolated meniscal tear patients. Of the 10 case series that reported Lysholm scores, the pooled mean score was 89.5 ± 4.6 at 30.4 ± 14.5 months' follow-up.[††] In their case series of inside-out suture repairs, Albrecht-Olsen and Bak[4] did not report the mean Lysholm score but noted that 16 of their 19 patients had good or excellent scores a mean of 18 months after repair. Given that a "good" Lysholm score is usually related to a numerical score of 84 to 94,[8] this study falls in line with the other quantitatively reported studies. Comparing studies using inside-out suture repair[17,18,34] to the various types of all-inside repair,[14,19,21,25,35,37,45] the pooled Lysholm scores were similar: inside-out, 87.8 ± 4.3; all-inside, 90.2 ± 4.8. Tegner activity scores were reported in 2 of the inside-out suture repair case series (mean = 5.6 ± 0.2) and by 6 of the all-inside case series (mean = 5.5 ± 1.0) a mean of 30 months after repair.[‡‡] After review of the pooled Lysholm and Tegner outcomes, there was minimal difference between the inside-out and all-inside repair techniques.

Operative Time

One of the proposed benefits of the all-inside repair technique is that it is quicker to perform, thereby reducing operative time. Of the 19 included studies, however, only 3 included information on the operative time.[1,21,25] The study by Albrecht-Olsen et al[1] was a level II randomized controlled trial comparing fixation with inside-out suture technique and all-inside meniscus arrow implants. The mean operative times were 60 minutes for the suture fixation and 30 minutes for the arrow fixation ($P < .001$). The definition of operative time was not clearly defined in any study such that it is unclear if the authors reported only the intraoperative time required for the actual fixation or if the complete skin-to-skin time is reported. In this regard, Laprell et al[25] was in line with the Albrecht-Olsen study, reporting an average of 29.3 minutes per all-inside procedure (range, 18-39 minutes) while Kotsovolos et al[21] reported that an "additional" 11 minutes per procedure was required in their study using the FasT-Fix. While the published data are limited, the all-inside technique does appear to require less operative time (up to 50%) compared with the inside-out repair.

Complications

Complications were reported in 11 of the 19 studies.[§§] Given the small number of complications in each study, the authors frequently did not differentiate whether they occurred in patients with isolated meniscal tears or those with concomitant ACL reconstructions. The most commonly reported complications associated with meniscal fixation were swelling, pain, and nerve irritation–type symptoms.[1,9,19,21,22,35,41] These complications are discussed here if it were thought that they were reasonably attributable to the meniscal repair, regardless of whether they were specifically reported to occur in isolated meniscal tear patients.

Two of the 22 isolated meniscal tear patients in the study by Kotsovolos et al[21] had continued swelling and erythema at 1 month after fixation with the FasT-Fix. These patients underwent arthroscopic debridement and synovectomy and were given antibiotics. The cultures were negative but the arthroscopic evaluation demonstrated

**References 1, 2, 9, 15, 16, 19, 21, 22, 37.

††References 14, 17-19, 21, 25, 34, 35, 37, 45.

‡‡References 14, 17, 21, 25, 34, 35, 37, 45.

§§References 1, 9, 16, 19, 21, 22, 24, 35, 37, 41, 45.

substantial synovitis and no chondral lesion. Jones et al[19] reported a 31.6% rate of knee pain or tenderness at the repair site after meniscus arrow fixation. These symptoms resolved within 12 months in all but 1 patient. Koukoulias et al[22] reported 3 cases of soft tissue irritation at the arrow fixation site in their case series (17 ACL-intact, 45 ACL-reconstructed). The symptoms resolved within 4 months in 2 of these patients. The third patient had additional irritation of the infrapatellar branch of the saphenous nerve requiring removal of the subcutaneous arrow tip under local anesthesia. Albrecht-Olsen et al[1] reported that 2 patients in their arrow group had pain along the infrapatellar nerve and 5 patients in their suture group had symptoms in the distribution of the saphenous nerve. Steenbrugge et al[41] reported 1 patient in their suture group with saphenous neuropraxia and 2 patients in their arrow group with irritation of the soft tissue overlying the implant. Cannon and Vittori,[9] in their study of the inside-out technique, reported 1 peroneal nerve palsy that fully recovered except for some slight residual hyperesthesia in the first dorsal web space. Overall, there were 17 of 122 patients (14%) with local irritative symptoms associated with all-inside fixation/implants.[19,21,22] Nerve symptoms occurred in 3 of 130 patients (2%) with all-inside implants[1,22] and 7 of 75 patients (9%) with inside-out suture repair.[1,9,41]

Five studies have reported the occurrence of prominent implants or the need for implant removal.[19,22,24,35,45] Four of these studies involved the use of meniscus arrows and 1 used the Clearfix meniscal screw. Two studies reported a total of 6 of 54 patients (11%) with either a painless prominence or skin irritation from underlying arrows.[35,45] All except 2 cases resolved on their own over 3 to 7 months. Two patients had local extra-articular injections of lidocaine and triamcinolone that resulted in eventual resolution without surgery.[35] Four studies reported the need for either superficial or arthroscopic removal of an implant.[19,22,24,45] Three of 83 patients had superficial removal of implants under local anesthesia for soft tissue or nerve irritation, of which 1 implant had actually migrated transcutaneously.[19,22] In 2 other studies, 1 meniscal screw had migrated from the meniscus to the posterolateral corner of the knee joint (1 of 25 patients) and 3 meniscus arrows (3 of 57 patients) had migrated out of the meniscus and become symptomatic. These implants were removed arthroscopically.[24,45]

The use of rigid implants on the surface of the meniscus has raised concerns regarding the possibility of femoral cartilage damage. Although follow-up MRI may be able to give some information about the local cartilage, true diagnosis of implant-related chondral damage is limited to those patients undergoing a second-look arthroscopy. Patients may present with an effusion, knee aching, joint-line tenderness, pain with squatting or strenuous activity, or even mechanical symptoms.[24,37] Chondral damage can range from a small impression with intact cartilage to full-thickness tram-track gouging.[1,16,24,37] Across 4 studies, chondral damage was seen in 15 of 66 (23%) second-look arthroscopies.[1,16,24,37] Care must be taken, however, in the interpretation of these data as 3 of these 4 studies only performed second-look arthroscopies in symptomatic patients.[16,24,37] This reported prevalence, therefore, likely overpredicts the true prevalence of chondral injury in patients with rigid meniscal implants.

Only 3 studies used newer generation all-inside implants that leave only suture on the meniscal weight-bearing surface.[7,14,21] Kotsovolos et al[21] performed a second arthroscopy on 2 of their 58 patients (for prolonged effusion and synovitis) and noted that there was no new chondral damage in the region of the FasT-Fix implants. Barber et al[7] performed repeat arthroscopies on symptomatic patients but did not report any new chondral damage or if any of the relooks were done in patients with isolated meniscal tears. Hoffelner et al[14] did not perform any second-look arthroscopies. The data on chondral damage associated with the newer generation all-inside implants are therefore limited.

Postoperative infection occurred in 2 of the 19 studies.[1,41] Four studies[9,22,25,35] reported that there were no infections and the remainder were assumed to have no infections but this was not specifically stated. In the Albrecht-Olsen et al[1] study comparing suture fixation and the meniscus arrow, 1 patient in the suture group returned 5 days after surgery with fever and a swollen knee. This patient required an arthroscopic synovectomy and partial meniscectomy. Cultures revealed *Staphyloccocus aureus*. In their retrospective cohort study of suture fixation versus meniscal arrow, Steenbrugge et al[41] reported a case of superficial infection in each group. Unfortunately, they did not indicate if these patients had isolated meniscal tears or concomitant ACL reconstructions.

One of the goals behind the initial all-inside repair techniques of Morgan and Albrecht-Olsen was to reduce the risk to the posterior neurovascular structures.[2,3,31] While the all-inside techniques have reduced the frequency of reported nerve injury/irritation (pooled results: all-inside = 2%; inside-out = 9%), the various all-inside techniques have brought forward new complications not formerly seen in suture-only repairs. Fourteen percent of patients across the included studies reported local irritation attributable to the all-inside implants and there was a 6% rate of implant prominence or need for removal (either under local anesthetic or reoperation). Multiple studies included second-look arthroscopies and reported a range of chondral damage because of prominent rigid implants. The all-inside techniques have therefore succeeded in reducing the reported prevalence of nerve injury or symptoms but at the cost of other troubling complications. Pooling all of the available complications data, the odds ratio relating the complications associated with the inside-out technique to those of the all-inside techniques was 0.55 (95% confidence interval = 0.27, 1.10).

DISCUSSION

Our understanding of the role of the meniscus has advanced substantially over the past 30 years. Initially thought to be a structure that should be removed at the least sign of injury,[30] it is now highly regarded for its critical role in shock absorption,[46] load transmission,[23,47] and knee stability.[5,28,29] Because of these important roles in knee function, much research has shown the clear association between meniscal injury/meniscal loss (eg, partial/complete meniscectomy) and the development of degenerative changes and osteoarthritis of the knee. This information has recently been summarized in a systematic review by Salata et al.[36] As this understanding has increased, surgeons and scientists have been continually trying to develop better ways to repair torn menisci to achieve healing and preservation of its function. The evolution of meniscal repair techniques has followed advancements in arthroscopy that have allowed direct visualization and repair of the injured meniscus while minimizing operative morbidity.

Previous literature has demonstrated various factors that improve (eg, concurrent ACL reconstruction, young age, tears near the meniscocapsular junction)[9,38] and inhibit (eg, ACL deficiency/joint instability)[6,22,40] the ability of the meniscus to heal. When evaluating the success or effectiveness of the various repair techniques for torn menisci, however, the majority of studies have not stratified for the effects of these confounders. For example, in a recent systematic review of all-inside meniscus repair techniques by Lozano et al,[26] all 32 studies in the review included a mix of ACL injured/reconstructed individuals and those with isolated meniscal tears (1 study indicated concomitant procedures but did not specify any details[32]). Given the current knowledge that meniscus healing is highly dependent upon the stability of the knee and concomitant ACL reconstruction, we thought it was appropriate to evaluate the effectiveness of both inside-out and all-inside techniques in patients without these known confounders (ie, isolated meniscal tears).

The aforementioned lack of studies that focused on patients with isolated meniscal tears (2 studies[4,15]) presented a challenge for this systematic review. Given this issue, our data gathering was limited to studies that stratified their results, to some extent, by whether or not the meniscal tear was isolated. Even in these studies, data were not always stratified for all of the included outcome measures. Furthermore, there was a distinct lack of high-level evidence to evaluate. The systematic review by Lozano et al[26] included 8 level I through III articles, whereas the current study includes only 3.[1,16,41] Only 2 of those studies compared inside-out suture technique to an all-inside implant.[1,41]

Any discussion of successful healing is heavily dependent on the definition of success/failure. The studies included in this review have used a variety of definitions for failure of healing. The various definitions have included (1) clinical symptoms of joint-line pain, effusion, and/or mechanical symptoms[7,9,17,18,22,24,25]; (2) appearance of healing on second-look arthroscopy[9,15]; (3) need for subsequent surgery (and usually partial meniscectomy)[4,19,45]; and (4) lack of healing on MRI (ie, high signal indicative of fluid traversing the meniscus)[14] or CT (contrast traversing the tear).[9] The pooled estimates of failure were 17% for inside-out suture techniques and 0% to 28% for the various all-inside implants. Ignoring the ambiguity in the meniscal screw study by Tsai et al,[45] the pooled failure rate for the all-inside implants was 19%.[||||] The heterogeneity and case series design of the reviewed studies limits the strength of these conclusions. Given these limitations, however, there appears to be no substantial difference in failure rate between inside-out and all-inside repair techniques in isolated peripheral, longitudinal meniscal tears.

The most commonly reported subjective functional scoring scale was the Lysholm scale. This scale was originally published for use in patients with knee ligament injuries.[27] While a group of patients with meniscal injuries was used in the validation process, no data to support the validity and responsiveness of the scale in meniscal injury was included in the development. In fact, the authors state that "these differences between different knee disorders. . . suggest a need for different or modified scoring scales for the follow-up of patients with different diagnoses."[27] From the publication of this scale in 1982 until 2007, however, there was no other meniscus-specific subjective outcome measure available. Given the common usage of the Lysholm scale in meniscus patients, without solid support for its validity and responsiveness, Briggs et al[8] investigated the reliability, validity, and responsiveness of both the Lysholm scale and the Tegner activity scale in patients with isolated meniscal tears and those with meniscal injuries combined with other knee injuries. They stated that "in general, the Lysholm and Tegner scales demonstrated acceptable psychometric parameters." More recently, Kirkley et al[20] developed the Western Ontario Meniscal Evaluation Tool (WOMET). This is a disease-specific quality-of-life tool that is completed entirely by the patient and has been assessed for reliability, validity, and responsiveness and found to be superior to the Lysholm for patients with meniscal injuries.[20,42] This may be a better option for evaluating the disease-specific quality of life in future studies of meniscal injury and repair.

The pooled results from the case series in this review have demonstrated that most patients undergoing meniscal repair attain a "good" rating of function on the Lysholm scale. Comparing inside-out repairs to all-inside repairs demonstrated a mean difference of 2 points (88 vs 90). According to Briggs et al,[8] the minimal clinically important difference (MCID) for the Lysholm scale is 10 points. The difference identified in this review, therefore, is likely not clinically relevant. The Tegner scores, again based only on multiple case series, were equal between the inside-out and all-inside groups (5.6 vs 5.5). While these Tegner scores place the patients' activity level fairly low on the sports scale (slightly above jogging twice a week or cross-country skiing),[43] it is unknown how much this level is limited by the status of the knee after repair versus the patients' volitional decrease in activity level with increasing age and the history of a meniscus injury. While the Lysholm scale may not be the optimum outcome for the evaluation of function after meniscal repair, it was likely

[||||]References 4, 14, 15, 18, 19, 22, 24, 25.

the best one available at the time of the included studies. Based on the results of this systematic review, the outcomes of the Lysholm and Tegner scales have descriptively shown no difference between the inside-out and all-inside techniques.

In the current state of health care, measures of cost-effectiveness and cost-benefit are paramount to clinical decision-making. This focus is clearly relevant in this evaluation of inside-out and all-inside techniques. One of the tenets of Albrecht-Olsen's work was to develop an all-inside device that would shorten operative time.[2,3] If a procedure can be performed quicker, either direct savings are achieved or more patients can be treated with the same amount of operative resources. The balancing variable, however, is the increased cost of the all-inside implants relative to the cost of the standard sutures used for the inside-out procedure. Only 3 of the studies in this review included data on operative time. Additionally, the definition of operative time was not well defined in either study. The limited data available show that, as expected, the operative time for the all-inside procedure was shorter than the time required for the inside-out suturing. Unfortunately, while some studies reported the mean number of all-inside implants used, they did not stratify them for the isolated meniscal tear patients. To complicate this scenario, different implants and different implant companies likely have different costs. The use of hospital contracts based on exclusive use or economies of size/volume will also vary the cost of the implants. Although no study will be able to definitively determine the cost-effectiveness of every implant in every hospital or outpatient surgical center scenario, future studies should clearly define and track the operative time required for the use of each technique/implant and should include a parallel cost analysis incorporating the type and cost of implants used. This analysis should ensure that future complications are also tracked as the resources required to treat the complications and clinical failures should be included in the cost-effectiveness analysis.

Postoperative complications, as they relate to the surgeon's choice of repair technique, can be categorized as either intraoperative, early, or late. No vascular complications were reported in any of the included studies. Of a less serious nature, no authors commented on the occurrence of iatrogenic chondral injuries during the index procedure. Early complications include superficial or deep infection and local irritative symptoms causing pain, swelling, or nerve irritation. Three of the 19 studies reported a total of 3 superficial infections, and in 2 of these the authors did not clarify whether they were patients with isolated tears.[1,9,41] The pooled infections rate is therefore 1%, and could be as low as 0.3% (1/311 patients) in isolated meniscal tears.

Initial concerns with local nerve injury after inside-out repair techniques were addressed in the 1980s by the addition of posterior knee safety incisions for the retrieval of sutures and knot-tying directly onto the posterior capsule.[11,31,39] Despite the use of a posterior capsular dissection, the pooled rate of nerve irritation was 9% for the inside-out group. It is concerning that the pooled rate in this review is an order of magnitude higher (9%) than what was reported in the initial AANA (Arthroscopy Association of North America) survey.[11] It is not known, however, how the threshold for the reporting of nerve injuries in the AANA survey compares to that in the studies by Albrecht-Olsen et al, Steenbrugge et al, and Cannon and Vittori.[1,9,11,41] These results suggest that even with the use of a posterior capsular dissection, the inside-out suture technique remains associated with an appreciable risk of local nerve injury.

Despite Albrecht-Olsen's hopes for avoiding neurovascular injury with the use of an all-inside arrow implant,[3] these all-inside techniques are not completely protective of local nerve irritation or injury. While lower than the rate of nerve injury with the inside-out technique, the all-inside technique was associated with a 2% rate of nerve irritation. These symptoms were seemingly caused by prominent implants impinging on the overlying nerve.[1,22] In addition to these nerve symptoms, all-inside implants were associated with a 14% rate of local pain or swelling at the implant site that lasted from 1 to 12 months. These symptoms are likely attributable to the presence, breakdown, migration, or breakage of the implant. Although many of these symptoms settle with time, some patients have required local anesthetic/steroid injections or transcutaneous/arthroscopic removal.[19,22,24,35,45]

The late complication of chondral impression, scuffing, or full-thickness gouging is a concern when using all-inside implants, particularly first-generation devices. The true rate of chondral injury is difficult to determine as diagnosis is based on second-look arthroscopy. Reports of such injury relative to all patients receiving implants, therefore, likely underestimate the actual prevalence. In the current review, all accounts of chondral injury were associated with use of a meniscus arrow implant.[1,24,37,41] It may be hypothesized that newer generation implants that leave only suture on the meniscal surface, instead of more solid implants of polylactic acid or other composites, could reduce the risk of such chondral damage. Given the potential for implant-induced chondral damage, future studies are warranted to compare different generations of all-inside repair devices to determine the relative time frame for the development of degenerative changes.

The evaluation of different treatment techniques is frequently limited by possible confounding variables. In this review, there were many variables that could affect surgical outcome independent of the inside-out or all-inside technique used. The lack of head-to-head comparison studies compounded this issue by requiring the comparison of different patient populations in this systematic review. The possible confounding variables include, but are not limited to (1) patient age and other demographic features; (2) location, type, and size of the meniscal tears; (3) duration of the preoperative symptoms; (4) differences in surgical techniques; (5) concomitant ligamentous instability; (6) lower extremity mechanical malalignment; (7) surgeon's level of ability; (8) postoperative rehabilitation protocol; and (9) length of postoperative follow-up. We have addressed the issues of meniscal tear characteristics and concomitant ligamentous instability through our inclusion and exclusion criteria. Within the limitations of the published data, we have addressed the issues of duration of preoperative symptoms and the differences between all-inside techniques by stratifying the outcomes. The majority of studies reported the cases of the "senior author" but the literature does not allow the evaluation of the "senior author's" skills or training. No studies reported or discussed mechanical alignment. Finally, we reviewed the published information on both postoperative rehabilitation programs and the length of follow-up and were unable to find any meaningful relationships or conclusions in the data available. Apart from the confounding variables discussed, the limitations of this systematic review follow. (1) There were only 2 studies meeting our inclusion criteria that limited their patient population to isolated meniscal tears. This resulted in the need for partial data extraction from the remaining 17 studies. Many other similar studies had to be excluded because their patient populations included both isolated tears and tears associated with other intra-articular injuries, without sufficiently stratifying their data. (2) Given the focused inclusion criteria, there was limited high-level evidence from which to pool results. There were 2 level II randomized controlled trials, 1 level III retrospective cohort, and 16 case series from which to draw data. (3) There were a variety of definitions of clinical failure. Pooling heterogeneously defined failure rates limits the strength of the conclusion. (4) The data available in the published literature limited pooled analysis and comparisons to those based primarily on frequencies and percentages. (5) Advances in the design and increases in the number of different all-inside implants available on the market today may limit the generalizability of the previous studies to current surgical choices and alter concerns related to chondral injury with these devices.

CONCLUSION

In this systematic review of inside-out versus all-inside meniscal repair in isolated peripheral, longitudinal, unstable meniscal tears, there is no clear benefit of 1 technique over the other with regard to structural healing or perioperative complications. This outcome, however, is based primarily on level IV evidence. Clinical failure rates and subjective outcomes are similar between groups. Operative time appears to be shorter when using all-inside implants; however, the available data are limited. Both techniques have demonstrated complications—nerve injury or irritation associated with the inside-out technique; and implant breakage/migration, swelling, nerve irritation, and chondral damage associated with the all-inside implants.

Future prospective cohort studies or randomized controlled trials are required to further evaluate the short- and long-term success and complication rates associated with these repair techniques. A cost-effectiveness or cost-benefit analysis should be performed in parallel to determine the balance between reduced operative time and increased implant costs.

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