Archives of Orthopaedic and Trauma Surgery (2025) 145:150
https://doi.org/10.1007/s00402-025-05772-5

RESEARCH

Comparison of clinical outcomes among patients treated with high tibial osteotomy and meniscal repair of degenerative medial meniscal tear with mild varus deformity

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Received: 22 January 2024 / Accepted: 19 January 2025

Abstract

Introduction The clinical benefits of high tibial osteotomy (HTO) in patients with mild varus deformity with degenerative medial meniscal tear (DMMT) remain unclear. This study aimed to compare clinical outcomes among middle-aged patients with mild varus deformity who underwent arthroscopic meniscal repair and HTO for DMMT.

Materials and methods In this retrospective study, patients who underwent isolated arthroscopic meniscal repair via the inside-out technique and those who underwent medial opening-wedge HTO were assigned to group M and H, respectively. The inclusion criteria were: an age of 40–65 years; percentage of mechanical axis of 30–50% measured using full-length weight-bearing anteroposterior radiographs; Kellgren–Lawrence grade ≤ 2; minimum postoperative two-year follow-up; and HTO correction angle < 10°. Clinical outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS) and minimal clinically important difference achievement rate for the KOOS subscales preoperatively and at the final follow-up.

Results Group M and H included 21 and 41 patients, respectively. The median ages were 53 and 58 years in groups M and H, respectively. In group H, 24 cases underwent meniscal repair. No significant differences in all KOOS subscales were found preoperatively. However, the median KOOS symptoms subscale in group H (89.3) was significantly better than that in group M (80.4) at the final follow-up ($p = 0.04$).

Conclusion The main finding of the study indicated that KOOS symptoms after HTO were superior to those after isolated arthroscopic meniscal repair for DMMT. HTO might be a potentially useful treatment for DMMT in middle-aged patients with mild varus deformity, even with a small correction angle.

Level of evidence Retrospective comparative study, Level III.

Keywords High tibial osteotomy · Meniscal repair · Varus deformity · Clinical outcome

Abbreviations

DMMT	Degenerative medial meniscal tear
%MA	% of the mechanical axis
HTO	High tibial osteotomy
K-L	Kellgren–Lawrence
MOWHTO	Medial opening-wedge high tibial osteotomy
BMI	Body mass index
FTA	Femoral tibial angle
MPTA	Medial proximal tibial angle
JLCA	Joint-line convergence angle
AP	Anteroposterior
ICCs	Intra- and inter-observer correlation coefficients
ICRS	International Cartilage Repair Society
KOOS	Knee Injury and Osteoarthritis Outcome Score
MCID	Minimal clinically important difference
ADL	Activities of daily living
QOL	Quality of life
PROMs	Patient-reported outcome measures

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Published online: 01 February 2025

Introduction

Degenerative medial meniscal tear (DMMT), often involving horizontal and complex tears in many cases [1], gradually develops in middle-aged or older individuals without acute trauma. The treatment of DMMT remains controversial, encompassing nonoperative, arthroscopic approaches, or other surgical procedures. However, due to the crucial importance of preserving the meniscal hoop structure, an increasing number of arthroscopic meniscal repairs have been reported [2, 3].

The cellularity of a torn meniscus is significantly influenced by patient age [4], resulting from a decrease in vascular density with increasing age [5]. Studies, including patients aged > 40 years, have reported a lower meniscal healing rate after arthroscopic repair evaluated through second-look arthroscopy [6]. In addition to patient age, the presence of varus deformity (% of the mechanical axis [%MA] < 30) negatively affects the healing rate following arthroscopic repair of DMMT [7].

Regarding varus deformity, high tibial osteotomy (HTO), correcting lower limb alignment, is an option that could reduce the load on the medial tibiofemoral compartment, decrease medial meniscus extrusion, and improve clinical outcomes [8]. Following HTO, even without arthroscopic meniscal repair, a 50% complete healing rate of medial meniscal posterior root tears has been demonstrated on second-look arthroscopy [9]. In addition, satisfactory clinical outcomes after arthroscopic meniscal repair and HTO for medial meniscal posterior root tears have been reported. However, these findings are not specific to cases of DMMT [10]. Thus, the clinical benefits of HTO in patients with mild varus deformity (%MA ≥ 30) for DMMT are controversial. In fact, surgeons often contemplate whether to perform isolated arthroscopic meniscal repair or HTO for DMMT.

This study aimed to compare clinical outcomes among middle-aged patients with mild varus deformity undergoing isolated arthroscopic meniscal repair and HTO for DMMT. It was hypothesised that HTO could more effectively improve clinical outcomes compared with isolated arthroscopic meniscal repair of DMMT in middle-aged patients with mild varus deformity.

Materials and methods

Patients

This retrospective comparative study was approved by our Institutional Review Board (reference number: 302 − 178). Patients who underwent treatment for DMMT at our hospital between 2016 and 2021 were enrolled in this study. No patients underwent meniscectomy. To preserve the meniscal hoop structures, our indication for meniscal tears, even if DMMT, is to avoid meniscectomy whenever possible. The trimming of the degenerative and unstable edge was performed in some cases.

We consecutively analysed the data of meniscal repair ($n = 89$) and HTO ($n = 193$) cases.

The inclusion criteria were: an age of 40–65 years; Kellgren–Lawrence (K–L) grade ≤ 2; %MA of 30–50%; minimum postoperative two-year follow-up; and HTO correction angle < 10°.

In contrast, the exclusion criteria were: history of surgery on the ipsilateral knee; closed-wedge HTO; medial opening-wedge distal tuberosity osteotomy; and pull-out technique for root tear.

DMMT was defined as a lesion occurring without significant acute trauma in patients aged > 35 years [11]. The clinical outcomes, failure rates, and healing rates of meniscal repair were compared based on a cut-off age of 40 years [6]. Therefore, patients aged > 40 years were included in this study.

The final decision for undergoing either meniscal repair or HTO was made by patients after a discussion with the surgeon on both procedures, surgical technique, advantages and disadvantages, rehabilitation program, postoperative recovery, and possible complications. The patients who underwent isolated arthroscopic meniscal repair using the inside-out technique were assigned to group M, and those who underwent medial opening-wedge HTO (MOWHTO) were assigned to group H.

Surgical procedure

In group M, the Henning system of inside-out meniscal repair (Stryker Japan, Tokyo, Japan) was used throughout the entire process. In group H, we routinely performed the arthroscopy before HTO. Concurrent procedures were also performed if needed, such as arthroscopic meniscal repair via the all-inside or inside-out technique. The patients in group H underwent MOWHTO with biplanar osteotomy, the target %MA of the HTO was the Fujisawa point [12]. HTO plate fixation was performed using either the TomoFix Medial High Tibial Plate (DePuy Synthes, West Chester, PA, USA) or Tris Medial HTO Plate System (Olympus Terumo Biomaterials Corp., Tokyo, Japan). An artificial bone graft was implanted in the gap at the osteotomy site. The surgical procedures were performed by four senior surgeons.

Postoperative rehabilitation

In group M, a knee brace was used to immobilise the knee in extension for four weeks postoperatively. Partial

weight-bearing was allowed at 1–2 weeks, followed by full weight-bearing at 2–3 weeks postoperatively. Non-weight-bearing range of motion exercises without a brace were permitted up to 90° at one week postoperatively. In group H, a knee brace was used for four weeks. The patients were permitted to perform half weight-bearing at one week and full weight bearing at two weeks postoperatively. Non-weight-bearing range of motion exercises without a brace were started on the first postoperative day.

Clinical evaluations

Age, sex, body mass index (BMI), and follow-up period were assessed as demographic data. The patients were evaluated based on radiographic and clinical outcomes preoperatively and at the final follow-up. Osteoarthritis stage was determined via X-ray radiography using the K-L grade. The femoral tibial angle (FTA), medial proximal tibial angle (MPTA) and joint-line convergence angle (JLCA) were measured using weight-bearing anteroposterior (AP) radiographs. In addition, the %MA and mechanical lateral distal femoral angle were measured using full-length weight-bearing AP radiographs. The tibial posterior slope was measured using lateral-view radiographs. Radiographic parameters were measured using the Picture Archiving Communication System at our institute. All measurements were recorded preoperatively and at the final follow-up by two orthopaedic surgeons. The accuracy of the radiographic measurements was evaluated using intra- and inter-observer correlation coefficients (ICCs): for preoperative and final follow-up measurements, all ICCs were > 0.8. Next, the HTO correction angle was also determined. The meniscal tear pattern, suture technique, number of sutures, and severity of cartilage lesions (International Cartilage Repair Society [ICRS] grade) were evaluated using arthroscopic images. The operative time, HTO correction angle, suture technique, and number of sutures were evaluated as operative findings.

Clinical outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS) [13] and minimal clinically important difference (MCID) achievement rate for the KOOS subscales preoperatively and at the final follow-up. The MCID was defined as the smallest difference in an outcome score measured before and after an intervention perceived as beneficial by patients [14]. The MCID after arthroscopic meniscal repair was established for each KOOS subscale as follows: symptoms, 12.3; pain, 11.8; activities of daily living (ADL), 11.4; sports, 16.7; and quality of life (QOL), 16.9 [15]. The MCID after opening-wedge HTO without meniscal repair was established for each KOOS subscale as follows: symptoms, 15.1; pain, 15.4; ADL, 17; sports, 11.2; and QOL, 16.5 [16]. The differences in all KOOS subscales in group M from preoperative to the final follow-up were compared with the MCID for meniscal repair [15]. The differences in all KOOS subscales in group H from preoperative to final follow-up were compared with the MCID for HTO [16].

Statistical analysis

All statistical analyses were performed using EZR (version 1.61; Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (version 4.2.2; The R Foundation for Statistical Computing, Vienna, Austria). More precisely, it is a modified version of the R commander designed to add statistical functions frequently used in biostatistics [17]. The Mann–Whitney U test and Fisher's exact test were used to compare continuous and categorical variables between the two groups, respectively. The Wilcoxon signed-rank test was used to compare preoperative and final follow-up data in the same group. Statistical significance was set at $p < 0.05$. Statistical power was calculated using G*Power (version 3.1.9.6). Based on an effect size of 0.8; a sample size of 21 in group M and 41 in group H; and alpha error probability of 0.05 for two groups, a calculated power of 0.82 would be required.

Results

In total, 21 and 41 patients were enrolled in groups M and H, respectively (Fig. 1). Group M consisted of 14 males and 7 females, and group H consisted of 21 males and 20 females. The median BMI was higher in group H than in group M (Table 1). None of the patients experienced surgery-related complications.

No significant differences in preoperative radiographic parameters were found between the two groups. At the final follow-up, significant differences were found in the FTA, %MA, MPTA, and JLCA (Table 2).

The median HTO-correction angle was 7.0°. Significant differences in the meniscal tear pattern and number of sutures were found between the two groups. In group H, 14 and 10 cases underwent repair using the inside-out and all-inside techniques, respectively. The ICRS grade of the medial femoral condyle was more severe in group H ($p < 0.01$) compared with group M (Table 3).

No significant differences in any of the preoperative KOOS subscales were observed between the two groups (Table 4). The KOOS symptoms in group H were significantly better than those in group M at the final follow-up ($p = 0.04$) (Table 4). No significant difference in the MCID achievement rate was found between the two groups (Table 5).

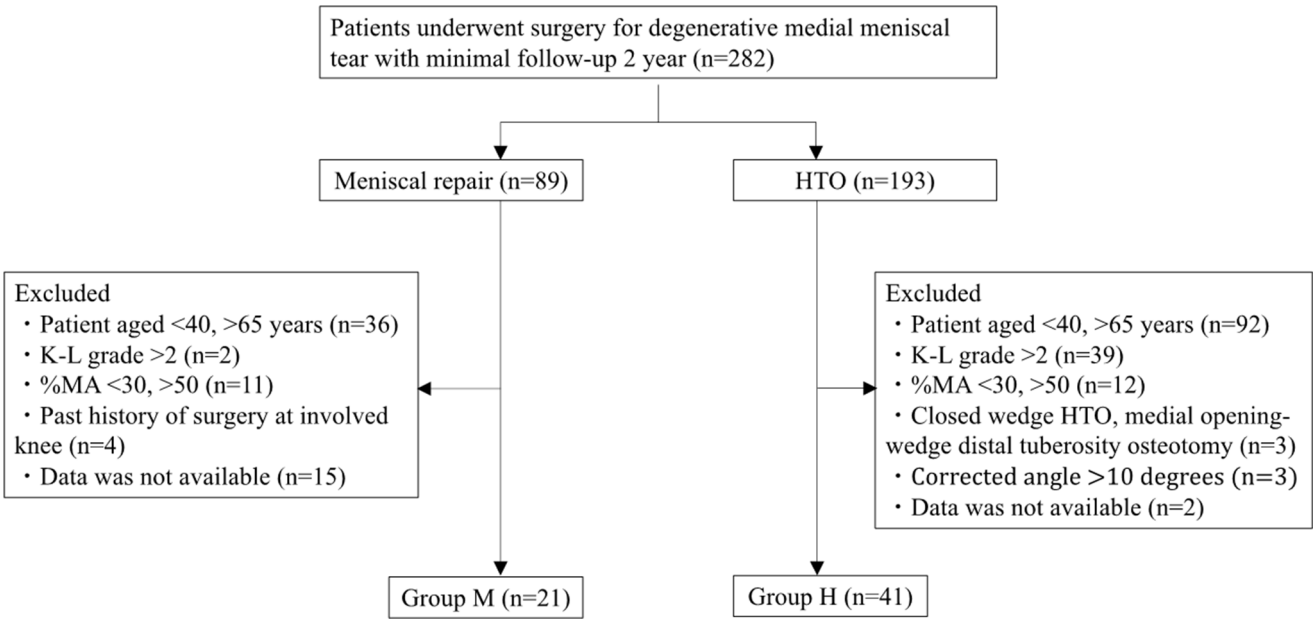

Fig. 1 Flowchart of patients' inclusion in the study. Abbreviations: K-L, Kellgren-Lawrence; HTO, high tibial osteotomy; %MA, % of the mechanical axis

Table 1 Patient characteristics in both groups

	Group M (n=21)	Group H (n=41)	p-value
Age (years)			
Median	53 (47-59)	58 (50-61)	0.100
Sex (male)			
no (%)	14 (66.7)	21 (51.2)	0.288
BMI (kg/m^2)			
Median	24.0 (20.8-25.0)	27.3 (24.8-29.0)	<0.001*
Final follow-up (year)			
Median	2.0 (2.0-3.8)	3.0 (2.0-4.0)	0.565

*p<0.05

The variables are presented as median (inter-quartile range, q25–q75).

Abbreviations: BMI, body mass index

Discussion

The most important finding of this study was that the KOOS symptoms after HTO were superior to those after isolated arthroscopic meniscal repair of DMMT in middle-aged patients with mild varus deformity. Moreover, all KOOS subscales after HTO were better than those after isolated arthroscopic meniscal repair at the final follow-up, although no statistical significance was found except for the KOOS symptoms.

The low biological healing potential, influenced by ageing [4, 5] and the presence of varus deformity (%MA < 30%) [7], could impact the unfavourable clinical outcomes of DMMT in middle-aged patients. Patient age has been reported to significantly affect the cellularity of a torn meniscus [4]. Moreover, overall vascular density could decrease with increasing age, contributing to lower meniscal healing potential [5].

Surgical procedures affect the clinical outcomes of meniscal tears. According to the 2016 European Society for Sports Traumatology, Knee Surgery and Arthroscopy meniscus consensus, arthroscopic partial meniscectomy should only be considered after proper, standardised clinical, and radiological evaluations and when the response to nonoperative management has not been satisfactory for degenerative meniscal lesion [11]. Meniscectomy was found to

Table 2 Radiographic parameters

	Group M (n=21) Median	Group H (n=41) Median	p-value
K-L grade			
no (0/1/2/3/4)			
preoperative	1/6/14/0/0	0/6/35/0/0	0.120
final follow-up	0/6/15/0/0	0/10/27/4/0	0.485
FTA (°)			
preoperative	177.0 (176.0-178.2)	178.1 (176.5-179.0)	0.298
final follow-up	177.4 (176.2-178.2)	172.0 (170.1-174.0)	<0.001*
%MA (%)			
preoperative	39.4 (35.0-43.4)	37.3 (32.0-40.0)	0.117
final follow-up	40.3 (37.5-47.0)	62.8 (55.1-66.35)	<0.001*
MPTA (°)			
preoperative	85.1 (83.5-85.9)	85.0 (84.4-86.5)	0.129
final follow-up	85.1 (83.5-85.6)	90.5 (89.9-91.9)	<0.001*
mLDFA (°)			
preoperative	87.1 (86.0-88.9)	88 (87.0-90.0)	0.251
JLCA (°)			
preoperative	1.6 (1.1-1.9)	2.0 (0.7-3.0)	0.406
final follow-up	1.5 (1.3-1.7)	0.8 (0.1-2.0)	0.037*
TPS (°)			
preoperative	7.5 (6.0-10.0)	8.1 (6.6-10.0)	0.428
final follow-up	7.5 (6.1-10.3)	8.0 (6.6-10.1)	0.392

*p<0.05

The variables are presented as median (inter-quartile range, q25–q75).

Abbreviations: K-L, Kellgren–Lawrence,; FTA, femoral tibial angle,; %MA, % of the mechanical axis,; MPTA, medial proximal tibial angle,; JLCA, joint line convergence angle,; mLDFA, mechanical lateral distal femoral angle,; TPS, tibial posterior slope

worsen the International Knee Documentation Committee score at late follow-up (>18 months), although it improved at early follow-up (≤18 months) [18]. Accordingly, selecting the appropriate approach for treating DMMT remains controversial.

Lower limb alignment is a crucial factor involving postoperative clinical outcomes. Varus alignment and a small MPTA are related to medial meniscus tears and extrusion as osteoarthritis progression [19, 20]. Moreover, the tibiofemoral contact pressures were significantly higher with greater varus alignment than with valgus alignment, according to a previous biomechanical study [21]. In addition, the medial meniscus extrusion and peak contact pressure of the medial compartment significantly elevated during varus alignment [22]. Therefore, the correction of lower limb alignment using HTO in patients with varus deformity was considered. Astur et al. reported that HTO decreased medial meniscus extrusion after six weeks postoperatively. A systematic review reported that HTO showed high survivorship rate, and good clinical outcomes according to MCID and PASS [23]. Furthermore, all KOOS subscales, visual analogue scores, and Tegner activity scores improved after a minimum two years of follow-up [8]. Similar to a previous study, all KOOS subscales after HTO were superior to those after isolated arthroscopic meniscal repair, although no statistical significance was observed except for the symptoms in this study.

Table 3 Operative findings

	Group M (n=21)	Group H (n=41)	p-value
operative time (min)			
Median	60.5 (49.8-84.5)	104.0 (89.5-133.0)	<0.001*
correction angle (°)			
Median		7 (6-8)	
tear pattern			
no (%)			
longitudinal	1 (4.8)	0 (0)	<0.001*
horizontal	6 (28.6)	3 (7.3)	
radial	3 (14.3)	14 (34.1)	
flap	0 (0)	0 (0)	
degenerative	2 (9.5)	19 (46.3)	
complex	9 (42.9)	5 (12.2)	
suture technique			
no (%)			
no	0 (0)	17 (41.5)	<0.001*
all-inside	0 (0)	10 (24.4)	
inside-out	21 (100)	14 (34.1)	
suture number			
Median	6 (6-8)	3 (2-7)	0.010*
ICRS grade			
% (0/1/2/3/4)			
MFC	52.9/23.5/5.9/11.8/5.9	13.2/7.9/28.9/34.2/15.8	0.003*
MTP	41.2/41.2/17.6/0/0	21.1/36.8/26.3/7.9/7.9	0.394
LFC	100/0/0/0/0	92.1/5.3/2.6/0/0	1
LTP	64.7/35.3/0/0/0	60.5/34.2/2.6/0/2.6	1
Trochlea	88.2/0/0/0/11.8	65.8/21.1/2.6/7.9/2.6	0.058
Patella	88.2/5.9/0/5.9/0	78.9/21.1/0/0/0	0.109

*p<0.05

The variables are presented as median (inter-quartile range, q25–q75).

Abbreviations: ICRS, International Cartilage Repair Society; MFC, medial femoral condyle; MTP, medial tibial plateau; LFC, lateral femoral condyle; LTP, lateral tibial plateau

The HTO, which corrects lower limb alignment, is an effective joint-preservation method for relatively young active patients [24]. The presence of preoperative complete joint space narrowing negatively impacted the HTO survival rate [25], and HTO had a good clinical outcome of KOOS even in patients with early osteoarthritis over two-year follow-up [26]. Moreover, Itou et al. reported that HTO with an even slight valgus correction from neutral alignment achieved clinical improvements that exceeded the MCID for patient-reported outcome measures (PROMs) [27]. El-Azab et al. also reported that HTO significantly improved postoperative symptoms and function, even in patients with under-correction of the osteotomy (postoperative %MA < 50) [28]. In our study, the median correction angle was 7.0° using the HTO, achieving satisfactory clinical outcomes. The KOOS pain, sports and QOL in group H were not significantly better than those in group M, but approached statistical significance, respectively ($p = 0.072$, 0.064, 0.079). HTO tended

Table 4 Preoperative and final follow-up KOOS values

		Group M (n=21) Median	Group H (n=41) Median	p-value
Symptoms	preoperative	62.5 (38.4-75.9)	64.3 (51.8-76.8)	0.495
	final follow-up	80.4 (67.9-88.4)	89.3 (80.7-96.3)	0.042*
	p-value	0.006*	<0.001*	
Pain	preoperative	50.0 (33.3-69.0)	55.6 (47.2-66.7)	0.391
	final follow-up	80.6 (70.8-88.9)	88.9 (83.3-96.4)	0.072
	p-value	0.003*	<0.001*	
ADL	preoperative	74.3 (54.8-89.0)	72.1 (64.7-80.9)	0.649
	final follow-up	89.7 (76.8-98.5)	93.6 (86.8-98.9)	0.400
	p-value	0.002*	<0.001*	
Sports	preoperative	40 (8.8-60.0)	40 (15.5-55.0)	0.874
	final follow-up	57.5 (31.3-75.0)	75.0 (56.3-80.0)	0.064
	p-value	0.004*	<0.001*	
QOL	preoperative	37.5 (12.5-56.3)	31.3 (15.9-42.2)	0.326
	final follow-up	46.9 (32.8-75.0)	75.0 (57.8-81.3)	0.079
	p-value	0.020*	<0.001*	

*p<0.05

The variables are presented as median (inter-quartile range, q25–q75).

Abbreviations: ADL, activities of daily living; QOL, quality of life; KOOS, Knee Injury and Osteoarthritis Outcome Score

Table 5 MCID achievement rates for the KOOS subscales at the final follow-up

	Group M (n=21) no (%)	Group H (n=41) no (%)	p-value
Symptoms	12 (57.1)	26 (63.4)	0.784
Pain	15 (71.4)	37 (90.2)	0.075
ADL	14 (66.7)	19 (46.3)	0.180
Sports	7 (33.3)	25 (61.0)	0.060
QOL	10 (47.6)	29 (70.7)	0.098

*p<0.05

Abbreviations: ADL, activities of daily living; QOL, quality of life; KOOS, Knee Injury and Osteoarthritis Outcome Score; MCID, minimal clinically important difference

to be superior to meniscus repair in terms of KOOS pain, sports and QOL. Considering the results of previous reports and those of the present study, HTO could be a potentially useful treatment for DMMT in middle-aged patients with mild varus deformity, even with a small correction angle.

While we have discussed the advantages of HTO, it has some disadvantages. HTO is more surgically invasive than meniscal repair. In addition, some complications of HTO exist, such as fracture, infection, deep vein thrombosis [29], non-union, and vascular injury [30]. In this study, none of the patients experienced surgery-related complications. However, adequate informed consent on the advantages and disadvantages of each surgical technique should be performed by patients and surgeons to decide surgical technique.

This study has some limitations. First, this is a retrospective study. Therefore, selection bias might have occurred, selecting HTO in patients with high BMI, smaller %MA, and worse chondral condition. However, there was a uniformity of age, preoperative lower limb alignment, and K–L grade in both groups. Second, the number of cases was not large with a short follow-up period, a minimum postoperative two-years. If the follow-up period had been longer, the KOOS and MCID achievement rates in group M might have worsened because of ageing, mild varus deformity, and osteoarthritic changes. Third, this study did not examine meniscal healing using second-look arthroscopy or magnetic resonance imaging. Only PROMs were evaluated.

Conclusion

The main finding of this study revealed that the KOOS symptoms after HTO were superior to those after isolated arthroscopic meniscal repair of DMMT with mild varus deformity in middle-aged patients. Moreover, all KOOS subscales after HTO were better than those after isolated arthroscopic meniscal repair at the final follow-up, although no statistical significance was found except for the KOOS symptoms. Our results revealed that HTO might be a potentially useful treatment, even with a small correction angle.

Acknowledgements We would like to thank Editage (www.editage.jp) for English language editing.

Author contributions All the authors were involved in the development of this study. KH: study design, data collection, statistical analysis, literature review, and manuscript writing; SO: study design, manuscript editing, and supervision; KH: data collection; YI: data collection; YO: data collection; TK: data collection; AT: supervision.

Funding This study did not receive any specific grants from funding agencies in the public, commercial, or non-profit sectors.

Data availability The data are not publicly available due to the privacy of patients.

Declarations

Ethical approval This retrospective chart-review study involving human participants was conducted in accordance with the ethical standards of the relevant institutional committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent All study participants provided informed consent, and the study design was approved by the appropriate Ethics Review Board.

Social Media Handles * Instagram: none.
* Twitter: none.
* Facebook: none.
* LinkedIn: none.

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

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