Second-Look Arthroscopic Evaluation of Healing Rates After Arthroscopic Repair of Meniscal Tears

A Systematic Review and Meta-analysis

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Background: Evaluation of meniscal healing status after repair is important, as it allows the surgeon to inform patients whether they can increase their activities or return to sports.

Purpose: To identify the healing rates after arthroscopic repair of meniscal tears via second-look arthroscopic evaluation.

Study Design: Systematic review; Level of evidence, 4.

Methods: Searches of PubMed, Embase, Scopus, and the Cochrane databases were conducted to identify relevant studies published before June 1, 2020. Studies were eligible for this meta-analysis if they provided data regarding healing status of the meniscus at second-look arthroscopy. Random-effects meta-analyses were generated to provide pooled meniscal healing estimates. We further performed subgroup analysis to investigate the healing rates of the meniscus under different situations.

Results: A total of 41 studies with 1908 individuals were included in the study. The pooled analysis showed the complete healing rate was 74% (95% confidence interval [CI], 67%-80%), the partial healing rate was 10% (95% CI, 6%-16%), and the failure rate was 12% (95% CI, 10%-15%) for arthroscopic repair of meniscal tears via second-look arthroscopic evaluation. Sensitivity analysis demonstrated that no individual study affected the overall healing rate by >1%. Subgroup analysis found higher meniscal healing rates in patients with the following characteristics: age <40 years, male, body mass index <26, red-red tear location, tear in posterior horn, vertical tear, outside-in technique, repair concomitant with anterior cruciate ligament reconstruction, weight-restricted rehabilitation, and time interval from meniscal repair to second-look arthroscopy >12 months.

Conclusion: In this systematic review, the complete healing rate was 74%, the partial healing rate was 10%, and the failure rate was 12% for arthroscopic repair of meniscal tears via second-look arthroscopic evaluation.

Keywords: healing rates; meniscal repair; meniscus; second-look arthroscopy

The meniscus protects the joint cartilage and plays an important role in joint stability through axial load distribution, shock absorption, and load bearing. The poor long-term outcomes after meniscectomy have been well documented.6 The extent of resection relates to the degree of radiologic osteoarthritis,19 whereas meniscal repair could lead to significantly less arthritis progression and subsequent knee arthroplasty compared with nonoperative management and partial meniscectomy.10,50 As a result, it is important to preserve as much meniscal tissue as possible for patients with meniscal injury; in response, meniscal repair has become the optimal treatment for tears located at the vascular zone.12

Evaluation of the meniscal healing status after repair is important, as it allows the surgeon to inform patients whether they can increase their activities or return to sports.46 The main diagnostic methods for a repaired meniscus include second-look arthroscopy, magnetic resonance imaging (MRI), and clinical assessment. In theory, although subjective scores, physical examinations, or patient satisfaction surveys can reflect the healing of the repaired meniscus to a certain extent, they cannot reflect the actual healing status of menisci. Compared with clinical assessment, MRI has been proposed as a better alternative to evaluate the repaired meniscus.4,16 However, MRI is less reliable in the postoperative evaluation of meniscal repair, as the scar at the repaired site frequently expresses a grade 3 signal that has been seen as evidence of an unhealed meniscus.41 In second-look arthroscopy, the situation is directly viewed and evaluated, so the actual healing
status after meniscal repair can be objectively judged. One study found that second-look arthroscopy was the most conclusive and accurate evaluating method for repaired meniscus compared with MRI and clinical assessment. However, because second-look arthroscopy is invasive and has certain surgical risks, few patients would choose to undergo second-look arthroscopy.

Although multiple previous studies have evaluated clinical results following meniscal repair, less is known regarding meniscal healing rates at second-look arthroscopy. As a result, we conducted a systematic review and meta-analysis to identify the healing rates after arthroscopic repair of meniscal tears via second-look arthroscopic evaluation. It was hypothesized that patients with younger age, lower body mass index (BMI), and red-red tear location would have a higher meniscal healing rate.

METHODS

This systematic review and meta-analysis was performed and reported according to the Meta-analysis Of Observational Studies in Epidemiology and the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklists.

Search Strategy and Study Eligibility

Two authors (W.D., X.L.) independently identified studies that reported on the healing status of the meniscus at second-look arthroscopy by systematically searching PubMed (1946 to February 1, 2021), Embase (1974 to June 1, 2020), Scopus (1966 to February 1, 2021), and the Cochrane Library database (2020; Issue 6). For the database searches, terms related to meniscal repair and meniscal suture were combined with those related to second-look arthroscopy without language restriction (full details of the search strategy are provided in Supplemental Table S1, available online). Studies were eligible for this review if they provided data regarding healing status of the meniscus at second-look arthroscopy. References of included studies were screened, and backward citation tracking was performed using Web of Science to identify articles not found in the original literature search. As studies with very small sample sizes are often case reports and do increase the risk of bias, these small sample studies with <5 patients were excluded from this meta-analysis. Studies performing repeat arthroscopy only in patients with persistent symptoms were also excluded. Disagreements on eligibility of full-text articles were resolved by consensus or by discussion with a third reviewer (Y.A.).

Data Extraction

The following information was independently extracted from each article by 2 trained investigators (W.D., J.W.) using a standardized form: first author, year of publication, country, study design, number of participants, meniscal healing rate, patients’ demographics, tear characteristics, meniscal repair methods, adjuvant procedures, and postoperative factors. The primary outcome was meniscal healing rate. The definition of partial healing in the included studies was also extracted and is summarized in Supplemental Table S2 (available online). When studies involved the same population of patients, only the most comprehensive or recent publication was included, with the former taking precedence.

Quality Assessment

In observational studies, the investigator observes individuals without manipulation or intervention. This is in contrast to randomized controlled trials (RCTs), where investigators do intervene and look at the effects of the intervention on an outcome. As the methodologies of these study types are largely different, different quality assessment tools were used for them. The quality of the observational studies was assessed via a modified version of the Newcastle-Ottawa Scale. This scale assesses quality in several domains: sample representativeness and size, comparability, ascertainment of meniscal healing status, and statistical quality; studies are judged to be at low risk or high risk of bias (scoring details are provided in Supplemental Table S3, available online). For RCTs, the Cochrane Risk of Bias tool was used to assess quality, in which each trial is scored as high, low, or unclear risk of bias according to the following domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. All discrepancies were resolved by discussion between 2 reviewers (X.L., X.H.), with the adjudication of a third reviewer (Y.A.).

Data Synthesis

Estimates of meniscal healing rates were calculated by pooling the study-specific estimates with 95% confidence intervals (CIs) using random-effects meta-analyses that
accounted for between-study heterogeneity. Heterogeneity across studies was assessed by using the I² statistic. The I² values of 25%, 50%, and 75% were considered to indicate low, moderate, and high heterogeneity, respectively. The influence of individual studies on the overall healing rate was explored by serially excluding each study in a sensitivity analysis. We further performed subgroup analysis to investigate the influence of different factors on the healing rates after meniscal repairs. Based on the previous studies, factors included in subgroup analysis were age, sex, BMI, histologic location of tear, anatomic location of tear, type of tear, side of meniscus, repair methods, repair devices, anterior cruciate ligament (ACL) reconstruction, ACL-insufficient knee, type of rehabilitation after surgery, time interval from meniscal repair to second-look arthroscopy, and study design. In addition, we performed additional analyses regarding healing rate with studies that included patients before and after the study period 2010 to account for the development of new rehabilitation protocols and operative techniques. To perform the subgroup analysis, we split the data of patients into subsets (eg, male and female patients) according to the different factors. Then, pooled analyses were conducted for the subsets. We further investigated potential sources of heterogeneity via meta-regression analysis, which attempts to relate differences in effect sizes to study characteristics. Factors examined were patients’ demographics (age, sex, BMI), tear characteristics (histologic location of tear, anatomic location of tear, type of tear, side of meniscus), meniscal repair methods, repair devices, adjuvant procedures (ACL reconstruction [ACLR], ACL-insufficient knee), and other factors (type of rehabilitation after surgery, time interval from meniscal repair to second-look arthroscopy, study design, and study period). Publication bias was assessed by using the Begg and Egger tests. All analyses were performed using R Version 3.2.3 (R Foundation for Statistical Computing) and Stata Version 13.1 (StataCorp). Statistical tests were 2-sided and used a significance threshold of P < .05.

RESULTS

Literature Search

In the initial search, we identified 1003 records. To this, we added 2 using reference mining. After examination of the titles and abstracts, there were 117 potentially eligible studies assessed for inclusion. After reviewing the full text, 41 studies were included in the meta-analysis. The study flow diagram, including the reasons for exclusion of studies, is shown in Figure 1.

Study Characteristics and Quality

The study characteristics are presented in Table 1. These studies were published between 1991 and 2021. The sample size of the studies ranged from 5 to 140, with a total of 1908 individuals. The mean age of the patients ranged from 19 to 58 years. The mean BMI of the patients ranged from 23.6 to 66.6. Factors examined were patients’ demographics (age, sex, BMI), histologic location of tear, anatomic location of tear, type of tear, side of meniscus, repair methods, repair devices, anterior cruciate ligament (ACL) reconstruction, ACL-insufficient knee, type of rehabilitation after surgery, time interval from meniscal repair to second-look arthroscopy, and study design. In addition, we performed additional analyses regarding healing rate with studies that included patients before and after the study period 2010 to account for the development of new rehabilitation protocols and operative techniques. To perform the subgroup analysis, we split the data of patients into subsets (eg, male and female patients) according to the different factors. Then, pooled analyses were conducted for the subsets. We further investigated potential sources of heterogeneity via meta-regression analysis, which attempts to relate differences in effect sizes to study characteristics. Factors examined were patients’ demographics (age, sex, BMI), tear characteristics (histologic location of tear, anatomic location of tear, type of tear, side of meniscus), meniscal repair methods, repair devices, adjuvant procedures (ACL reconstruction [ACLR], ACL-insufficient knee), and other factors (type of rehabilitation after surgery, time interval from meniscal repair to second-look arthroscopy, study design, and study period). Publication bias was assessed by using the Begg and Egger tests. All analyses were performed using R Version 3.2.3 (R Foundation for Statistical Computing) and Stata Version 13.1 (StataCorp). Statistical tests were 2-sided and used a significance threshold of P < .05.

References 2, 3, 7, 13–15, 17, 20, 21, 24, 26, 28–32, 34–37, 39, 43, 47–49, 51, 54, 58–60, 65, 67, 68, 70.
Body Mass Index. A total of 7 studies \(^1\) reported the BMI of the patients. When the BMI was \(\geq 26\), the complete healing rate was 64\% (177/260 knees; 95\% CI, 49\%-76\%; \(I^2 = 78\%\)), the partial healing rate was 12\% (47/260 knees; 95\% CI, 2\%-43\%; \(I^2 = 94\%\)), and the failure rate was 13\% (36/260 knees; 95\% CI, 8\%-21\%; \(I^2 = 54\%\)). When the BMI was \(< 26\), the complete healing rate was 75\% (136/178 knees; 95\% CI, 57\%-87\%; \(I^2 = 79\%\)), the partial healing rate was 8\% (21/178 knees; 95\% CI, 1\%-55\%; \(I^2 = 95\%\)), and the failure rate was 12\% (21/178 knees; 95\% CI, 8\%-17\%; \(I^2 = 0\%\)).

Histologic Location of Tear. A total of 15 studies \(^4\) reported the relationship between tear histologic location and meniscal healing rate. When the tear was located in red-red, the complete healing rate was 84\% (448/557 knees; 95\% CI, 76\%-90\%; \(I^2 = 79\%\)), the partial healing rate was 9\% (59/557 knees; 95\% CI, 6\%-14\%; \(I^2 = 60\%\)), and the failure rate was 6\% (50/557 knees; 95\% CI, 3\%-12\%; \(I^2 = 74\%\)). When the tear was located in red-white, the complete healing rate was 67\% (219/345 knees; 95\% CI, 54\%-78\%; \(I^2 = 79\%\)), the partial healing rate was 16\% (61/345 knees; 95\% CI, 10\%-24\%; \(I^2 = 55\%\)), and the failure rate was 17\% (65/345 knees; 95\% CI, 11\%-25\%; \(I^2 = 59\%\)). None of the studies reported the healing rate when the tear was located in white-white.

Anatomic Location of Tear. A total of 16 studies \(^5\) reported the relationship between the anatomic location of the tear and meniscal healing rate. When the tear was located in the body of the meniscus, the complete healing rate was 61\% (38/65 knees; 95\% CI, 12\%-95\%; \(I^2 = 91\%\)), the partial healing rate was 3\% (7/65 knees; 95\% CI, 1\%-95\%; \(I^2 = 89\%\)), and the failure rate was 21\% (15/65 knees; 95\% CI, 7\%-46\%; \(I^2 = 66\%\)). When the tear was located in the posterior horn, the complete healing rate was 77\% (258/328 knees; 95\% CI, 67\%-85\%; \(I^2 = 71\%\)), the partial healing rate was 14\% (47/328 knees; 95\% CI, 8\%-24\%; \(I^2 = 72\%\)), and the failure rate was 7\% (23/328 knees; 95\% CI, 4\%-12\%; \(I^2 = 39\%\)). When the tear was located in the posterior root, the complete healing rate was 64\% (150/226 knees; 95\% CI, 31\%-87\%; \(I^2 = 93\%\)), the partial healing rate was 8\% (45/226 knees; 95\% CI, 1\%-52\%; \(I^2 = 95\%\)), and the failure rate was 11\% (31/226 knees; 95\% CI, 5\%-22\%; \(I^2 = 57\%\)).

\(^{4}\)References 3, 7, 13, 20, 28–30, 39, 41, 43, 49, 51, 55, 65, 70.

\(^{5}\)References 3, 13, 15, 17, 26, 31, 35–37, 41, 48, 54, 55, 60, 68, 69.
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TABLE 1
Characteristics of the Included Studies

| Study (Year) | Country | No. of Patients | Mean Age, y | Male Sex, n (%) | Patient Recruitment | Mean Time From Meniscal Repair to Second-Look Arthroscopy, mo | Risk of Bias |
|--------------|---------|----------------|-------------|-----------------|--------------------|-------------------------------------------------------------|-------------|
| Jing et al26 (2020) | China | 27 | 55 | 12 (44) | 2015-2017 | NR | High |
| DePhillipo et al17 (2019) | USA | 64 | 31 | NR | 2010-2018 | 5 | High |
| Kanto et al30 (2019) | Japan | 104 | 24 | 40 (38) | 2009-2015 | 15 | High |
| Kaminski et al28 (2019) | Poland | 40 | 29 | 29 (73) | 2014-2015 | 9 | Low |
| Lee et al36 (2021) | South Korea | 25 | 58 | 8 (32) | 2014-2016 | NR | High |
| Seo et al52 (2020) | South Korea | 61 | 30 | 52 (85) | 2012-2016 | 16 | Low |
| Song et al33 (2019) | China | 75 | 28 | 65 (87) | 2013-2015 | 10 | High |
| Tsuji et al29 (2019) | Japan | 41 | 30 | 18 (44) | 2008-2016 | NR | Low |
| Chen et al13 (2018) | China | 46 | 26 | 34 (73) | 2010-2014 | 32 | High |
| Lee et al37 (2018) | South Korea | 56 | 53 | 4 (7) | 2010-2015 | 16 | High |
| Tsuji et al38 (2018) | Japan | 18 | 19 | 14 (78) | 2011-2015 | 6 | High |
| Matsushita et al39 (2017) | Japan | 87 | 25 | 44 (51) | 2004-2012 | NR | High |
| Park et al17 (2017) | South Korea | 11 | 49 | NR | 2010-2016 | 15 | High |
| Ahn et al5 (2015) | South Korea | 32 | 42 | 23 (72) | 2004-2008 | 14 | High |
| Kang et al50 (2015) | South Korea | 19 | 35 | 15 (79) | 2010-2012 | 17 | High |
| Ra et al48 (2015) | South Korea | 7 | 29 | 6 (86) | 2007-2011 | 26 | High |
| Cho14 (2014) | South Korea | 13 | 34 | NR | 2010-2012 | 14 | High |
| Cho and Song15 (2014) | South Korea | 13 | 54 | 1 (8) | 2005-2010 | 8 | High |
| Hagino et al31 (2014) | Japan | 57 | 24 | 27 (47) | 2006-2009 | NR | High |
| Song et al16 (2014) | South Korea | 15 | 35 | 12 (80) | 2008-2011 | 24 | High |
| Ra et al49 (2013) | South Korea | 12 | NR | 8 (67) | 2007-2009 | 30 | High |
| Ruiz-Iban et al22 (2012) | Spain | 14 | 47 | 6 (43) | 2004-2008 | 14 | High |
| Kim et al33 (2011) | South Korea | 30 | 55 | 5 (17) | 2003-2007 | NR | Low |
| Miao et al34 (2011) | China | 81 | 25 | 68 (84) | 2005-2007 | 25 | Low |
| Seo et al35 (2011) | South Korea | 11 | 55 | 1 (9) | 2006-2008 | 13 | High |
| Ahn et al36 (2010) | South Korea | 140 | 30 | 126 (90) | 1997-2007 | 37 | High |
| Suganuma et al37 (2010) | Japan | 27 | 26 | 21 (78) | 1994-2005 | 25 | Low |
| Tachibana et al38 (2010) | Japan | 46 | 27 | 20 (43) | 2005-2008 | 14 | High |
| Lee et al39 (2009) | South Korea | 20 | 51 | 9 (45) | 2004-2006 | 32 | High |
| Feng et al40 (2008) | China | 64 | 25 | 40 (63) | 2002-2006 | NR | High |
| Sarimo et al50 (2005) | Finland | 13 | 26 | 11 (85) | 1999-2003 | 8 | Low |
| Soejima et al22 (2005) | Japan | 17 | 24 | 15 (88) | 1989-1997 | 9 | High |
| Asik et al22 (2002) | Turkey | 47 | 27 | 35 (74) | NR | 6 | Low |
| Kurosakka et al41 (2002) | Japan | 111 | 21 | 45 (41) | 1986-1994 | 13 | High |
| Albrecht-Olsen et al5 (1999) | Denmark | 68 | 26 | 55 (81) | NR | 3 | High |
| van Trommel et al52 (1998) | USA | 5 | 20 | NR | NR | 4 | High |
| Asahina et al1 (1996) | Japan | 98 | 23 | 32 (33) | 1986-1994 | 16 | High |
| Horibe et al53 (1995) | Japan | 122 | 22 | 62 (51) | 1986-1993 | 8 | High |
| Kimura et al54 (1995) | Japan | 46 | 22 | 21 (46) | 1978-1990 | 10 | High |
| Tenuta and Arciero57 (1994) | USA | 51 | 22 | NR | 1987-1991 | 11 | High |
| Morgan et al58 (1991) | USA | 74 | 26 | 46 (62) | NR | 9 | High |

NR, not reported.

Type of Tear. A total of 18 studies†† reported the relationship between type of tear and meniscal healing rate. When the tear type was bucket-handle, the complete healing rate was 76% (157/206 knees; 95% CI, 68%-83%; I² = 23%), the partial healing rate was 7% (17/206 knees; 95% CI, 3%-16%; I² = 29%), and the failure rate was 16% (32/206 knees; 95% CI, 11%-21%; I² = 0%). When the tear type was vertical, the complete healing rate was 78% (411/531 knees; 95% CI, 67%-86%; I² = 84%), the partial healing rate was 10% (64/531 knees; 95% CI, 5%-19%; I² = 83%), and the failure rate was 10% (56/531 knees; 95% CI, 6%-16%; I² = 74%). When the tear type was radial, the complete healing rate was 64% (42/75 knees; 95% CI, 35%-86%; I² = 75%), the partial healing rate was 28% (21/75 knees; 95% CI, 19%-39%; I² = 0%), and the failure rate was 13% (12/75 knees; 95% CI, 4%-32%; I² = 50%). Only 1 study reported the healing rate of horizontal tears. When the tear type was a horizontal tear, the complete healing rate was 73% (8/11 knees; 95% CI, 39%-94%), the partial healing rate was 18% (2/11 knees; 95% CI, 2%-52%), and the failure rate was 9% (1/11 knees; 95% CI, 0%-41%) after repair. Only 1 study reported the healing rate of complex tears.†† When the

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††References 2, 3, 5, 7, 13, 20, 41, 43, 49, 53, 55, 60, 63, 65, 68-70.
tear type was a complex tear, the complete healing rate was 70% (33/47 knees; 95% CI, 55%-83%), the partial healing rate was 21% (10/47 knees; 95% CI, 11%-36%), and the failure rate was 9% (4/47 knees; 95% CI, 2%-20%) after repair.

**Side of Meniscus.** A total of 13 studies‡‡ reported the relationship between the side of the meniscus and meniscal healing rate. When the tear was located in the medial meniscus, the complete healing rate was 77% (401/523 knees; 95% CI, 67%-84%; $I^2 = 78$%), the partial healing rate was 6% (60/523 knees; 95% CI, 2%-16%; $I^2 = 89$%), and the failure rate was 15% (85/523 knees; 95% CI, 12%-20%; $I^2 = 35$%). When the tear was located in the lateral meniscus, the complete healing rate was 79% (209/272 knees; 95% CI, 69%-86%; $I^2 = 56$%), the partial healing rate was 5% (24/247 knees; 95% CI, 1%-16%; $I^2 = 79$%), and the failure rate was 14% (35/247 knees; 95% CI, 10%-19%; $I^2 = 0$%).

**Repair Methods.** A total of 37 studies§§ reported the relationship between repair methods and meniscal healing.

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‡‡References 2, 7, 17, 20, 29, 30, 32, 39, 41, 43, 53, 65, 67.

§§References 2, 3, 5, 7, 8, 13–15, 17, 20, 21, 24, 26, 29, 31, 32, 34–37, 39, 41, 43, 48, 49, 51, 53–55, 58–60, 63, 65, 67, 68, 70.
When the repair method was all-inside, the complete healing rate was 78% (506/658 knees; 95% CI, 69%-84%; $I^2 = 77\%$), the partial healing rate was 11% (92/658 knees; 95% CI, 6%-19%; $I^2 = 84\%$), and the failure rate was 8% (60/658 knees; 95% CI, 5%-12%; $I^2 = 55\%$). When repair method was inside-out, the complete healing rate was 68% (467/652 knees; 95% CI, 57%-78%; $I^2 = 86\%$), the partial healing rate was 8% (74/652 knees; 95% CI, 3%-19%; $I^2 = 91\%$), and the failure rate was 8% (50/652 knees; 95% CI, 14%-23%; $I^2 = 53\%$). When repair method was outside-in, the complete healing rate was 94% (76/103 knees; 95% CI, 54%-99%; $I^2 = 71\%$), the partial healing rate was 9% (15/103 knees; 95% CI, 11%-41%; $I^2 = 30\%$), and the failure rate was 3% (12/103 knees; 95% CI, 1%-66%; $I^2 = 65\%$). When repair method was pullout suture, the complete healing rate was 71% (80/121 knees; 95% CI, 64%-75%; $I^2 = 93\%$), the partial healing rate was 3% (4/121 knees; 95% CI, 1%-7%; $I^2 = 94\%$), and the failure rate was 16% (20/121 knees; 95% CI, 8%-26%; $I^2 = 65\%$).

### Repair Devices

Three studies reported the relationship between repair devices and meniscal healing rates. When the devices were sutures, the complete healing rate was 80% (28/35 knees; 95% CI, 63%-92%), the partial healing rate was 0% (0/35 knees; 95% CI, 0%-10%), and the failure rate was 20% (7/35 knees; 95% CI, 8%-37%). When the devices were arrows, the complete healing rate was 87%...
(78/90 knees; 95% CI, 78%-92%; $I^2 = 0$%), the partial healing rate was 2% (3/90 knees; 95% CI, 1%-34%; $I^2 = 61$%), and the failure rate was 10% (9/90 knees; 95% CI, 5%-18%; $I^2 = 0$%).

**Meniscal Repair With ACLR.** A total of 18 studies with 1020 knees reported the healing status of meniscal repair when combined with ACLR. When meniscal repair was combined with ACLR, the complete healing rate was 79% (771/1020 knees; 95% CI, 72%-85%; $I^2 = 82$%), the partial healing rate was 11% (135/1020 knees; 95% CI, 7%-17%; $I^2 = 83$%), and the failure rate was 9% (114/1020 knees; 95% CI, 6%-13%; $I^2 = 70$%).

**Healing Rate in Patients With Isolated Meniscal Repair.** A total of 13 studies reported the healing status of isolated meniscal repair. Among the 206 knees that underwent isolated meniscal repair, the complete healing rate was 69% (124/206 knees; 95% CI, 49%-84%; $I^2 = 83$%), the partial healing rate was 9% (18/206 knees; 95% CI, 3%-26%; $I^2 = 0$%).

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**Figure 4.** Forest plot of overall failure rate of repaired meniscal tears by second-look arthroscopic evaluation.

![Forest plot of overall failure rate of repaired meniscal tears by second-look arthroscopic evaluation.](image)

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References 3, 5, 7, 13, 20, 29, 30, 32, 39, 41, 43, 53, 55, 59, 60, 65, 67, 69.

References 5, 14, 15, 28, 31, 32, 35, 37, 43, 53, 58, 67, 68.
| TABLE 2 | Association Between Factors and Meniscal Healing Rate<sup>a</sup> |
|---------|--------------------------------------------------|
|         | Complete Healing Rate | Partial Healing Rate | Failure Rate | Complete Healing Rate | Partial Healing Rate | Failure Rate |
|         | Pooled Rate (95% CI) | Pooled Rate (95% CI) | Pooled Rate (95% CI) | Pooled Rate (95% CI) | Pooled Rate (95% CI) | Pooled Rate (95% CI) |
| **Factor** | **(95% CI)** | **(95% CI)** | **(95% CI)** | **(95% CI)** | **(95% CI)** | **(95% CI)** |
| Age <40 y | 75 (69-81) | 84 (69-84) | 9 (5-14) | 90 (6-49) | 13 (10-16) | Complete Healing Rate | 83 (69-84) | 77 (6-84) | 11 (6-19) | 84 (8-81) | 8 (5-12) | 5 (5-12) | 55 |
| ≥40 y | 63 (34-85) | 90 (6-49) | 90 (6-49) | 8 (3-18) | 59 | Partial Healing Rate | 68 (57-78) | 86 (3-19) | 91 (14-23) | 18 (14-23) | 53 |
| Sex | | | | | | | | | | | | | |
| Male | 76 (62-86) | 70 (1-17) | 5 (1-17) | 74 (13-23) | 17 (0) | Failure Rate | 63 All-inside | 78 (54-99) | 71 (11-41) | 9 (1-66) | 13 (1-66) | 65 |
| Female | 66 (54-76) | 68 (3-33) | 12 (1-17) | 90 (10-25) | 16 (6-25) | | Pullout suture | 24 (9-5) | 93 (1-55) | 16 (8-28) | 65 |
| BMI <26 kg/m<sup>2</sup> | 75 (57-87) | 79 (1-55) | 6 (8-17) | 95 (2-43) | 12 (0) | Repair method | 80 | Sutures<sup>b</sup> | 83 (63-92) | NA | 0 (0-10) | 20 (8-37) | 0 |
| ≥26 kg/m<sup>2</sup> | 64 (49-76) | 78 (2-43) | 12 (8-21) | 94 (5-21) | 13 (5-11) | | Outside-in | 71 (54-99) | 93 (11-41) | 9 (1-66) | 13 (1-66) | 65 |
| Histologic location of tear | | | | | | | | | | | | | |
| Red to red | 84 (76-90) | 79 (6-14) | 9 (6-14) | 60 (3-12) | 6 (3-12) | ACL-related factors | 69 (49-84) | 83 (3-26) | 95 (12-29) | 19 (12-29) | 38 |
| Red to white | 67 (54-78) | 79 (10-24) | 16 (11-25) | 55 (7-52) | 17 (7-52) | | Isolated meniscal repair | 67 (41-86) | 81 (0-57) | 27 (12-51) | 76 |
| Anatomic location of tear | | | | | | | | | | | | | |
| Body | 61 (12-95) | 91 (1-95) | 3 (1-95) | 89 (7-46) | 21 (7-46) | Motion restricted | 79 (72-85) | 82 (7-85) | 11 (1-77) | 83 (7-83) | 9 (6-13) | 70 |
| Posterior horn | 77 (67-85) | 71 (8-24) | 14 (4-12) | 72 (3-12) | 39 | Wt restricted<sup>c</sup> | 69 (64-100) | 83 (1-36) | NA | 8 (1-36) | 0 (NA) | 19 (12-29) | 38 |
| Posterior root | 64 (31-87) | 93 (1-52) | 8 (5-22) | 95 (5-22) | 11 (5-22) | ACL-insufficient knee | 67 (54-83) | 81 (0-57) | 27 (12-51) | 76 |
| Type of tear | | | | | | | | | | | | | |
| Bucket-handle | 76 (68-83) | 23 (3-16) | 7 (1-16) | 29 (11-21) | 16 | Time from meniscal repair to second-look arthroscopy | 73 (59-84) | 63 (1-45) | 7 (8-18) | 93 (7-12) | 0 |
| Vertical | 78 (67-86) | 84 (5-19) | 10 (5-12) | 83 (6-16) | 10 (6-16) | ≤12 mo | 73 (61-82) | 85 (3-21) | 92 (10-18) | 13 (10-18) | 46 |
| Radial | 64 (35-86) | 75 (19-39) | 28 (4-32) | 0 (0-41) | 13 (0-41) | >12 mo | 69 (69-90) | 93 (2-15) | 93 (5-14) | 9 (5-14) | 76 |
| Horizontal<sup>d</sup> | 73 (39-94) | 18 NA | 18 NA | 9 NA | 9 NA | Study design | 68 (59-76) | 0 (11-26) | 15 (9-23) | 0 |
| Complex<sup>e</sup> | 70 (55-83) | 21 (11-36) | 21 (2-20) | 9 (2-20) | 9 | RCT | 74 (67-81) | 89 (5-16) | 12 (9-15) | 65 |
| Side of meniscus | | | | | | | | | | | | | |
| Medial | 77 (67-84) | 78 (2-16) | 6 (2-16) | 89 (12-20) | 15 (12-20) | Study period | | | | | | |

(continued)
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Table 2 (continued)

| Factor          | Complete Healing Rate | Partial Healing Rate | Failure Rate |
|-----------------|-----------------------|----------------------|--------------|
|                 | Pooled Rate (CI) | I², % | Pooled Rate (CI) | I², % | Pooled Rate (CI) | I², % | Factor |
| Lateral         | 79 (69-86) | 56 | 5 | 79 (10-19) | 0 | ≤2010 |
|                 | 75 (69-80) | 66 | 8 | 86 | 13 | 54 |
| >2010           | 72 (60-82) | 91 | 12 | 92 | 10 | 69 |

*ICL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; NA, not applicable; RCT, randomized controlled trial; wt, weight.

| Type of Rehabilitation After Surgery. A total of 32 studies* reported the relationship between meniscal healing rate and type of rehabilitation after surgery. When the rehabilitation protocol was motion restricted, the complete healing rate of the meniscus was 76% (112/148 knees; 95% CI, 66%-81%; I² = 49%), and the failure rate was 24% (17/74 knees; 95% CI, 14%-39%; I² = 73%). When the rehabilitation protocol was weight restricted, the complete healing rate was 94% (128/136 knees; 95% CI, 90%-97%; I² = 0%), and the failure rate was 6% (4/65 knees; 95% CI, 4%-13%; I² = 74%). When the rehabilitation protocol was dual restricted (motion and weight restricted), the complete healing rate of the meniscus was 82% (158/191 knees; 95% CI, 77%-87%; I² = 20%), and the failure rate was 18% (23/129 knees; 95% CI, 13%-29%; I² = 38%). | Time From Meniscal Repair to Second-Look Arthroscopy. A total of 35 studies* reported the patient’s time interval from meniscal repair to second-look arthroscopy. When the time interval was at most 12 months, the complete healing rate was 73% (487/662 knees; 95% CI, 66%-82%; I² = 79%), the partial healing rate was 56% (226/404 knees; 95% CI, 46%-66%; I² = 81%), and the failure rate was 11% (70/631 knees; 95% CI, 7%-16%; I² = 69%). When the time interval was >12 months, the complete healing rate was 73% (697/946 knees; 95% CI, 67%-79%; I² = 89%), the partial healing rate was 12% (108/851 knees; 95% CI, 8%-20%; I² = 74%), and the failure rate was 11% (97/887 knees; 95% CI, 7%-16%; I² = 68%). |

| References 2, 3, 7-8, 13-15, 17, 20, 21, 24, 26, 28-30, 32, 35, 37, 41, 47, 48, 51, 53, 54, 58, 60, 63, 65, 67-70.
| References 2, 3, 5, 7-8, 13-15, 17, 24, 28-30, 32, 34, 35, 37, 41, 43, 47-49, 51, 53-55, 58-60, 63, 65, 67-70.
TABLE 3
Univariate Meta-Regression for Complete Healing Rate at Second-Look Arthroscopy<sup>a</sup>

| Factor                                                                 | Metaregression Coefficient (95% CI) | \(P\)  |
|------------------------------------------------------------------------|-------------------------------------|--------|
| Patient demographics                                                   |                                     |        |
| Age (<40 vs ≥40 y)                                                     | -0.16 (−0.31 to −0.02)              | .029   |
| Sex (male vs female)                                                   | -0.05 (−0.26 to 0.16)               | .602   |
| BMI (<26 vs ≥26)                                                       | -0.10 (−0.37 to 0.17)               | .402   |
| Tear characteristics                                                   |                                     |        |
| Histologic location of tear (red-red vs red-white)                     | -0.16 (−0.29 to −0.02)              | .026   |
| Anatomic location of tear (body vs other)                              | 0.08 (−0.31 to 0.48)                | .644   |
| Type of tear (vertical vs other)                                       | -0.08 (−0.23 to 0.07)               | .260   |
| Side of meniscus (medial vs lateral meniscus)                          | 0.04 (−0.09 to 0.17)                | .534   |
| Meniscal repair methods                                                |                                     |        |
| Repair method (all-inside vs other)                                    | -0.06 (−0.19 to 0.07)               | .326   |
| Repair device (arrows vs sutures)                                      | -0.06 (−0.66 to 0.65)               | .972   |
| Adjuvant procedures                                                    |                                     |        |
| ACLR (repair with ACLR vs isolated meniscal repair)                    | 0.15 (0.02 to 0.28)                 | .029   |
| ACL-insufficient knee without ACLR (repair in ACL-insufficient knee vs repair in stable knee) | -0.01 (−0.30 to 0.29) | .989   |
| Other factors                                                          |                                     |        |
| Type of rehabilitation after surgery (motion + wt restricted vs other)  | -0.01 (−0.23 to 0.22)               | .970   |
| Time from meniscal repair to second-look arthroscopy (<12 vs >12 mo)    | -0.07 (−0.21 to 0.07)               | .317   |
| Study design (RCT vs observational study)                              | 0.03 (−0.25 to 0.31)                | .822   |
| Study period (<2010 vs >2010)                                          | 0.08 (−0.75 to 0.92)                | .840   |

<sup>a</sup>ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; RCT, randomized controlled trial; wt, weight.

### Metaregression Analysis

In univariate metaregression analysis, the meniscal healing rate was higher in studies with patients aged <40 years than studies with patients aged ≥40 years (\(P = .029\)), tears located in red-red were associated with a higher meniscal healing rate than tears located in red-white (\(P = .026\), and the meniscal healing rate was higher in studies with meniscus repaired during ACLR than studies with isolated meniscal repair (\(P = .029\)) (Table 3). We did not perform the multivariate metaregression, as there were only 3 studies<sup>7,39,41</sup> containing these 3 factors at the same time.

### Publication Bias

The Egger and Begg tests were performed to investigate publication bias. The Egger test indicated no evidence of publication bias (\(P = .09\)). Similarly, in the Begg test, there was no evidence of substantial publication bias (\(P = .27\)) (Supplemental Figure S1, available online).

### DISCUSSION

In our study, the pooled analysis showed that the complete healing rate was 74%, the partial healing rate was 10%, and the failure rate was 12% for arthroscopic repair of meniscal tears via second-look arthroscopic evaluation. Sensitivity analysis demonstrated that no individual study affected the overall healing rate by >1%. Subgroup analysis found higher meniscal healing rates in age <40 years, male, BMI <26, red-red tear location, tear in posterior horn, vertical tear, outside-in technique, repair concomitant with ACLR, weight-restricted rehabilitation, and time interval from meniscal repair to second-look arthroscopy >12 months groups.

A previous study has reported that medial meniscal repairs were significantly more likely to fail than were lateral repairs, when diagnosed via clinical assessment.<sup>38</sup> However, in our study, a similar healing rate was detected between the medial and lateral meniscus. In addition, one of the interesting findings of our study was that compared with healing rates in the bucket-handle tear group, the complete and partial healing rates were higher in the vertical tear group. This difference may be caused by the longer tears and less repair stability of bucket-handle tears. In several studies, horizontal and radial tears have been compared with root tears of the medial meniscus posterior horn in that typical degenerative tears in both share an increased incidence and severity of cartilage degeneration.<sup>64</sup> In our study, the complete healing rate of horizontal tear was 73%, radial tear was 64%, and root tear was 64%. Meniscus protects the articular cartilage from high-contact pressures. This action is dependent on the longitudinal orientation of the intrameniscal circumferential fibers and results in the generation of hoop tension in the meniscus as a vertical load is applied.<sup>1</sup> Regarding the integrity of circumferential fibers in meniscal tears, horizontal tears may be in a better situation than radial and root tears.

The relationship of the ACL and meniscus has been well studied.<sup>40</sup> There are a growing number of studies showing that meniscal tears repaired at the time of ACLR may have an improved healing rate over those repaired in...
isolation. The mechanism behind this phenomenon is still uncertain; in addition, no meta-analysis or systematic review has confirmed it. It has been theorized that the effect is created by augmentation of the repair from the intra-articular release of peptides, growth factors, and mesenchymal pluripotent stem cells from the bone marrow when drilling reconstruction tunnels. In our study, when combined with ACLR, the complete healing rate of the meniscal repair was higher than that of isolated meniscal repair (79% vs 69%).

Current postoperative rehabilitation protocols after meniscal repair vary widely. No consensus exists with regard to the optimal amount of weightbearing, range of motion, or speed at which the patient progresses through the rehabilitation phases. Previous studies have suggested early range of motion and immediate postoperative weight-bearing appear to have no detrimental effect on the chances for clinical success after meniscal repair. In our study, when the rehabilitation protocol was weight restricted, the complete healing rate was 92%, which was higher than that for the motion restricted (82%), dual restricted (70%), and accelerated strategy groups (73%). However, this should be interpreted with caution because the rate of the weight-restricted group was only from 1 study.

The study had several key strengths. In this study, we used a detailed and robust search strategy that spanned multiple databases and was without language restriction. A detailed assessment of methodological quality of the included studies was performed. We systematically explored for sources of heterogeneity using several study-level characteristics and tested for evidence of effect modification. It should be noted that we chose to focus on healing status at second-look arthroscopy as the main indicator of outcomes after meniscal repair, which have been limitations of previous systematic reviews by use of clinical assessment and MRI. Our results remained robust in sensitivity analysis; in addition, formal testing demonstrated no evidence of publication bias.

This study had several limitations. First, although all studies in this review were appraised for methodological quality, no participants were excluded based on methodological quality as per recommendations of the Cochrane review. The inclusion of lower-quality studies in this meta-analysis may have affected the results of this study. Second, a substantial amount of the heterogeneity among the studies remained unexplained by the variables examined. Unexamined factors, such as the cause of injury, may contribute to the meniscal failure rate. Third, although 41 studies representing 1908 patients were included, several results were based on 1 to 10 studies; as a result, type II statistical error due to an underpowered analysis might have occurred.

CONCLUSION

In this systematic review, the complete healing rate was 74%, the partial healing rate was 10%, and the failure rate was 12% for arthroscopic repair of meniscal tears via second-look arthroscopic evaluation.

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