Arthroscopic Meniscectomy for Medial Meniscus Horizontal Cleavage Tears in Patients under Age 45

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Purpose: The purpose of this study was to evaluate the demographics, clinical features, and outcomes of arthroscopic partial meniscectomy (APM) for isolated medial meniscus horizontal cleavage tears (MMHCTs) in patients under 45 years of age.

Materials and Methods: We retrospectively reviewed 98 patients (100 knees) under 45 years who underwent APM for MMHCTs. Clinical outcomes were assessed using International Knee Document Committee (IKDC) subjective core, Tegner activity scale, visual analog scale (VAS) pain score, and a question on the symptom relief.

Results: 79% were male and 70% had no trauma. The mean symptom duration was 10 months. At arthroscopy, a flap tear was identified in 75%. At a mean of 19-month follow-up, the IKDC subjective score, Tegner activity scale, and VAS pain score were significantly improved compared to the preoperative values ($p=0.025$, $p=0.043$, and $p=0.032$, respectively). While 85% were free of symptoms, 15% had persistent pain. No significant differences in outcomes were observed based on the tear type and the presence of flap tears. No progression or development of radiographic degenerative changes was observed in all knees.

Conclusions: Demographics of MMHCTs under age 45 showed a male dominance and higher frequency of non-traumatic tears. APM was beneficial to symptomatic HCTs in this cohort during the short-term follow-up. Type of HCTs and combined flap tears did not affect clinical outcomes.

Keywords: Knee, Medial meniscus, Horizontal tear, Arthroscopy, Meniscectomy

Introduction

Horizontal cleavage tears (HCTs) can occur as a result of degeneration caused by shear force with or without a discrete injury and can extend to the inferior articular surface or the free edge of the meniscus¹⁾. The immobility of the medial meniscus posterior horn (MMPH) makes it vulnerable to tears. HCTs are common in the middle-aged or older patients and the prevalence increases with age²⁻⁴⁾. A large-scale study of middle-aged and elderly pa-

tients reported that 35% had degenerative HCTs²⁾. However, HCTs can also occur in younger patients⁵⁻⁷⁾. Terzidis et al.⁷⁾ reviewed 378 isolated meniscal tears in young athletes and found that 22.5% of the tears were HCTs. As HCTs can result in changes in the tibiofemoral contact mechanics that may lead to cartilage degeneration⁸⁾, it is mandatory to know the characteristics and natural courses of HCTs in younger patients. Causes, clinical features, and natural courses of HCTs in younger patients may differ from those in the middle-aged and elderly patients. However, little is known about the demographics, clinical features, and treatment outcomes in younger patients with MMPH HCTs.

Treatment options for symptomatic HCTs include meniscectomy and repair when the conservative treatment fails^{9,10)}. A recent systematic review has suggested promising outcomes of repair of HCTs⁹⁾; however, the classic approach has been arthroscopic partial meniscectomy (APM) due to poor healing potentials after repair¹¹⁻¹⁴⁾. Most previous studies have reported the results of APM in middle-aged or elderly patients and the benefits of arthroscopic surgery for degenerative meniscus tears are still debatable in these patients^{10,15-17)}. As the articular cartilage is likely

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to be healthier in younger population, prognosis in these patients can be expected to be better than that in older patients. However, there is limited literature reporting clinical outcomes and prognosis following APM for HCTs in patients younger than middle-aged persons.

The purposes of the present study were to investigate the demographics of MMPH HCTs and clinical outcomes of APM in patients under age 45. In addition, we investigated differences in demographics and clinical outcomes according to tear morphology and the presence of combined flap tears. Given HCTs and articular cartilage in younger patients are not degenerative, we hypothesized that 1) APM would resolve symptoms and provide satisfactory outcomes, 2) clinical features and outcomes would be different depending on the horizontal tear morphology and the presence of combined flap tears, 3) HCTs with a flap tear would be more symptomatic than HCTs without a flap tear, and 4) resultant clinical outcomes after APM would be better in patients with combined flap tears than those without flap tears.

Materials and Methods

This study was approved by the Institutional Review Board of our institution (AS13091-001). Medical records, magnetic resonance imaging (MRI) scans, and arthroscopic images (including videos) were reviewed for patients who underwent arthroscopic surgery for meniscus tears between 2005 and 2013. Inclusion criteria for this study were patients with 1) medial meniscus HCTs, 2) partial meniscectomy for meniscus tears, 3) normal or minimal radiographic arthritic changes (Kellgren-Lawrence [KL] grade 0 and 1), 4) normal or International Cartilage Repair Society grade 1 and 2 cartilage lesions, and 5) <45 years of age. Patients were

excluded if they had combined cruciate or collateral ligament injuries of the knee, lateral meniscus tears, fractures around knees, previous surgeries on the same knee, and inflammatory arthritis of the knee. Data such as age, sex, body mass index (BMI), presence of trauma (sports injury or traffic accident) causing acute onset of pain, primary symptoms, clinical signs, physical examinations, and time from the onset of symptom to clinic visit were collected from electronic medical records.

Preoperative diagnosis was confirmed using MRI (1.5-T or 3.0-T) in all patients. MMPH HCTs were classified according to the presence of intra-articular extension on the sagittal MRI scans that extends from the central part of the mid body to the posterior root of the medial meniscus. A type 1 tear was defined as a horizontal tear that transected the meniscus horizontally to the inner margin of the MMPH with no intra-articular exit (Fig. 1A). A type 2 tear was defined as a horizontal tear that extended to the inferior articular surface of the MMPH (Fig. 1B).

Arthroscopic findings were reviewed using videos, photos, and intraoperative notes. The types of HCTs (same as the MRI classification) and the presence of meniscus flap fragments and pathologic lesions of the articular cartilage were assessed in each patient. If the type of HCT was different between MRI and arthroscopy, the arthroscopic type was selected for analysis. The meniscal flap fragment was defined during arthroscopy as an easily displaceable tear that had free edges (Fig. 2). Two independent observers reviewed the MRI scans and arthroscopic findings in a 2-week period to ensure reliability.

1. Arthroscopic Intervention

Arthroscopic surgeries were performed by three experienced orthopedic surgeons. Our surgical indication for MMPH HCTs

Fig. 1. (A) Tear type 1 is defined as a horizontal tear that transects the meniscus horizontally to the inner margin of the medial meniscus posterior horn. (B) Tear type 2 is a tear that proceeds to the inferior articular surface of the medial meniscus posterior horn.

Fig. 2. A medial meniscus posterior horn (MMPH) horizontal tear with a combined flap tear. (A) A 36-year-old male patient presented with right knee pain. The coronal magnetic resonance imaging shows the combined flap tear segment of the MMPH horizontal tear as separate and displaced fragments (arrowheads). (B) In this patient, arthroscopy revealed the displaced flap tear (arrow) near the intercondylar notch.

in younger patients was localized knee pain combined with discomfort during high flexion such as cross-legged sitting or squatting. During arthroscopy, unstable superior or inferior leaves of HCTs and displaceable flap fragments (if present) were resected using basket forceps. In most cases, the inferior leaves were resected back to relatively normal stable tissue with a 3–5 mm peripheral rim. After resection, the central part of the meniscus was contoured. If there were pathologic cartilage lesions, unstable cartilage tissues were removed. No additional procedures for cartilage lesions such as multiple drilling or microfracture were performed.

All patients underwent a similar rehabilitation program postoperatively. Medications (such as non-steroidal anti-inflammatory drugs) were prescribed postoperatively for two weeks and discontinued. Full range of motion without load and full weight bearing were encouraged immediately postoperatively. During the first 4 weeks, four plane straight leg raising and quadriceps setting exercises were performed. Patients began isotonic and isokinetic-strengthening exercises as tolerated. Squatting with full flexion or cross-legged sitting position was not allowed for 2 months postoperatively. Patients were allowed to return to previous sports activities 3 months after operation.

2. Radiological and Clinical Outcomes

Pre- and postoperative mechanical axis of the lower extremity and degenerative changes (KL grade) were evaluated using preoperative and last follow-up plain radiographs including the bilateral standing lower extremity anteroposterior view, both knee standing 45° flexion posteroanterior view, both knee standing 30° flexion lateral view, and both knee skyline view. Physical tests such as palpation on the tibiofemoral joint line, McMurray test, Apley test, and squatting test were routinely performed preoperatively. Of those, the presence of joint line tenderness was included for analysis. Clinical outcomes were assessed using International Knee Document Committee (IKDC) subjective score, Tegner activity scale, visual analog scale (VAS) pain score (range, 0 to 10; 0

refers to pain free and 10 refers to most severe pain), and a single question on the resolution of symptoms compared to the preoperative status.

3. Statistical Analysis

Demographic variables and clinical outcomes were compared based on the type of HCTs, presence of combined flap tear, and resolution of symptoms. The independent samples *t*-test (numerical data) and chi-square test (categorical data) were used for statistical analysis. The reliability of the MR classification and arthroscopic classification of the HCT type was assessed using κ statistics. Inter- and intraobserver reliability was defined as follows: <0, poor agreement; 0–0.20, slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; 0.81–1.00, almost perfect agreement¹⁸⁾. All analyses were performed with SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA). A *p*-value <0.05 was considered statistically significant.

Results

1. Demographics

A total of 100 knees in 98 patients met the inclusion and exclusion criteria and they were included in this study (Table 1). The mean age of the included patients was 40 years. One female and one male patients had MMPH HCTs in both knees. There were 79 knees (79%) in male patients and 21 knees in female patients. Seventy knees (70%) had no significant trauma event (Table 2). Common injury mechanisms that patients recalled were a sudden twist, change in direction, jumping, landing or forceful deep knee flexion during sports, or walking down the stairs. The mean time of symptom duration was 10 months. The most common preoperative symptom was pain during walking (56%), followed by pain during deep flexion (31%), locking of the knee (8%), and a giving-way sensation (2%). Eighty knees (80%) had positive medial joint line tenderness preoperatively.

Both arthroscopic and MRI classifications exhibited almost

Table 1. Demographics of Medial Meniscus Posterior Horn Horizontal Cleavage Tears

Characteristic	Horizontal tear			p-value ^{a)}
	Type 1 (n=45)	Type 2 (n=55)	Total	
Age (yr)	37±8.7	38±9.1	40±8.1	NS
Sex (M/F)	37/8	42/13	79/21	NS
Body mass index (kg/m ²)	24±3	24±3	24±3	NS
Related to trauma (yes/no)	20/25	10/45	30/70	0.005
Kellgren-Lawrence grade				
Grade 0	39	48	87	
Grade 1	6	7	13	
Preop mechanical HKA angle (°) ^{b)}	178±2	179±3	178±2	NS
Symptom duration (mo)	6±13	13±11	10±18	NS
Positive joint line tenderness (%)	89	73	80	NS
Arthroscopic confirmed flap tear (%)	80	73	75	NS
Symptom improvement (%)				
Free of symptoms	82	89	85	NS
Persistent	18	11	15	NS
Preop IKDC subjective score	43±2.5	41±1.9	42±2.1	NS
Postop IKDC subjective score	87±2.5	89±1.8	88±1.7	NS
Preop median Tegner scale	3	3	3	NS
Postop median Tegner scale	5	5	5	NS
Preop VAS pain score	3.2±1.3	3.3±1.8	3.2±1.7	NS
Postop VAS pain score	0.9±0.7	0.7±0.8	0.7±0.7	NS
Mean follow-up period (mo)	19±23	19±20	19±20	NS

Values are presented as mean±standard deviation or number of cases.

NS: not statistically significant, Preop: preoperative, HKA: hip-knee-ankle, IKDC: International Knee Documentation Committee, Postop: postoperative, VAS: visual analogue scale.

^{a)}Comparison between the tear type 1 and 2. ^{b)}Values less than 180° represent varus limb alignment.

perfect agreement in an inter-observer and two intraobserver reliability tests (Table 3): 45 knees had type I HCTs and 55 knees had type II HCTs. The number of non-traumatic tear was significantly different between type 1 and type 2 HCTs ($p=0.005$), while no significant differences were observed in other demographics (Table 1).

2. Arthroscopic Findings

During arthroscopy, no torn menisci appeared repairable due to the long time after the onset of symptoms (average, 10 months). Combined flap tears were identified in 75 knees (75%). Patients with a flap tear tended to have more non-traumatic tears and significantly shorter symptom duration to surgery than those

Table 2. Demographics of Medial Meniscus Posterior Horn Horizontal Cleavage Tears according to the Presence of Trauma

Characteristic	Horizontal tear		p-value
	Traumatic (n=30)	Non-traumatic (n=70)	
Age (yr)	35±6	49±7	NS
Sex (M/F)	29/1	50/20	0.002
Body mass index (kg/m ²)	24±4	24±3	NS
Tear type 1 (%)	70	34	0.005
Kellgren-Lawrence grade			
Grade 0	29	58	
Grade 1	1	12	
Preop mechanical HKA angle (°) ^{a)}	178±3	178±2	NS
Symptom duration (mo)	2±1	16±26	0.003
Positive joint line tenderness (%)	60	81	0.005
Arthroscopically confirmed flap tear (%)	90	66	0.010
Symptom improvement (%)			
Free of symptoms	80	89	NS
Persistent	20	11	NS
Preop IKDC subjective score	44±5.2	43±4.1	NS
Postop IKDC Subjective score	88±3.5	87±5.8	NS
Preop median Tegner scale	3	3	NS
Postop median Tegner scale	5	5	NS
Preop VAS pain score	2.9±1.6	3.3±1.3	NS
Postop VAS pain score	0.3±0.6	0.8±0.6	NS
Mean follow-up period (mo)	21±31	18±32	NS

Values are presented as mean±standard deviation or number of cases.

NS: not statistically significant, Preop: preoperative, HKA: hip-knee-ankle, IKDC: International Knee Documentation Committee, Postop: postoperative, VAS: visual analogue scale.

^{a)}Values less than 180° represent varus limb alignment.

without a flap tear ($p=0.018$ and $p=0.009$) (Table 4). However, no significant differences were observed in other variables between patients with a flap tear and without a flap tear. Pathologic cartilage lesions observed with arthroscopy are presented in Table 5.

3. Clinical Outcomes

There were no postoperative complications and no additional surgeries after the index surgery in all knees. At the last follow-up (mean, 19 months), the mean IKDC subjective score, Tegner activity scale, and VAS pain score significantly improved compared to the previous values ($p=0.025$, $p=0.043$, and $p=0.032$, respectively). Eighty-five knees (85%) were free of symptoms and engaging in previous activities after the index surgery, while

Table 3. Inter- and Intraobserver Reliability Tests for Horizontal Cleavage Tear Classification

Characteristic	MRI	Arthroscopy
Interobserver		
Weighted κ	0.936	0.897
95% CI	0.882–0.991	0.820–0.919
Intraobserver 1		
Weighted κ	0.901	0.911
95% CI	0.770–1.000	0.841–0.986
Intraobserver 2		
Weighted κ	0.802	0.873
95% CI	0.620–0.984	0.787–0.950

MRI: magnetic resonance imaging, CI: confidence interval.

Table 4. Demographics of Medial Meniscus Posterior Horn Horizontal Tears according to the Presence of a Flap Tear

Characteristic	Horizontal tear		p-value
	Flap (+)	Flap (–)	
Cases	74	26	
Age (yr)	38±9	40±9	NS
Sex (M/F)	61/13	18/8	NS
Body mass index (kg/m ²)	24±3	23±3	NS
Related to trauma (yes/no)	47/27	23/3	0.018
Kellgren-Lawrence grade			
Grade 0	68	19	
Grade 1	6	7	
Preop mechanical HKA angle (°) ^{a)}	178±2	178±2	NS
Symptom duration (mo)	6±10	21±31	0.009
Positive joint line tenderness (%)	76	81	NS
Symptom improvement (%)			
Free of symptoms	89	85	NS
Persistent	11	15	NS
Preop IKDC subjective score	43±5.2	46±3.1	NS
Postop IKDC Subjective score	87±5.3	89±6.4	NS
Preop median Tegner scale	3	3	NS
Postop median Tegner scale	5	5	NS
Preop VAS pain score	3.1±1.2	3.5±1.7	NS
Postop VAS pain score	0.6±0.7	0.9±0.7	NS
Mean follow-up period (mo)	19±25	21±26	NS

Values are presented as mean±standard deviation or number of cases.

NS: not statistically significant, Preop: preoperative, HKA: hip-knee-ankle, IKDC: International Knee Documentation Committee, Postop: postoperative, VAS: visual analogue scale.

^{a)}Values less than 180° represent varus limb alignment.

Table 5. Pathologic Cartilage Lesions Confirmed during Arthroscopy

Characteristic	International Cartilage Repair Society		
	Grade 0	Grade 1	Grade 2
Medial femoral condyle	88	2	10
Medial tibial plateau	97	0	3
Lateral femoral condyle	100	0	0
Lateral tibial plateau	99	0	1
Patella	98	0	2
Trochlea	98	0	2

15 knees (15%) had persistent pain during daily activities. There were no significant differences in age, sex ratio, BMI, cause of injury, HCT type, hip-knee-ankle angle, symptom duration, and preoperative clinical scores between patients who were free of symptoms and patients who had persistent pain, except for the presence of preoperative joint line tenderness (70% vs. 100%; $p=0.012$). No significant differences were observed in outcomes based on the type of HCTs (type 1 vs. type 2) and the presence of combined flap tears.

Minimum 36-month follow-up outcomes were available for 39 knees: 31 knees were free of symptoms and engaging in previous activities after the index surgery, while 8 knees had persistent pain during daily activities. Significant differences were found in the mean preoperative VAS pain score (3.7 vs. 2.4) and symptoms duration (21 months vs. 6 months) between patients who were free of symptoms and patients who had persistent pain.

No progression or development of radiographic degenerative changes was observed in all knees at the last follow-up.

Discussion

Although HCTs are more common in older patients, they can occur in younger patients. However, little is known about the demographics, clinical features, and treatment outcomes of HCTs in younger patients. This study investigated the demographics and clinical outcomes following arthroscopic meniscectomy for HCTs in patients who were younger than 45 years of age and had relatively healthy cartilage condition. We found that demographic characteristics of less than 45-year-old patients with MMPH HCTs are male dominance (79%), higher prevalence of non-traumatic tears (70%), and tolerable symptoms (mean symptom duration: 10 months). At a mean of 19 months of follow-up, 85% were free of symptoms with no progression of radiographic degenerative changes after partial meniscectomy. Contrary to our hypotheses, no significant differences were seen in the outcomes

according to the type of HCTs (type 1 vs. type 2) and the presence of a combined flap tear. Our study supports the evidence that younger patients with symptomatic HCTs benefit from the APM, although the superiority of meniscectomy over other treatment methods will be further investigated. This information can be helpful in determining the treatment plan for symptomatic HCTs in younger patients.

The etiology of HCTs in younger patients remains unknown. Previous studies have suggested that HCTs in younger patients may occur due to overuse or trauma rather than degeneration unlike in older patients⁷⁾. In the present study, 70% of patients showed no history of significant trauma. However, it is unclear whether these patients were subjected to repeated or overuse injury. We investigated demographics associated with non-traumatic HCTs in younger patients. Compared to traumatic HCTs, non-traumatic HCTs showed less male-dominance, higher prevalence of type 2 tears, longer duration of symptoms, greater incidence of flap tears, and higher presence of joint line tenderness (Table 2). However, no significant differences were observed in age, BMI, limb alignment, and outcomes between the traumatic and non-traumatic groups. Our findings were partly similar to those of Kim et al.¹³⁾ study on isolated HCTs in patients less than 40 years old. They found no significant differences in age, sex, duration of symptoms, physical assessments, pre/postoperative Lysholm score, and IKDC score. Further study will be required to determine the etiology and natural course of non-traumatic HCTs in younger patients.

Many flap tears begin with HCTs. In our series, the displaceable flap tears were found in 75 knees (75%) during arthroscopy. The clinical significance of a flap tear is that it can be displaced centrally or peripherally, leading to mechanical symptoms, which requires arthroscopic management¹⁹⁻²²⁾. Given that displaceable flap tears cause mechanical symptoms, it was hypothesized that 1) HCTs with a flap tear would be more symptomatic than HCTs without a flap tear, and 2) resultantly clinical outcomes after meniscectomy would be better in patients having combined flap tears compared to patients without flap tears. We found that HCTs with a flap tear had significantly shorter duration of symptoms to operation compared to HCTs without a flap tear (6 months vs. 22 months). However, preoperative and postoperative clinical scores showed no significant differences between HCTs with a flap tear and without a flap tear. In addition, the most frequent symptom in patients with a flap tear was pain during walking at ground level, while mechanical symptoms were less frequently seen in our series. This finding does not support our hypothesis that HCTs with combined flap tears would be more symptomatic

than HCTs without flap tears. One of the possible reasons would be the size of the flap fragment. Once a tear in the meniscus becomes of significant size, more obvious symptoms of giving way and locking may develop.

A HCT divides the meniscus into superior and inferior leaves resembling a fish mouth or it extends to the superior or inferior articular surface, developing into a superior or inferior flap tear^{1,23)}. In the current study, we investigated if any differences would exist between type 1 and type 2 HCTs and if classification would be helpful in determining the treatment plan and prognosis. We assumed that type 2 HCTs would have worse clinical courses and be unresponsive to conservative treatment because type 2 HCTs tend to have more displaceable flap tears compared to type 1 HCTs. However, no significant differences were observed in the frequency of flap tears and preoperative VAS pain score between type 1 and type 2 HCTs except the longer presentation time in type 2 HCTs. One possible reason for longer presentation time in type 2 HCTs could be the cause of injury. Type 2 HCTs had more non-traumatic tears that showed longer symptom duration compared to the traumatic tear group. Generally, patients having sudden onset of knee pain following trauma tend to visit clinics earlier than those having gradual onset of non-traumatic knee pain. However, there could be other factors affecting the presentation time. Further long-term follow-up studies will be required to determine the clinical significance of our HCTs classification.

Varus alignment, old age, high BMI, concomitant cartilage loss, and greater severity of joint degeneration have been documented as poor prognostic factors of partial meniscectomy in middle-aged or older patients²⁴⁻²⁶⁾. However, in younger patients, prognostic factors are not determined yet. In the present study, 15% had no improvement with persistent pain after partial meniscectomy at an average of 19 months of follow-up. Our study showed that there were no significant differences in preoperative demographics between patients who were postoperatively free of symptoms and patients who had no postoperative improvement, except for the joint line tenderness. However, it was difficult to compare results between the two groups due to the limited number of failure cases and significantly longer follow-up period in patients having persistent pain, which may have affected the results of our study. Regarding the subgroup analysis for a minimum 36 months of follow-up, patients with persistent pain had significantly lower preoperative VAS pain scores and shorter symptom duration than patients who were free of symptoms at an average of 54 months of follow-up. However, this subgroup analysis has statistical limitation due to the small number of fail-

ure cases (8 knees). Further studies will be needed to determine whether younger patients with HCTs have better outcomes after arthroscopic meniscectomy compared to older patients with HCTs.

Our study has several limitations. First, isolated MMPH HCTs are relatively rare in patients under 45 years of age; thus, only a small number of cases were evaluated although 8 years of medical records were reviewed for enrollment. The cases were enrolled from an 8 years of period. Second, due to ethical reasons, only patients treated with arthroscopic intervention for symptomatic MMPH HCTs were included in this study. Some patients may have had clinically occult displaced meniscal tear fragments that were missed on preoperative MRI, and thus these patients would not have been selected for arthroscopic surgery. Third, the retrospective study design and small number of failure cases limited our ability to identify risk factors for poor prognosis. Finally, this was not a comparative study with other treatment methods; therefore, it is uncertain that meniscectomy is superior to other treatment methods for MMPH HCTs. Despite these limitations, we believe our demographic data and analysis help improve understanding of the characteristics of MMPH HCTs in younger patients.

Conclusions

Demographics of MMHCTs under the age of 45 years showed male dominance and higher prevalence of non-traumatic tears. APM was beneficial to symptomatic HCTs in this cohort during the short-term follow-up. The type of HCTs and combined flap tears did not affect the clinical outcomes.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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