Arthroscopic Repair of Horizontal Meniscal Cleavage Tears With Marrow-Stimulating Technique

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Purpose: The purpose of this study was to evaluate patients after arthroscopic repair of meniscal horizontal tears with a marrow-stimulating technique through clinical signs and second-look arthroscopy. **Methods:** We retrospectively reviewed a consecutive series of 32 meniscal repairs with horizontal cleavage tears and evaluated them through clinical assessment and second-look arthroscopic examinations. Arthroscopic meniscal repair and a marrow-stimulating technique were performed. Functional outcomes were evaluated using the visual analog scale (VAS) pain score, Lysholm knee scoring scale, and Tegner activity scale. Assessment of meniscal healing was evaluated clinically by the presence of meniscal signs; second-look arthroscopy was performed in 11 patients. Correlation between chronicity of a meniscal lesion (time from initial symptom [TFIS]) and meniscal healing was evaluated. **Results:** The mean follow-up period was 45.6 ± 13.9 months. Improvements in mean VAS scores from 6.7 to 1.9 ($P < .001$) were observed. The Lysholm score increased from 48.0 ± 14.4 to 92.0 ± 6.3 ($P < .001$). The Tegner activity score increased from 3.3 ± 1.1 to 6.8 ± 0.8 ($P < .001$). At the last follow-up, 29 of 32 patients (91%) were evaluated as healing in the clinical assessment. Of the 11 patients who underwent second-look arthroscopy, 8 (73%) showed complete healing, 2 (18%) had incomplete healing, and 1 (9%) failed to heal. Correlation between TFIS and meniscal healing was clinically significant ($P = .001$) but arthroscopically insignificant ($P = .085$) on second-look arthroscopy. **Conclusions:** The meniscal repair procedure for horizontal cleavage tears in the present study suggests an alternative treatment option to approach the treatment of meniscal tears extending into the avascular zone and degenerative tissue. The marrow-stimulating technique using a cannulated reamer can be considered as an alternative method for the augmentation of meniscal healing. **Level of Evidence:** Level IV, therapeutic case series.

The critical role of the meniscus is protection for the knee joint cartilage through shock absorption and load distribution.[1,2] In recent systematic reviews of the outcomes of meniscal repair, the result at more than 5 years postoperatively showed very similar rates of meniscal failure (22.3% to 24.3%) for all techniques investigated, and although meniscal repairs have a higher reoperation rate than do partial meniscectomies, they are associated with better long-term outcomes, with higher clinical scores and less degeneration seen radiologically.[3,4] Meniscal repair offers the potential to avoid the long-term articular cartilage degeneration that has been shown to result after meniscectomy.

The indications for meniscal repair are expanding with more understanding of meniscal pathophysiology and vascular anatomy and improved arthroscopic repair methods. Traditionally, vertical longitudinal tears located in the meniscal periphery (the "red-red" and "red-white" vascularized zones) have represented the optimal indication for repair. In recent studies, meniscal repair was successfully performed for tears in avascular zones ("white-white" zone), more complex tears, and full-thickness radial tears.[5,6] Surgical techniques that have been developed to stimulate a healing response include mechanical abrasion, fibrin clot application, and growth factor application, and these various augmentation techniques for meniscal repair have been attempted for meniscal neovascularization.[7]

Despite improvements in meniscal repair, the horizontal cleavage tears still remain an indication for meniscectomy because of the poor vascularization and meniscal tissue degeneration that can be shown in meniscal horizontal tears. In most studies of this type of tear, the skill and technique of meniscectomy are

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discussed; there are just 2 reports of meniscal repair for horizontal cleavage tears.[8,9] Therefore, we present arthroscopic repair for meniscal horizontal cleavage tears with all-inside instrumentation and a bone marrow—stimulation technique as an augmentation method for meniscal healing.

The purpose of this study was to evaluate patients after arthroscopic repair of meniscal horizontal tears with a marrow-stimulating technique. Evaluation was performed through clinical signs and second-look arthroscopy. We hypothesized that repair of horizontal meniscal tears with a marrow-stimulating technique would result in successful healing rates.

Methods

Between February 2007 and September 2011, a consecutive cohort of 71 patients who were diagnosed as having horizontal tears of the medial meniscus (MM) or lateral meniscus (LM) by magnetic resonance imaging (MRI) was evaluated. Among these 71 patients, 58 patients who showed positive findings on the McMurray test as well as joint-line tenderness underwent arthroscopic surgery. Inclusion criteria for the study were arthroscopic repair of meniscal horizontal tears and a minimum follow-up time of 24 months after arthroscopic repair. Exclusion criteria were individuals with greater than grade 3 degenerative changes, irreparable tissue damage of the meniscus, or concomitant ligament injury. Of the 59 patients who underwent arthroscopic surgery, 9 patients were excluded for greater than grade 3 degenerative changes, and 8 were excluded for irreparable tissue damage of the meniscus. Forty-two patients had articular cartilage degeneration of Outerbridge grade 2 or less and repairable meniscal tissue. Nine patients were excluded for concomitant anterior cruciate ligament injury. Of the 33 patients who underwent arthroscopic repair of meniscal horizontal tears, one patient was lost to follow-up and was excluded from the study. Thus, 32 patients constitute the participants in the present study. All patients were retrospectively evaluated through clinical assessment, and 11 patients underwent second-look arthroscopic examinations.

Surgical Technique

One surgeon (J-H.A.) performed the surgery in all 32 cases. Diagnostic arthroscopy was performed to detect the pathologic state of the meniscus and articular cartilage before the decision for meniscal repair was made. We performed meniscal repair for horizontal cleavage tears with concomitant articular cartilage degeneration of Outerbridge grade 2 or less. The meniscus was trimmed along the inner margin with an arthroscopic punch followed by an electric shaver to expose the margins of the tear and remove damaged tissue. Vertical sutures were made using FAST-FIX anchors (Smith & Nephew Endoscopy, Andover, MA) to approximate both the femoral and tibial surfaces of the torn meniscus. The FAST-FIX needle was inserted into the tibial (inferior) surface with the first anchor, and the second anchor was placed across the horizontal cleavage tears into the femoral (superior) surface. We tried to place the first anchor into the more peripheral portion of the tibial surface compared with the anchor insertion site of the femoral surface to avoid eversion of the inner margin of the meniscus. The repair was performed in 5- to 10-mm intervals to have the effect of a vertical mattress suture on the horizontal cleavage tears (Fig 1).

For the augmentation of meniscal healing at the avascular zone of the horizontal tear, we used a 5-mm cannulated reamer to stimulate bleeding in the intercondylar notch. The threaded guide pin was inserted at the medial wall of the intercondylar notch and the posterior cruciate ligament injury was noted. At this point, using a 5-mm cannulated reamer, we made a hole of 5-mm diameter and 20-mm depth into the medullary bone to encourage bleeding of bone marrow elements and clot formation in the joint (Fig 2).

To protect the repaired meniscus, a knee extension brace was applied for 6 weeks postoperatively. Knee

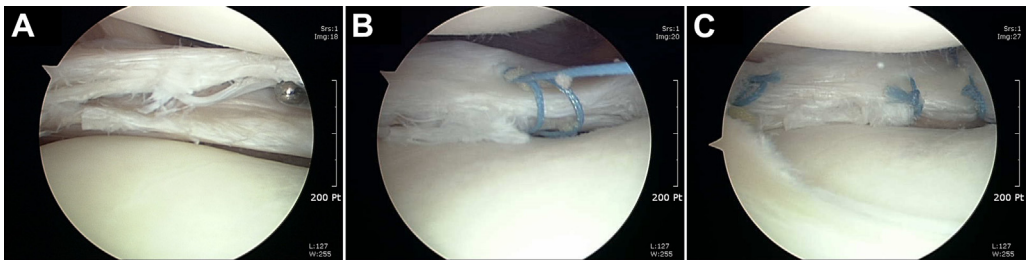

Fig 1. Arthroscopic repair for horizontal cleavage tears of lateral meniscus in 38-year-old man who had injured his right knee playing basketball 2 years previously. (A) Extensive horizontal cleavage tears with degeneration reached the peripheral edge of the meniscus. (B) The FAST-FIX needle was inserted into the tibial (inferior) surface with the first anchor, and the second anchor was placed across the horizontal cleavage tears into the femoral (superior) surface. (C) The completed repair with 5- to 10-mm intervals with the effect of a vertical mattress suture.

range of motion was permitted to 60° of flexion in the first 2 weeks, 90° at 4 weeks, 120° at 6 weeks, and full flexion at 8 weeks after surgery. Patients were restricted to partial weight-bearing movements with crutches for 4 weeks postoperatively. At this point, patients were allowed to walk with gradual weight bearing. At 1 year after arthroscopic repair, second-look arthroscopy was performed in volunteers to confirm whether the repaired meniscus had healed.

Functional Assessment

The patients were evaluated at 6, 12, and 24 months, and yearly thereafter. At the last follow-up, the functional status of the patients was reviewed. The visual analog scale (VAS) pain score, Lysholm knee scoring scale, and Tegner activity scale were used preoperatively and at each review.

Clinical and Arthroscopic Assessment of Meniscal Healing

For assessment of meniscal healing using Barrett's criteria, a repaired meniscus was considered healed if there was no joint-line tenderness, no effusion, and a negative McMurray test result at the latest follow-up.[10] If one or more of these parameters was present, the result was classified as a failure. Eleven of the patients volunteered to have second-look arthroscopy to confirm whether the repaired meniscus had healed. By second-look arthroscopy, we classified meniscal healing at the repair site into 3 groups: complete healing, incomplete healing, and failure. Complete healing signified healing over the length of the tear with no visible unhealed area. Incomplete healing was restoration of the stability of the repaired site, although a partial-thickness defect was visible. In the partial healing group, the unhealed cleft of tear had to be less than 30% of the whole length of the initial horizontal cleavage tear. Failure was recorded when the repaired meniscus was unstable because of poor healing, or the residual unhealed area was greater than 30% of the length of the initial tear at any location along the tear site. Correlation between chronicity of a meniscal lesion (time from initial symptom [TFIS]) and meniscal healing was evaluated. We also evaluated correlation between meniscal healing and smoking.

Statistics

The paired t test was used for comparison of the preoperative and postoperative VAS, Lysholm score, and Tegner activity score. The Mann-Whitney U test was used for correlation between meniscal healing and TFIS and smoking. Significance was set at $P < .05$.

Results

The mean follow-up period was 45.6 ± 13.9 months (range, 26 to 71 months). Twenty-three men (72%) and 9 women (28%) were included in the study population. The average age at the time of meniscal repair was 42.1 ± 9.5 years (range, 19 to 54 years). The MM was affected in 19 cases (59%) and the LM was affected in 13 cases (41%). The number of FAST-FIX anchors used averaged 3.8 ± 1.2 (range, 2 to 7) (Table 1).

The VAS pain score decreased to a mean value of 1.9 ± 1.0 (range, 0 to 3), which was statistically significant compared with the preoperative mean value of 6.7 ± 0.6 (range, 6 to 8) ($P < .001$).

Overall, the Lysholm score increased to a mean value of 92.0 ± 6.3 (range, 61 to 100), which was statistically significant compared with the preoperative mean value of 48.0 ± 14.4 (range, 9 to 64) ($P < .001$). Twenty-three patients (72%) had an excellent or good outcome, 8 patients (25%) had a fair to good result, and 1 patient (3%) had a poor result (Table 2).

Preoperatively, the mean preinjury Tegner activity score was 3.3 ± 1.1 (range, 1 to 5), whereas the postoperative mean value was 6.8 ± 0.8 (range, 5 to 8), and this difference was statistically significant ($P < .001$) (Table 2).

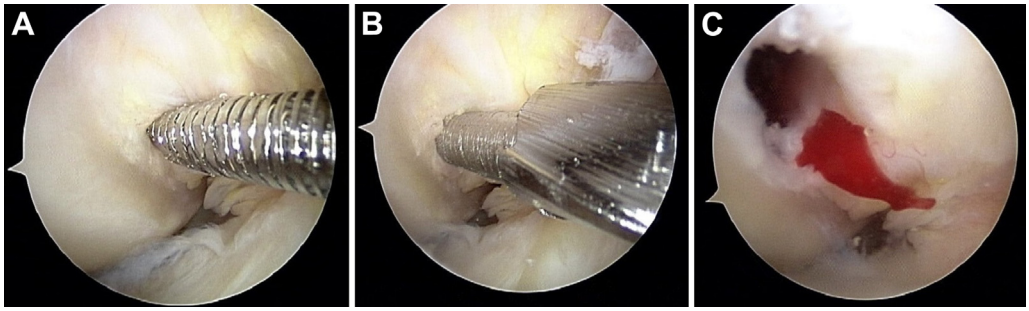

Fig 2. Marrow-stimulating technique for the augmentation of meniscal healing in the isolated meniscal tear. (A) The threaded guide pin was inserted at the medial wall of the intercondylar notch. (B) A bone tunnel was made in the medullary bone with a 5-mm cannulated reamer. (C) The hole had a 5-mm diameter and 20-mm depth to encourage bleeding of bone marrow. The marrow bleeding from the bone tunnel was shown after reducing the arthroscopic inflow.

Table 1. Study Demographics

Variable	Study Group (n = 32)
Age, yr (± SD)	42.1 (± 9.5; range, 19-54)
Sex, n (%)	
Male	23 (72)
Female	9 (28)
Side of tear, n (%)	
Medial meniscus	19 (59)
Lateral meniscus	13 (41)
FAST-FIX anchors, n (± SD)	3.8 (± 1.2; range, 2-7)

SD, standard deviation.

At the last follow-up, we found no signs of meniscal tears in 29 (91%) patients. One patient (3%) had a positive McMurray test and tenderness on joint-line palpation, 1 patient (3%) had tenderness on joint-line palpation, and 1 patient (3%) had tenderness on joint-line palpation plus effusion. No patient had locking episodes. These 3 cases (9%) were considered failures by Barrett's criteria (Table 3).

Second-look arthroscopy was performed in 11 patients at a mean of 17.4 ± 3.1 months after the first procedure (range, 11.3 to 25.1 months). Of the 11 patients who underwent second-look arthroscopy, 10 patients had clinically successful results and 1 had meniscal symptoms, such as pain on squatting, effusion, or locking. Treatment was considered a failure according to Barrett's criteria in this patient. Two patients whose treatment was considered a failure did not want second-look arthroscopy. During the second-look arthroscopy, repaired menisci were divided into complete healing, incomplete healing, and failure to heal groups according to our criteria. Among 11 patients, 8 (73%) showed complete healing, 2 (18%) had incomplete healing, and 1 (9%) failed to heal (Fig 3). The overall rate of complete or incomplete healing at arthroscopy was 91% (Table 3). Of the 2 menisci with incomplete healing at arthroscopy, one was in a symptomatic patient, and this patient underwent an additional partial meniscectomy. One patient in the failure group was also symptomatic and underwent additional partial meniscectomy.

Correlation between TFIS and meniscal healing was clinically significant ($P = .001$) but arthroscopically insignificant ($P = .085$). Correlation between smoking history and meniscal healing was clinically and arthroscopically insignificant ($P = .552$ and $P = .491$, respectively).

Table 3. Clinical and Arthroscopic Assessment of Meniscal Healing of Horizontal Tears

Clinical assessment* (n = 32)	
Healing	29 (91)
Failure	3 (9)
	1 case, tenderness on joint line
	1 case, tenderness on joint line and effusion 1 case, tenderness on joint line and positive McMurray test result
Second-look arthroscopic findings (n = 11)	
Complete healing	8 (73)
Incomplete healing	2 (18)
Failed to heal	1 (9)

NOTE. Data presented as n (%).
*Clinical judgment was determined by Barrett's criteria.

Comparison of MM and LM Cases

The MM was affected in 19 cases and the LM was affected in 13 cases in the present study. In clinical assessment of meniscal healing by Barrett's criteria, 17 cases were considered to have healed and 2 were considered to be failures in the MM, and 12 cases were considered to have healed and 1 was considered a failure in the LM. The failure rates were 10.5% and 7.7%, respectively. By second-look arthroscopy in 11 cases (6 MM and 5 LM), there were 4 cases of complete healing, 1 case of incomplete healing, and 1 failure in the MM; there were 4 cases of complete healing, 1 case of incomplete healing, and no failures in the LM (Table 4). There was no significant difference in failure rate in the clinical assessment and second-look arthroscopy between the 2 groups ($P = 1.000$ and $P = 1.000$, respectively).

Discussion

The results of this study show that despite the strategies used for horizontal meniscal tears in previous studies,[11-17] the meniscal repair in horizontal cleavage tears could restore the anatomic shape of the meniscus and preserve its function.

The majority of horizontal cleavage tears have been known to occur in older individuals, usually without a history of injury. They extend from the inner free margin peripherally to the intrameniscal substance with myxoid degeneration and are accompanied by degenerative changes in the meniscal tissue, particularly arthritic changes of articular cartilage.[17] Many previous

Table 2. Clinical Outcomes of Meniscal Repair in Horizontal Tears

Lysholm Score			Tegner Activity Score		
Preoperative	Postoperative	*P* Value*	Preoperative	Postoperative	*P* Value*
48.03 (± 14.42)	91.97 (± 6.28)	<.001	3.25 (± 1.11)	6.78 (± 0.83)	<.001

NOTE. Data presented as mean (± standard deviation) unless otherwise indicated.
*Statistical differences according to paired *t* test.

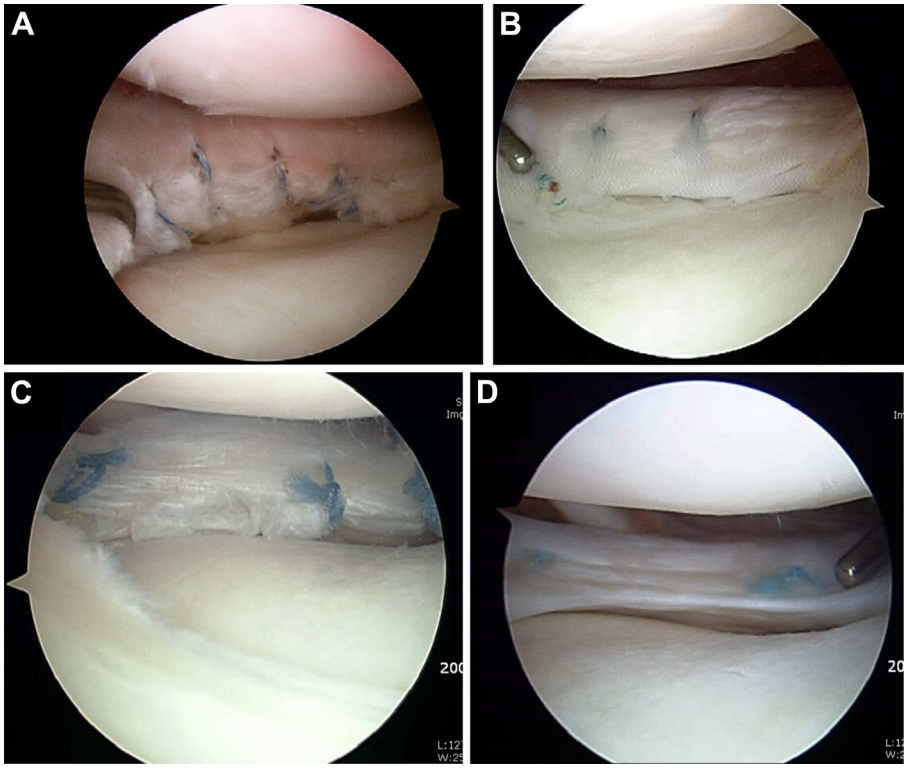

Fig 3. (A) Arthroscopic repair of horizontal cleavage tears of medial meniscus. (B) Second-look arthroscopy showed complete healing with closed cleft and regeneration of the pannus over the femoral surface of the medial meniscus. (C) Arthroscopic repair of horizontal cleavage tears of lateral meniscus. (D) Second-look arthroscopy showed complete healing.

studies reported that horizontal tears had little or no healing capacity and recommended partial meniscectomy or subtotal meniscectomy as the preferred treatment.[11-16] Christoforakis et al.[18] suggested that horizontal cleavage tears of the meniscus were highly associated with an increased incidence and severity of cartilage degeneration compared with other types of meniscal tears. Although horizontal meniscal tears were treated more often with meniscectomy than with repair in most previous studies, the consequences of meniscectomy with the increased intra-articular contact stress may result in knee osteoarthritis.[19] The preferred technique of meniscectomy in horizontal tears was to resect one leaf and spare the other leaf.[11-16] However, Haemer et al.[15] suggested that sparing one leaf offers no benefit over resecting both leaves with extensive horizontal meniscal tears in a study measuring the contact area and pressure on the tibial plateau of cadaveric sheep knees.

Table 4. Association Between Injured Meniscus Side and Healing Rate

	Healing Status*		
	Healing	Failure	*P* Value†
Side of meniscus (n = 32)			
Medial meniscus (n = 19)	17	2 (10.5)	1.000
Lateral meniscus (n = 13)	12	1 (7.7)	

	Second-Look Arthroscopy			
	Complete Healing	Incomplete Healing	Failure	
Side of meniscus (n = 11)				
Medial meniscus (n = 6)	4	1	1 (16.7)	1.000
Lateral meniscus (n = 5)	4	1	0 (0)	

NOTE. Data presented as n (%).
*Clinical judgment was determined by Barrett's criteria.
†Statistical differences according to 2-tailed Fisher exact test.

In several studies, horizontal tears have been compared with root tears of the MM posterior horn in that typical degenerative tears in both share an increased incidence and severity of cartilage degeneration.[20-22] Menisci protect 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.[23] Regarding the integrity of circumferential fibers in meniscal tears, horizontal tears may be in a better situation than other types of tears, which means that the stability of the meniscus after repair is possible if the repair procedure is performed for horizontal cleavage tears. Also, horizontal tears may be detected not only in the older population but also in younger patients such as individuals who play vigorous sports.[24] These points may raise the possibility and need for meniscal repair in horizontal cleavage tears.

Even though there were many critical opinions on meniscal healing after repair in horizontal tears, the

results of repair in our present study were 91% overall and 91% healing rate in the clinical evaluation and second-look arthroscopy, respectively. There were just 2 previous studies on meniscal repair for horizontal cleavage tears by Kamimura et al.[8] and Pujol et al.,[9] and they showed good clinical results after meniscal repair. In the study by Kamimura et al., 3 MM and 6 LM were treated, and all patients showed improvements in functional scores. In the study of Pujol et al., the meniscus was preserved in 80% of patients without additional meniscectomy after repair. Our present study also showed improved functional outcomes and high meniscal healing rates. These results in 3 studies of meniscal repair for horizontal tears were better than the previous critical opinions on meniscal repair for horizontal tears and the expectation of high failure rates.

We performed a marrow-stimulating technique for the augmentation of meniscal healing in isolated meniscal horizontal tears. Various augmentation techniques for meniscal healing in isolated meniscal tears have been introduced, including marrow stimulation, fibrin clot, growth factor application, and stem cell implantation in clinical practice and animal experiment studies.[7,25-32] In horizontal tears in a rabbit model, the in vivo effects of gelatin hydrogels incorporating fibroblast growth factor 2 on meniscal repair was reported.[33] In our present study, the marrow stimulation with a cannulated reamer at the intercondylar notch may be considered one of the factors that contributed to a high healing rate.

The evaluation of a repaired meniscus can be performed by second-look arthroscopy, clinical assessment, and MRI. Second-look arthroscopy is the most dependable way to determine meniscal healing.[34] Hoffelner et al.[35] reported that MRI after meniscal repair provided no definitive reliability on meniscal healing. In our present study, clinical assessment and second-look arthroscopy were used to evaluate meniscal healing after repair and they showed similar healing rates.

This study has 2 strengths. The comparatively large number of recruited cases compared with 2 previous similar studies[8,9] for repair of meniscal horizontal tears is the first strength of this present study. Second, we applied the marrow-stimulating technique with a cannulated reamer for isolated meniscal tears. This technique is a very simple and easy method if compared with the application of exogenous fibrin clot as used by Kamimura et al.[8]

Limitations

Our study required retrospective data collection and analysis, which could have allowed patient selection bias and confounding. Another limitation is the relatively small number of patients for evaluation of multiple variables. Further comparative studies on meniscal healing using large numbers of participants should be performed to assess the various types of meniscal tears and the horizontal cleavage tears to certify the healing potential of horizontal tears.

Conclusions

The meniscal repair procedure for horizontal cleavage tears in the present study suggests an alternative treatment option for meniscal tears extending into the avascular zone and degenerative tissue. The marrow-stimulating technique with a cannulated reamer can be considered as an alternative method for the augmentation of meniscal healing.

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