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The effect of the tear pattern and the number of preoperative locking episodes on the functional outcome following arthroscopic bucket-handle meniscal tear repair

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Abstract

Relatively larger size, displacement, the complexity of the bucket-handle meniscal tear (BHMT)s, and the fact that they can cause locking can be challenging for treatment. This study aimed to evaluate the effect of tear pattern and the number of preoperative locking episodes on the functional outcome and failure rate following arthroscopic BHMT repairs. 84 patients who underwent arthroscopic repair for BHMTs between 2013 and 2018 were included in the study. VAS, Lysholm, IKDC, Tegner, and overall satisfaction scale were used to assess functional and clinical outcomes. MRI was used for radiologic assessment method, and Barrett criteria were used for assessment clinical failure. The effects of BHMT pattern and the number of preoperative locking episodes were evaluated, and the effect of surgical and demographic features on failure was investigated following arthroscopic BHMT repair. The mean follow-up was 66.1 ± 16.2 months (range, 24-84 months). Improvement in VAS, Lyholm, IKDC scores, and patient satisfaction was significantly higher in patients with single locking history, and failure rate in this group was lower as well ($p=0.036$, $p=0.000$, $p=0.001$, $p=0.000$, $p=0.015$, respectively). Red--white (RW) zone tears, late repairs (>2 months), and smoking habits were found to be significantly higher in failed repairs ($p=0.036$, $p=0.015$, $p=0.028$, respectively). However, BHMT pattern did not affect clinical outcomes and failure rate ($p<0.05$). Recurrent preoperative locking episodes have a negative impact on clinical outcomes and meniscal healing. Especially, first time locking and peripheral BHMTs should be repaired in the early period regardless of tear pattern.

Keywords: Meniscal repair, bucket handle, failure, clinical, locking

Introduction

Bucket-handle meniscus tears (BHMTs) are vertical longitudinal tears in shape characterized by the central displacement of the inner part representing 10% to 26% of all meniscus tears [1,2]. Relatively larger size, displacement, the complexity of these tears, and the fact that they can cause locking can be challenging for treatment [3]. Lower healing rates of displaced BHMT repair have been reported compared to the naturally more stable non-displaced meniscus tear patterns [4].

BHMTs usually lead from close to the posterior tibial insertion of the meniscus extending to the middle third and even to the anterior horn, potentially causing displacement into the intercondylar notch or around the femoral condyle [5]. While BHMTs were mostly classified into two different forms in the literature as simple, centrally displaced or flipping to the intercondylar notch [6], Lim et al. [7] have reported three patterns as; simple centrally displaced upward (SCDU), simple centrally displaced downward (SCDD), and flipped separating the simple BHMTs into the upward and downward according to the facing orientation of the inner part (Figure 1). Displacement of the inner segment into the intercondylar notch may cause mechanical symptoms, locking, pain, and instability [2]. Centrally displaced BHMTs are generally minimally displaced within the compartment and have the potential of locking the knee; however, flipped BHMTs often cause the patient to experience intermittent symptoms in activities [8].

Figure 1. Bucket-Handle Meniscal Tear patterns classified by Lim et al. [11]. a. Simple centrally displaced upward, b. Simple centrally displaced downward, c. Flipped.

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Studies evaluating BHMT repair outcomes in terms of the patient demographics and preoperative or intraoperative surgical variables are limited in the literature [5,8-12]. Besides, studies on BHMT patterns are even fewer [7,8]. To our knowledge, there have been no direct comparative clinical studies involving the repair of BHMTs in terms of the number of preoperative locking episodes and the tear pattern. This study aimed to evaluate the effect of the tear pattern and the number of preoperative locking episodes as well as patient characteristics and surgical factors on the functional outcome and failure rate following arthroscopic BHMT repairs. The hypothesis was that locking recurrence and tear pattern would affect repair success and clinical outcomes following BHMT repairs.

Materials and Methods

Patients

A total of 462 patients underwent arthroscopic repair for a meniscal tear between 2013 and 2018 in our clinic. Of these, 84 patients who underwent arthroscopic repair for BHMTs and met the inclusion criteria were retrospectively evaluated from a database of prospectively collected data. All procedures were performed by two surgeons (xx, yd). The inclusion criteria were as follows: a meniscal tear due to trauma or sports injury; displaced BHMT demonstrated by magnetic resonance imaging (MRI) or detected intraoperatively (Figure 2); patients with at least one locking history; RR or RW zone tears; an arthroscopic BHMT with or without an anterior cruciate ligament (ACL) rupture. Exclusion criteria were a previous history of open or arthroscopic surgery for intra-articular lesions; less than two years follow-up duration, degenerative knee osteoarthritis; cartilage defect of grade 2 or above [13]; any tear shape other than BHMT; patellofemoral instability; rheumatoid conditions. After exclusions, a total of 84 patients were included. Persistent mechanical pain despite conservative treatment, extension restriction of the knee joint, severe pain with a loud click, and BHMTs with ACL ruptures were the indications for surgery. Study flowchart and patient exclusion details are summarized in Figure 3.

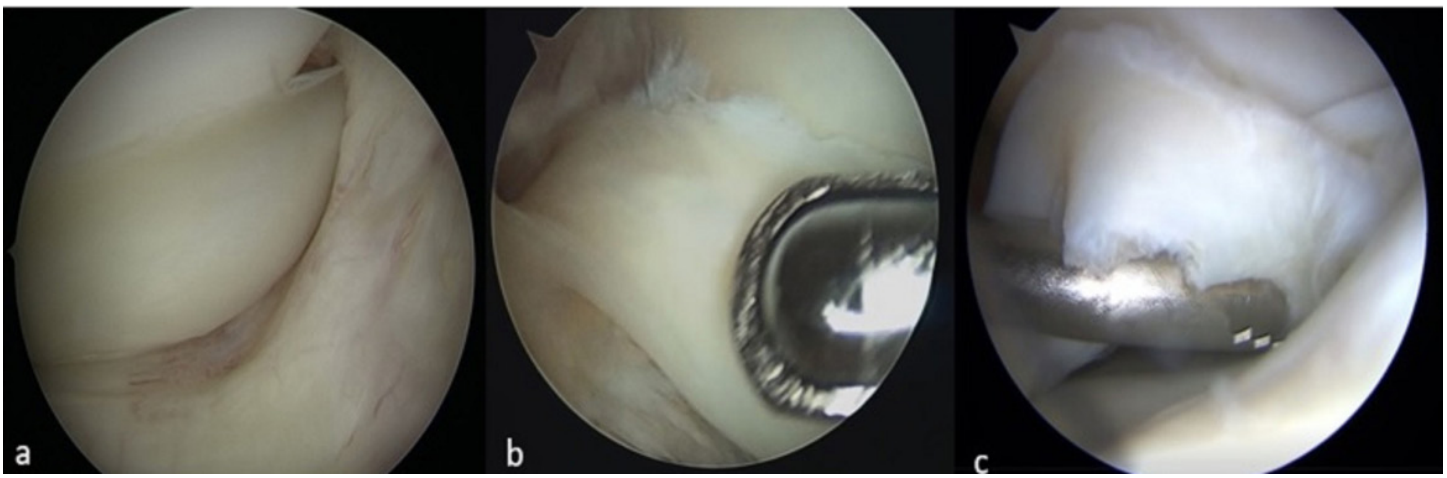
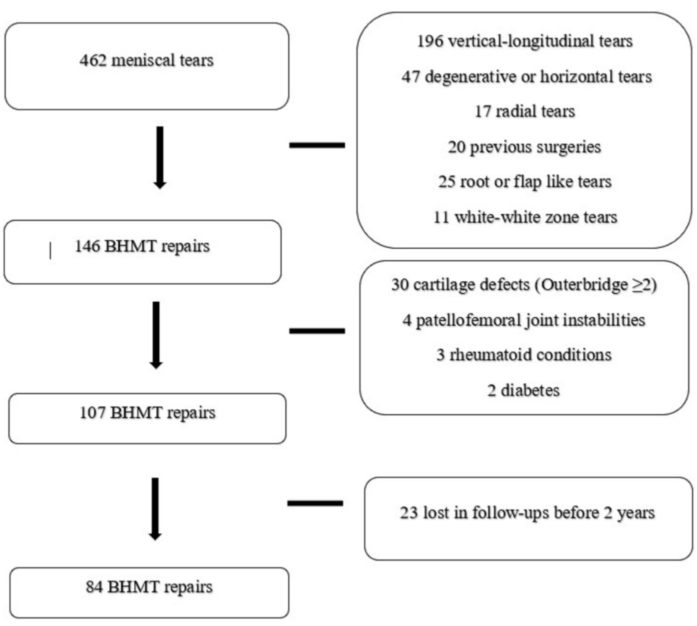


Figure 2. a. Simple centrally displaced lateral bucket-handle meniscal tear (BHMT)- upward orientation, b. Simple centrally displaced medial BHMT - downward orientation, c. Flipped medial BHMT



BHMT: Bucket-handle meniscal tear.

Figure 3. Study flowchart and patient exclusion details

Surgical technique

All operations were performed under general or spinal anesthesia using routine anteromedial and anterolateral portals. BHMT pattern and other intra-articular pathologies were determined examining all the knee compartments. The affected knee side (right, left), the side of the meniscal tear (medial, lateral), and tear localization (RR, RW zones) were recorded [14]. To determine the pattern, length, extent, or shape of the tear and to assess peripheral rim stability and reparability of the tear, probing was performed. The reduction of the inner part was achieved using a probe or arthroscopy clamp. Meniscal rasping was performed to the tear edges as an adjunct procedure to stimulate healing at the time of the repair. The all-inside suture procedure or a hybrid method (outside-in with all-inside) was performed depending on the tear location. An oblique or vertical suture configuration was used in all repairs. The BHMTs involving the posterior horn of the meniscus and the tears, including meniscal body, were repaired using the all-inside technique. However, an additional outside-in suture (the hybrid method) was used for tears extending to the anterior horn. The all-inside procedure was performed using Fast-Fix suture (Fast-Fix™ 360, Smith & Nephew, Andover MA, US). In contrast, the outside-in method was performed using #0 Polydioxanone suture (PDS) (Ethicon) sutures. A mean of 4.0 ± 1.0 (range, 2 to 7 sutures) sutures were used in meniscal repairs. All patients with ACL ruptures underwent an anatom¬ic single-bundle reconstruction using autogenous hamstring tendons with the Endo button Technique (Endobutton CL, Smith & Nephew). The clinical characteristics, operative features and demographic data of patients are summarized in Table 1 and Table 2.

Table 1. Patient demographics and operative features according to the locking feature

		Total (n=84)	Single locking (n=55)	Recurrent locking (n=29)	p value
Age (year)		29.7 ± 7.4	29.2 ± 7.5	30.6 ± 7.2	0.368
		28.5 (18-49)	28 (18-49)	29 (20-48)	
BMI (kg/m²)		24.4 ± 3.3	24.6 ± 2.2	24.7 ± 2.5	0.918
		24.5 (19.8-30.2)	24.6 (19.8-29.6)	24.3 (19.8-30.2)	
Sex (n/%)	**Female**	6 (7.1)	5 (9.1)	1 (3.4)	0.340
	Male	78 (92.9)	50 (90.9)	28 (96.6)	
Affected Knee side (n/%)	**Right**	48 (57.1)	30 (54.5)	18 (62.1)	0.508
	Left	36 (42.9)	25 (45.5)	11 (37.9)	
Torn meniscus (n/%)	**Medial**	68 (81.0)	51 (92.7)	17 (58.6)	0.000
	Lateral	16 (19.0)	4 (7.3)	12 (41.4)	
Time of repair (n/%)	**≤8 weeks**	51 (60.7)	44 (80.0)	7 (24.1)	0.000
	>8 weeks	33 (39.3)	11 (20.0)	22 (75.9)	
Zone of tears (n/%)	**Red-Red**	54 (64.3)	36 (65.5)	18 (37.9)	0.758
	Red-White	30 (35.7)	19 (34.5)	11 (62.1)	
Length of tears (n/%)	**<25 mm**	38 (45.2)	25 (45.5)	13 (44.8)	0.956
	>25 mm	46 (54.8)	30 (54.5)	16 (55.2)	
Smoking habits (n/%)	**Nonsmokers**	58 (69.0)	41 (74.5)	17 (58.6)	0.133
	Smokers	26 (31,0)	14 (25.5)	12 (41.4)	
Repair technique (n/%)	**Hybrid**	50 (59.5)	32 (58.2)	18 (62.1)	0.730
	All-inside	34 (40.5)	23 (41.8)	11 (37.9)	
Suture configuration (n/%)	**Oblique mattress**	30 (35.7)	21 (38.2)	9 (31.0)	0.516
	Vertical mattress	54 (64.3)	34 (61.8)	20 (69.0)	
Grade I cartilage degeneration (n/%)	**No**	58 (69.0)	37 (67.3)	21 (72.4)	0.628
	Yes	26 (31.0)	18 (32.7)	8 (27.6)	
Anterior cruciate ligament tear(n/%)	**No**	21 (25.0)	12 (21.8)	9 (31.0)	0.354
	Yes	63 (75.0)	43 (78.2)	20 (69.0)	
Anesthesia type (n/%)	**Regional**	46 (54.8)	28 (50.9)	18 (62.1)	0.329
	General	38 (45.2)	27 (49.1)	11 (37.9)	
Tear region (n/%)	**Total**	14 (16.7)	9 (16.4)	5 (17.2)	0.323
	Posterior 2/3	32 (38.1)	24 (43.6)	8 (27.6)	
	Posterior 1/3	38 (45.2)	22 (40.0)	16 (55.2)	
Bucket Handle Tear Pattern	**SSDU**	42 (50.0)	32 (58.2)	10 (34.5)	0.069
	SSDD	23 (27.6)	11 (20.0)	12 (41.4)	
	Flipped	19 (22.4)	12 (21.8)	7 (21.4)	
Sports participation	**Recreational**	30 (35.7)	20 (36.4)	10 (34.5)	0.984
	Competitive	40 (47.6)	26 (47.3)	14 (48.3)	
	Elite	14 (16.7)	9 (16.4)	5 (17.2)	
Number of sutures used		4.0 ± 1.0	4.0 ± 0.9	4.0 ± 1.1	0.953
		4 (2-7)	5 (2-7)	5 (2-7)	
Operative time (minutes)		72.3 ± 8.2	72.0 ± 8.0	72.9 ± 8.8	0.467
		75 (55-90)	75 (55-90)	75 (55-90)	

[a] Data are reported as mean ± SD / median(min-max) or n (%). BMI, Body mass index, SSDU: Simple centrally displaced upward, SSDD: Simple centrally displaced downward. Bolded P value indicates a statistically significant difference between groups (P <0.05)

Table 2. Patient demographics and operative features according to the bucket handle tear pattern º

		Simple centrally displaced upward (n=42)	Simple centrally displaced downward (n=23)	Flipped (n=19)	p value
Age (year)		29.2 ± 8.3 27 (18-49)	29.5 ± 6.4 28 (21-45)	30.9 ± 6.6 29 (19-48)	0.447
BMI (kg/m²)		24.9 ± 2.3 24.5 (19.8-29.6)	24.4 ± 2.3 23.5 (21.3-30.2)	24.4 ± 2.4 24.5 (19.8-29.3)	0.581
Sex (n/%)	**Female**	4 (9.5)	0 (0.0)	2 (10.5)	0.293
	Male	38 (90.5)	23 (100.0)	17 (89.5)	
Affected Knee side (n/%)	**Right**	26 (61.9)	14 (60.9)	8 (42.1)	0.321
	Left	16 (38.1)	9 (39.1)	11 (57.9)	
Torn meniscus (n/%)	**Medial**	35 (83.3)	18 (78.3)	15 (78.9)	0.856
	Lateral	7 (16.7)	5 (21.7)	4 (21.1)	
Time of repair (n/%)	**≤8 weeks**	34 (81.0)	11 (47.8)	6 (31.6)	0.000
	>8 weeks	8 (19.0)	12 (52.2)	13 (68.4)	
Zone of tears (n/%)	**Red-Red**	25 (59.5)	17 (73.9)	12 (63.2)	0.508
	Red-White	17 (40.5)	6 (26.1)	7 (36.8)	
Length of tears (n/%)	**<25 mm**	23 (54.8)	12 (52.2)	3 (15.8)	0.013
	>25 mm	19 (45.2)	11 (47.8)	16 (84.2)	
Smoking habits (n/%)	**Nonsmokers**	32 (76.2)	16 (69.6)	10 (52.6)	0.183
	Smokers	10 (23.8)	7 (30.4)	9 (47.4)	
Repair technique (n/%)	**Hybrid**	28 (66.7)	10 (43.5)	12 (63.2)	0.178
	All-inside	14 (33.3)	13 (56.5)	7 (36.8)	
Suture configuration (n/%)	**Oblique mattress**	13 (31.0)	8 (34.8)	9 (47.4)	0.461
	Vertical mattress	29 (69.0)	15 (65.2)	10 (52.6)	
Grade I cartilage degeneration (n/%)	**No**	28 (66.7)	18 (78.3)	12 (63.2)	0.513
	Yes	14 (33.3)	5 (21.7)	7 (36.8)	
Anterior cruciate ligament tear(n/%)	**No**	6 (14.3)	9 (39.1)	6 (31.6)	0.065
	Yes	36 (85.7)	14 (60.9)	13 (68.4)	
Anesthesia type (n/%)	**Regional**	24 (57.1)	14 (60.9)	8 (42.1)	0.434
	General	18 (42.9)	9 (39.1)	11 (57.9)	
Tear region (n/%)	**Total**	4 (9.5)	3 (13.0)	7 (36.8)	0.059
	Posterior 2/3	20 (47.6)	7 (30.4)	5 (26.3)	
	Posterior 1/3	18 (42.9)	13 (56.6)	7 (36.8)	
Locking feature	**Single**	32 (76.2)	11 (47.8)	12 (63.2)	0.069
	Repetitive	10 (23.8)	12 (52.2)	7 (36.8)	
Sports participation	**Recreational**	15 (35.7)	6 (26.1)	9 (47.4)	0.452
	Competitive	18 (42.9)	14 (60.9)	8 (42.1)	
	Elite	9 (21.4)	3 (13.0)	2 (10.5)	
Number of sutures used		3.9 ± 1.0 4 (2-7)	3.9 ± 0.9 4 (3-6)	4.3 ± 1.1 4 (3-7)	0.468
Operative time (minutes)		71.9 ± 8.2 75 (55-90)	72.3 ± 10.1 75 (55-90)	73.2 ± 6.6 75 (60-90)	0.836

º Data are reported as mean ± SD/ median(min-max) or n (%). BMI, Body mass index. Bolded P value indicates a statistically significant difference between groups (P < 0.05)

Postoperative rehabilitation

Same rehabilitation program was applied in order to wait for the meniscus to heal after meniscus repair, with or without ACL reconstruction (Car). Patients were immobilized in full extension for two weeks using an angle-adjustable brace to protect repaired menisci. Isometric quadriceps exercises commenced on postoperative day 1. When the patients could perform a straight leg raise, they were discharged. In the first six weeks, partial weight-bearing was allowed with crutches when the knee in full extension. After three weeks, quadriceps muscle exercises with weights were initiated. Six weeks after the surgery, full range of motion and unlimited weight-bearing were allowed. Running, squatting, and pivoting were allowed three, five, and six months after surgery, respectively. Re-initiation of sports activities was permitted at the end of the sixth month.

Assessment

The data, including patient demographics, tear characteristics, and operative features, were recorded. Clinical and functional evaluation was performed using the Visual Analog Scale (VAS), ranging from 0 to 10; 0 = no pain to 10 = the worst pain; the Lysholm score[15]; the Tegner Activity Scale[16] and the International Knee Documentation Committee (IKDC) knee evaluation form[17]-graded as A (normal), B (nearly normal), C (abnormal), or D (severely abnormal) both pre and post-operatively, and also overall satisfaction was evaluated postoperatively (very satisfied, satisfied, partially satisfied, or dissatisfied). Axial, coronal and sagittal MRI sequences were used for radiological evaluation of BHMT repair, and Barrett criteria were used for clinical assessment of meniscal healing [18], where the absence of joint tenderness, effusion, and locking as well as the presence of a negative McMurray test were considered indicative of a healed meniscus. The functional outcome scores and failure rate were used as primary outcome measures. After further dividing the patients according to the number of dislocations (single locking in 55 patients vs. repetitive locking in 29 patients) and tear pattern (SCDU in 42 patients, SCDD in 23 patients, and flipped in 19 patients), the effect of tear pattern and locking episode on outcomes were evaluated. Tear characteristics (zone, region, length, chronicity, side), repair technique, suture configuration, sports participation (recreational, competitive, elite-professional), body mass index (BMI), chondral status at the time of the repair, concomitant car, and smoking habits were also investigated in terms of failure status. Informed consent was obtained from all participants. The study was approved by our institutional review board (No. 2020/315).

Statistical analysis

SPSS version 22.0 for Windows (IBM Inc. Chicago, IL, USA) was used for statistical analysis. Distribution of normality was tested using the Shapiro–Wilk test. Mean, standard deviation, median, lowest, and highest values, and frequency ratio were used in descriptive statistics of the data. Depending on the group numbers compared to independent samples, a t-test or one-way ANOVA test was used for normally distributed data for the comparisons of variables between independent samples. Nonparametric tests were used if the data were not normally distributed. For intergroup comparisons of continuous variables, the Mann–Whitney U test or Kruskal–Wallis test were used depending on the group numbers compared. For the intragroup comparison, the Wilcoxon test was used. The chi-square test was used for the categorical data comparison. The Fischer exact test was used when the chi-squared test requirements were not met. The level of statistical significance was set at p-value <0.05.

Results

68 of 84 patients had medial BHMTs, where 16 patients had lateral BHMTs. While medial meniscus injury was more common in the single locking group; lateral meniscus injury was significantly higher in repetitive locking group (p=0.000). A single locking history was more common in patients who underwent surgery for 8 weeks or less, where repetitive locking was observed in those who underwent surgery for more than 8 weeks (p=0.000). The most common intra-articular pattern was SCDU (42 patients, 50%). The occurrence of the other patterns was: SCDD in 23 patients (27.6%), flipped in 19 patients (22.4%). Chronic tears (>8 weeks) and larger tears (>25 mm) were more likely to be flapped-like tears (p=0.000, 0.013, respectively). The mean follow-up period was 66.1 ± 16.2 months (range, 24-84 months). There was a significant improvement in clinical scores at the last follow-up compared to baseline (p <0.001). Improvement in VAS, Lysholm, IKDC scores, and patient satisfaction were significantly higher in patients with single locking history, and failure rate in this group was lower as well (p=0.036, p=0.000, p=0.001, p=0.000, p=0.015, respectively) (Table 3). BHMT pattern was found not to affect clinical and functional outcomes and failure rate (p<0.05). Outcomes, according to the tear pattern, are summarized in Table 4. Besides, RW zone tears, late repairs (>2 months), smoking habits were found to be significantly higher in failed repairs (p=0.036, p=0.015, p=0.028, respectively). Other parameters, including patient demographics, tear characteristics, and operative features, did not affect failure status. Outcomes, according to the failure status, are summarized in Table 5. Seventy-four (88.1%) of patients were at least partially satisfied with the surgery. Failure was noted in 14 patients (16.7%). MRI examination of these patients showed that BHMTs were transformed into complex or flap style tears in six patients and subsequent meniscectomy of the repaired meniscus was performed. The remaining eight patients underwent a repeated meniscal repair. ACL re-rupture was seen in two of these patients who underwent re-meniscus repair, and revision ACLr was performed for these patients with bone tendon bone autograft taken from the ipsilateral knee in the same session. Symptom-free patients could return to their preoperative activity levels after six months postoperatively. No patient had a recurrence of a locking episode at the last follow-up.

Discussion

The main findings of this study were that arthroscopic repair of BHMTs results in high patient satisfaction, functional scores, and low failure rate regardless of the tear pattern. However, recurrent preoperative locking episodes have a negative impact on clinical outcomes and meniscal healing. Besides, the more central location of BHMTs, late repairs, and smoking habits negatively affect the BHMT healing.

Management of BHMTs can be challenging for surgeons because of their relatively larger size, displacement, and the complexity of these tears [3,19]. Treatment options are meniscectomy and meniscus repair for BHMTs. Some studies reported 35.7% of the meniscectomy rate due to the irreducibility and degenerative nature of BHMTs [7]. Although lower healing rates of BHMT repair have been reported compared to the naturally more stable non-displaced meniscus tear patterns [4,20,21], meniscal preservation is increasingly favored to preserve joint kinematics and to prevent subsequent arthrosis especially in the active and athletic population [5,7]. Besides, in some studies, good clinical results and low failure rates have been reported even in chronic BHMT repairs suggesting the surgeons should consider repair instead of meniscectomy [3,4,11,14]. In this current study, a high rate of patient satisfaction was achieved especially in patients with single locking history and good clinical outcome after unstable meniscal tear repair. In accordance with the current literature, the outcome of this study supports preserving and repairing the meniscus in BHMTs regardless of the tear shape and the number of locking episodes.

A displaced BHMT can often be diagnosed with axial, coronal and sagittal MRI. However, spontaneous reductions can be encountered, mostly in the lateral meniscus, and MRI may not give definitive results in displaced BHMTs [10]. For that reason, the patients with no evidence of displaced BHMT with MRI were asked if they had a history of painful intermittent locking symptoms to detect the number of locking episodes. Different results have been reported in studies evaluating the outcomes of meniscal repairs between stable vertical longitudinal and unstable vertical longitudinal tears (BHMT) [3,4,14,20,21]. Since the patient group in this study consisted of only patients with unstable meniscal tears, a comparative analysis could not be made with stable tears. High meniscal union rates (70 patients, 83%) could be achieved with the repair of unstable meniscal tears. However, recurrent preoperative locking episodes found to have a negative impact on clinical outcomes and meniscal healing. So, it is suggested to repair BHMTs with first time locking especially in the early period because of their better healing potential.

Table 3. Comparison of pain and functional assessment scores of the groups with regard to locking feature

Evaluation method	Total	Single locking (n=55)	Repetitive locking (n=29)	p value
Time to failure (months)	13.7 ± 6.1	12.4 ± 6.9	14.4 ± 5.9	0.347
Failed repairs (n/%)	14 (16.7)	5 (9.1)	9 (31.0)	0.015
Follow-up time (months)	66.1 ± 16.2	64.1 ± 16.1	70.0 ± 16.0	0.086
Patient satisfaction (n%)				
Very satisfied	52 (61.9)	43 (78.2)	9 (31.0)	0.000
Satisfied	12 (14.3)	5 (9.1)	7 (24.1)	
Partially satisfied	10 (11.9)	4 (7.3)	6 (20.7)	
Dissatisfied	10 (11.9)	3 (5.5)	7 (24.1)	
VAS score (mean+sd)				
Preop	5.9 + 1.4	6.3 + 1.4	5.2 + 1.1	0.002
Postop	2.8 + 1.8	2.9 + 1.7	2.8 + 1.9	0.467
Pre-post difference	-3.0 + 1.9	-3.4 + 1.9	-2.4 + 1.7	0.036
Pre-post difference p	0.000	0.000	0.000	
Tegner score (mean+sd)				
Preop	3.4 + 1.5	3.6 + 1.5	3.1 + 1.4	0.259
Postop	7.8 + 2.0	8.1 + 1.5	7.1 + 2.7	0.172
Pre-post difference	4.3 + 2.4	4.5 + 2.1	3.9 + 2.9	0.618
Pre-post difference p	0.000	0.000	0.000	
Lysholm score (mean+sd)				
Preop	43.9 + 10.9	42.5 + 10.9	46.6 + 10.5	0.099
Postop	83.1 +13.7	86.7 + 10.9	76.3 + 16.0	0.000
Pre-post difference	39.2 + 16.3	44.2 + 13.6	29.6 + 16.8	0.000
Pre-post difference p	0.000	0.000	0.000	
IKDC score - median (range)				
Preop	4(2–4)	4(2–4)	4(2–4)	0.432
Postop	1(1–4)	1(1–4)	1(1–4)	0.001
Pre-post difference	-2 ((-3) – 1)	-2 ((-3) – 0)	-1 ((-3) – 1)	0.001
Pre-post difference p	0.000	0.000	0.000	

VAS: Visual Analog Scale, IKDC: International Knee Documentation Committee. Bolded P value indicates a statistically significant difference between groups (P <0.05)

Table 4. Comparison of pain and functional assessment scores of the groups with regard to Bucket Handle Tear Pattern.

Evaluation method	Simple centrally displaced upward (n=42)	Simple centrally displaced downward (n=23)	Flipped (n=19)	p value
Time to failure (months)	14.0 ± 6.1	12.0 ± 0.0	13.6 ± 7.3	0.903
Failed repairs (n/%)	7 (16.7)	1 (4.3)	6 (31.6)	0.062
Follow-up time (months)	64.5 ± 14.5	69.4 ± 16.3	65.5 ± 19.6	0.419
Patient satisfaction (n%)				
Very satisfied	28 (66.7)	14 (60.9)	10 (52.6)	0.315
Satisfied	3 (7.1)	6 (26.1)	3 (15.8)	
Partially satisfied	6 (14.3)	2 (8.7)	2 (10.5)	
Dissatisfied	5 (11.9)	1 (4.3)	4 (21.1)	
VAS score (mean+sd)				
Preop	6.0 + 1.6	5.7 + 1.4	6.0 + 0.9	0.720
Postop	2.8 + 2.0	2.2 + 1.0	3.8 + 1.7	0.007
Pre-post difference	-3.2 + 2.1	-3.5 + 1.5	-2.2 + 1.7	0.061
Pre-post difference p	0.000	0.000	0.000	
Tegner score (mean+sd)				
Preop	3.5 + 1.6	3.0 + 1.4	3.6 + 1.2	0.266
Postop	7.7 + 2.2	8.3 + 1.4	7.1 + 2.3	0.258
Pre-post difference	4.1 + 2.3	5.3 + 1.6	3.4 + 3.1	0.072
Pre-post difference p	0.000	0.000	0.000	
Lysholm score (mean+sd)				
Preop	41.6 + 10.4	46.7 + 12.2	45.6 + 9.7	0.280
Postop	83.3 +12.6	85.8 + 11.0	79.6 + 19.1	0.865
Pre-post difference	41.6 + 16.4	39.0 + 13.9	34.0 + 19.2	0.428
Pre-post difference p	0.000	0.000	0.000	
IKDC score - median (range)				
Preop	4(2–4)	4(2–4)	4(2–4)	0.309
Postop	2(1–4)	1(1–4)	1(1–4)	0.250
Pre-post difference	-2 ((-3) – 1)	-2 ((-3) – 0)	-2 ((-3) – 1)	0.593
Pre-post difference p	0.000	0.000	0.001	

VAS: Visual Analog Scale, IKDC: International Knee Documentation Committee. Bolded P value indicates a statistically significant difference between groups (P <0.05)

There are few descriptive studies in the literature regarding meniscal tear patterns [6,7,22]. Lim et al. classified three patterns as SCDU (type 1 - 29 patients, 69%), SCDD (type 2-7 patients, 16.7%), flipped tears (type 3- 4 patients, 9.5%) and they could not classify 2 patients (4.8%) [7]. In the classified groups, medial meniscus injury was predominant (31 patients, 73%) and there were 23 patients (54.8%) associated with ACL lesion. That study compared the intra-articular patterns of BHMTs and its relation to reducibility and found no association of intra-articular patterns with a combined ACL injury, mediolateral difference, chronicity, or reparability. However, it was declared that flapped-like tears were associated with more difficult tear reducibility and suggest an accurate assessment of rotational components of BHMTs to reduce the displaced fragment in BHMTs properly. Similarly, in this current study the most common intra-articular pattern was found as type 1 (50%), the occurrence of type 2 was 27.6%, and type 3 was 22.4%. Medial meniscus injury was predominant (68 patients, 81%) and concomitant ACL injury was higher (63 patients, 75%). Also, no association of age, sex, BMI, tear side, meniscus laterality, combined ACL injury was found with the BHMT pattern. However, chronic tears (>8 weeks) and larger tears (>25 mm) were more likely to be flapped-like tears. In this study, clinical evaluation of the results according to the tear pattern of BHMT repairs showed that improvement in clinical and functional scores, patient satisfaction, failure rate, and time to failure were not affected by the BHMT pattern.

To date, current studies examining the risk factors after BHMT repairs for surgical failure have focused mainly on demographic variables and operative features [2,5,9,11,14]. In these studies, many factors, such as young age [5], a procedure of ACL revision [5], smoking habit [14], and female gender [2], were found to increase the failure following BHMT repair. In contrast, concomitant ACL re¬construction at the time of meniscal repair [11] positively influenced the healing. In a recent review evaluating the effect of patient sex, devices used, repair technique, medial versus lateral meniscal repair, and the status of concurrent (ACL) reconstruction, it was found that the patient's sex only was found to affect the failure rate, as women (31%) were less likely to experience failure than were men (69%) [9]. The results of the present study showed that a more central location of BHMTs, late repairs, and smoking habits had a negative effect on the BHMT healing. However, no association was observed on variables such as age, sex, BMI, meniscus laterality, tear size or region, repair technique, suture number or configuration, additional pathologies (concomitant Car, cartilage degeneration) and sports participation.

Table 5. Patient demographics, tear patterns, and operative features according to the failure status. º

		Failure (+) (n=14)	Failure (-) (n=70)	p value
Age (year)		27.5 ± 8.9 25 (18-48)	30.1 ± 7.1 29 (18-49)	0.133
BMI (kg/m²)		24.1 ± 2.5 23.3 (19.8-28.4)	24.8 ± 2.3 24.6 (19.8-30.2)	0.293
Sex (n/%)	**Female**	1 (7.1)	5 (7.1)	1.000
	Male	13 (92.9)	65 (92.9)	
Affected Knee side (n/%)	**Right**	7 (50.0)	41 (58.6)	0.554
	Left	7 (50.0)	29 (41.4)	
Torn meniscus (n/%)	**Medial**	13 (92.9)	55 (78.6)	0.287
	Lateral	1 (7.1)	15 (21.4)	
Time of repair (n/%)	**≤8 weeks**	5 (35.7)	46 (65.7)	0.036
	>8 weeks	9 (64.3)	24 (34.3)	
Zone of tears (n/%)	**Red-Red**	5 (35.7)	49 (70.0)	0.015
	Red-White	9 (64.3)	21 (30.0)	
Length of tears (n/%)	**<25 mm**	6 (42.9)	32 (45.7)	0.845
	>25 mm	8 (57.1	38 (54.3)	
Smoking habits (n/%)	**Nonsmokers**	6 (42.9)	52 (74.3)	0.028
	Smokers	8 (57.1)	18 (25.7)	
Repair technique (n/%)	**Hybrid**	9 (64.3)	41 (58.6)	0.691
	All-inside	5 (35.7)	29 (41.4)	
Suture configuration (n/%)	**Oblique mattress**	5 (35.7)	25 (35.7)	1.000
	Vertical mattress	9 (64.3)	45 (64.3)	
Grade I cartilage degeneration (n/%)	**No**	10 (71.4)	48 (68.6)	0.833
	Yes	4 (28.6)	22 (31.4)	
Anterior cruciate ligament tear(n/%)	**No**	2 (14.3)	19 (27.1)	0.501
	Yes	12 (85.7)	51 (72.9)	
Anesthesia type (n/%)	**Regional**	8 (57.1)	38 (54.3)	0.845
	General	6 (42.9)	32 (45.7)	
Tear region (n/%)	**Total**	2 (14.3)	12 (17.1)	0.612
	Posterior 2/3	4 (28.6)	28 (40.0)	
	Posterior 1/3	8 (57.1)	30 (42.9)	
Bucket Handle Tear Pattern Sports participation	**SSDU**	7 (50.0)	35 (50.0)	0.062
	SSDD	1 (7.1)	22 (31.4)	
	Flipped	6 (42.9)	13 (18.6)	
Locking feature	**Single**	5 (35.7)	50 (71.4)	0.015
	Repetitive	9 (64.3)	20 (28.6)	
Number of sutures used		4.1 ± 1.0 4 (3-6)	4.0 ± 1.0 5 (2-7)	0.753
Operative time (minutes)		73.2 ± 11.1 75 (55-90	72.0 ± 7.6 75 (55-90)	0.710

º Data are reported as mean ± SD /median (min-max) or n (%). BMI, Body mass index, SSDU: Simple centrally displaced upward, SSDD: Simple centrally displaced downward. Bolded P value indicates a statistically significant difference between groups (P <0.05)

The evaluation methods for meniscal healing are usually considered to be clinical findings, MRI, magnetic resonance arthrography, computed tomography arthrography, and second-look arthroscopy [23,24], however, there has been no consensus yet in the evaluation of the results of meniscus healing and repair [8,23,24]. Although secondary-look arthroscopy is considered as the gold standard method to assess meniscal healing, a physical examination is still an accepted assessment tool because routine second-look arthroscopy or MRI investigation of every patient is not feasible in routine clinical practice. Clear evidence of clinical failure and MRI investigation was considered to define the healing and failure in this study. The overall failure rate in this study was 16.7% (14 patients), in line with the reported rates of 10.4-17% in the literature [2,12,25].

Studies evaluating BHMT patterns are limited in the literature. To our knowledge, this is the first direct comparative clinical study evaluating the repair of BHMTs in terms of preoperative locking episodes and the tear patterns.

This study has several limitations. First, it was retrospective, which limits our ability to control for selection bias, although we used the prospectively collected data of patients without loss of follow-up. Second, at least a two-year follow-up may be sufficient to evaluate the failure rate; nevertheless, long-term clinical and functional outcomes may differ, and more accurate results may be obtained with longer follow-up. Third, the absence of a second-look arthroscopic evaluation of all patients because of its more interventional and low applicability feature. The proportion of patients with asymptomatic failed repairs is unknown – asymptomatic failures might have been excluded. Thus, definitive meniscal healing was challenging to address accurately. Fourth, since this was a clinical study, only the intraoperative pattern of BHMTs were evaluated; anatomical parameters can also affect recurrent locking. Prospective long-term follow-up studies with a larger sample size are needed to evaluate the effect of preoperative locking episodes and tear pattern on arthroscopic BHMT repair results. Also, further anatomic studies evaluating soft-tissue characteristics associated with recurrent locking episodes of BHMTs are needed to identify patients who are at higher risk of recurrent locking.

Conclusion

Recurrent preoperative locking episodes have a negative impact on clinical outcomes and meniscal healing. However, clinical outcomes and failure rate following arthroscopic BHMT repair do not differ in terms of tear pattern. We suggest arthroscopic repair of BHMTs for first time locking and peripheral tears in the early period regardless of tear pattern because of their better healing potential.

Conflict of interests
The authors declare that they have no competing interests.

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Ethical approval
The study was approved by our institutional review board (No. 2020/315).

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