Comparative study between isolated medial meniscus root repair versus open-wedge high tibial osteotomy versus combined approach in patients with root tears, 2-year follow-up

Ahmed H.T. Waly

Department of Orthopaedic Surgery and Traumatologe, Arthroscopy and Sports Injury Unit, Alexandria University, Alexandria, Egypt

Correspondence to Ahmed H.T. Waly, MD, Zezenia, Alexandria, Postal Code 21532, Egypt. Tel: +20 122 218 6065; e-mail: drwaly28@gmail.com

Received: 13 November 2021
Revised: 30 November 2021
Accepted: 15 January 2022
Published: 31 May 2022

The Egyptian Orthopaedic Journal 2022, 57:42–51

Background
Medial meniscus root tears usually lead to loss of hoop tension of the meniscus and result in high-contact pressure in the medial compartment of the knee. Surgical management of those types of tears is mandatory to restore hope tension and to save medial compartment. This study was done to evaluate the necessity of medial root repair with high tibial osteotomy (HTO) for treatment of medial meniscus root tears.

Patients and methods
This is a prospective comparative study over 60 patients with medial meniscal root tears. The patients were classified randomly into three groups. The first group (group A) was treated with isolated medial meniscus posterior root tear repair (n=20). The second group (group B) was treated with isolated open-wedge high HTO (n=20). The third group (group C) was treated using combined medial meniscal root repair with high tibial open-wedge osteotomy (n=20). A clinical evaluation was made using range of motion (ROM) and pain assessment. Functional evaluation was done using Lysholm score and Hospital for Special Surgery score. Radiological evaluation was done using follow-up standing Lyon–Schuss films.

Results
Regarding the patients' reported outcome measures, one-way analysis of variance was calculated to compare means between the three groups. The results of isolated root repair were the worst and there was no statistically significant difference between groups B and C.

Conclusion
Results recommend isolated HTO as a solo fast-attack procedure with reliable durable clinical and radiological outcomes for the treatment of root tears of the posterior horn of the medial meniscus.

Keywords:
medial compartment failure, root tear, high tibial osteotomy, varus knees

Egypt Orthop J 57:42–51

1110-1148

Introduction

A medial meniscus posterior root tear (MMPRT) is an avulsion injury or radial tear that is usually located within 1 cm from the posterior root-attachment point of the medial meniscus [1].

MMPRTs commonly lead to loss of hoop tension of the medial meniscus and result in high-contact pressure in the medial compartment of the knee, similar to the result of a total meniscectomy. The loading stress increases during weight-bearing, accelerating the degeneration of medial tibiofemoral cartilage. Unrepaired MMPRTs are believed to be associated with progressive osteoarthritis (OA) and can lead to varus deformities and knee dysfunction [2–4].

To avoid OA progression and achieve meniscal healing, arthroscopic meniscal repair has been proposed, the clinical outcomes have been shown to be superior to those of partial meniscectomy. However, as meniscal repair itself does not affect varus deformities commonly associated with MMPRTs and OA progresses with age, the long-term effects of meniscal repair remain unpredictable [5–11].

Recently, high tibial osteotomy (HTO) has been performed to treat MMPRTs associated with varus deformities, and has demonstrated favorable results, with improved clinical outcome scores, in several observational studies. However, the reported healing rate of the meniscus in these studies remains unclear [12–18].

The aim of this prospective study was to identify the most favorable clinical protocol to treat MMPRTs and to investigate the real benefits of concurrent meniscal root repair during open-wedge HTOs (OWHTO).

Our null hypothesis was that there will be no difference in the mean of Lysholm score (primary outcome measure used) between the three groups. Our alternate hypothesis was that mean Lysholm score would be better in cases with combined approach (root repair plus HTO).

Patients and methods

This is a prospective comparative study over 60 patients with medial meniscal root tears. Patients were admitted to El Hadra University Hospital between January 2018 and August 2019. All cases were followed up for maximum 1 year postoperatively. MMPRTs were mainly diagnosed on the basis of MRI findings and were confirmed during arthroscopic examinations. They were classified according to Laprade classification [1].

The inclusion criteria were

(1) Patients with a symptomatic MMPRT planning to undergo surgical treatment after failed conservative treatment for at least 6 months.
(2) Patients with OA localized in the medial compartment of the knee and mild-to-moderate pain.
(3) Patients with a nearly normal range of motion (flexion contracture <10°).
(4) Active patients of all ages who had good compliance with the postoperative rehabilitation protocol.
(5) Varus deformity less than 10 degrees (Fig. 1).
(6) BMI less than 30.

Exclusion criteria

(1) Patients with a history of a knee injury.
(2) Patients with a lateral meniscus tear or discoid meniscus.
(3) Patients with knee instability.
(4) Patients with a varus knee deformity of greater than 5° or flexion contracture greater than 10°.
(5) Patients with severe patellofemoral arthritis.
(6) Patients with severe medial compartmental OA with excessive bony erosion or knee subluxation
(7) Super or morbid obese patients.

Patients were classified randomly into three groups. The first group (group A) was treated with isolated MMPRT repair (n=20). The second group (group B) was treated with isolated open-wedge HTO (n=20). The third group (group C) was treated using combined medial meniscal root repair with high tibial open-wedge osteotomy (n=20). All groups were matched for age, sex, and degree of varus and BMI (Fig. 2).

Figure 1

A case with bilateral varus knee with right-sided root tear.

Patients were assessed preoperatively using standing Schuss X-ray, weight-bearing long film from hip to ankle, and MRI films. A clinical evaluation was made using range of motion (ROM) and pain assessment. Functional evaluation was done using Lysholm score [19] and hospital for special surgery (HSS) score [20]. Radiological evaluation was done using follow-up standing Lyon–Schuss films [21].

Statistical evaluation was done using SPSS ver 25 (IBM, Chicago, Illinois, USA). One-way analysis of variance (ANOVA) test was used to compare between the three groups if data were parametric. χ^2-Test was used for qualitative data. The outcomes of continuous measurements were compared between the three groups. Statistical significance was accepted at P less than 0.05. Subgroup analyses of continuous variables were carried out with one-way ANOVA and least significant difference post-hoc test.

Figure 2

The three techniques used in the three groups.

This study was conducted in accordance with the Declaration of Helsinki and was approved by the university's Institutional Review Board. The study was approved by local ethical committee of Alexandria University Faculty of Medicine. An informed consent was taken from every patient submitted to the study.

Surgical technique

All patients were operated supine under general anesthesia with high-thigh tourniquet. A side support was used, and patients were positioned to allow free knee motion between 0 and 120°. First, knee arthroscopy was done to deal with any intra-articular pathologies and to assess medial compartment injury. Standard anterolateral and anteromedial portals were used. The cartilage damage to the medial condyles was graded according to the Outerbridge grading system [22]. Debridement, chondroplasty, or microfractures were performed first.

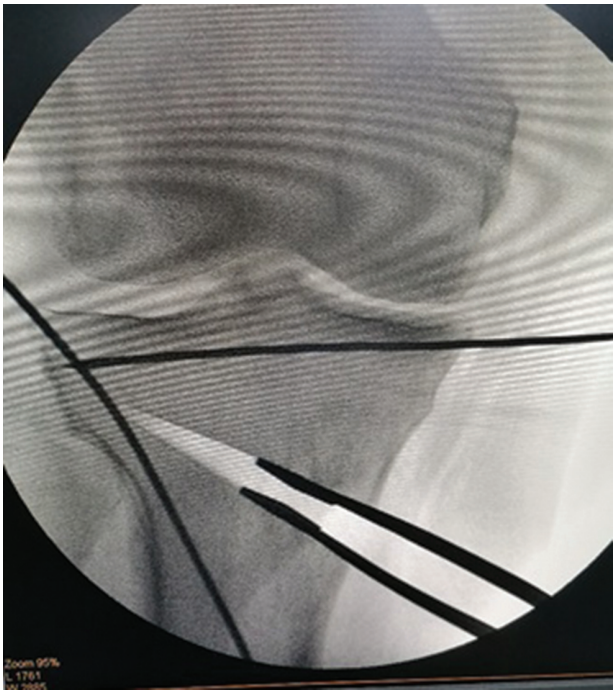
In group A (isolated medial root repair)

Medial meniscus root repair was done using pullout Fiberwire sutures (Arthrex, Naples, Florida, USA), at the posterior root. The sutures were applied to the meniscal tissue using the Knee Scorpion suture passer (Arthrex). The footprint was prepared using a curette. A Flipcutter (Arthrex) was used to create a tunnel at the footprint. Sutures were retrieved and fixed to the anteromedial tibial cortex over an ABS button (Arthrex). Sutures were tensioned at 30° of knee flexion.

In group B (isolated HTO)

A medial approach was used. A biplanar HTO was performed with guide pins under C-arm control to identify the targeted mechanical axis passing through the Fujisawa point [23]. The procedure was performed carefully so that the lateral hinge remained intact. Plate fixation was performed with angular stable plates (TomoFix Osteotomy System; DePuy Synthes, West Chester, Pennsylvania, USA). No bone grafts were implanted into the gap at the osteotomy site (Fig. 3)

Figure 3



A case with high tibial osteotomy for medial meniscus root tear.

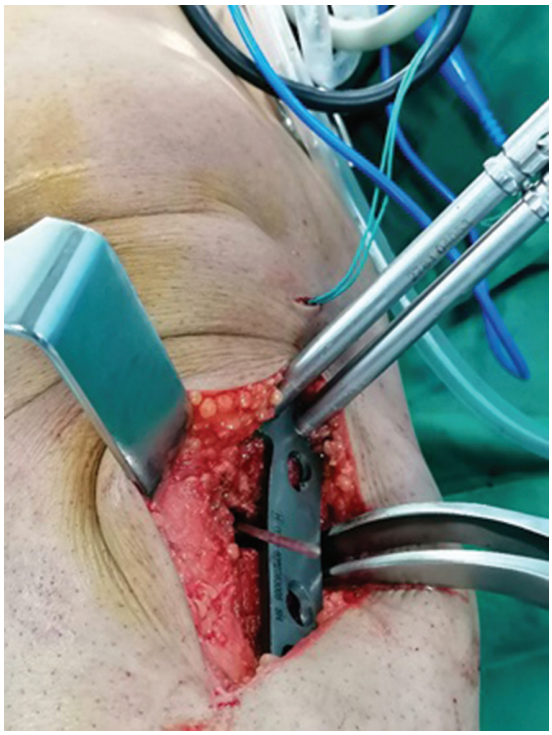
In group C (combined attack)

A medial approach was done first and then a medial release was followed. After that, medial meniscal root repair was done but not fixed to the button, until HTO was performed, and the plate was applied. Root sutures were then retrieved through the Flipcutter (Arthrex) tunnel created. The sutures were then fixed in 30° of knee flexion to the plate (TomoFix Osteotomy System; DePuy Synthes) (Figs. 4–7).

Postoperative rehabilitation

In all groups, weight-bearing was delayed for 6 weeks. Hinged knee brace was applied for 1.6 months. After that, weight-bearing was initiated as tolerated using

Figure 4



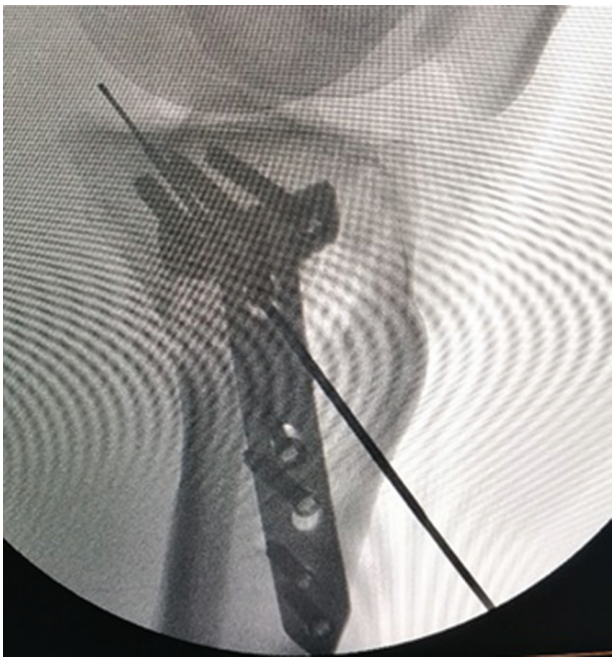
The Tomofix plate is mountained with a metal guide inside the root tunnel to avoid tunnel convergence with screws.

Figure 5

Fluoroscopic anteroposterior view showing the Tomofix plate proximal screws not converging with root tunnel.

crutches. Isometric and passive knee flexion exercises were started immediately after surgery. In patients with meniscal repairs, flexion was restricted to 90° in the first 6 weeks. Squatting was discouraged for 3 months.

Figure 6



Fluoroscopic lateral view showing the Tomofix plate proximal screws not converging with root tunnel.

Figure 7

Fixing root-pullout sutures to the Tomofix plate.

Clinical assessments

The patients were followed up at 6 weeks, and at 3, 6, 12, and 24 months postoperatively. The degrees of flexion contracture and knee flexion were measured preoperatively and at the final follow-up using a long-

arm goniometer. The Lysholm, visual analog scale, and HSS scores were used to assess knee function preoperatively and at the final follow-up.

Radiological evaluations

The hip–knee–ankle angle and weight-bearing line ratio were measured on full-length anteroposterior weight-bearing radiographs. The OA stage was evaluated on radiographs using the Kellgren–Lawrence (K–L) grading scale [24], which classified the patients into four groups (grades 1–4) by the severity of OA. All measurements were recorded preoperatively and at the final follow-up.

Results

The study included 60 patients who were admitted to El Hadra University Hospital with recurrent patellar dislocation. Group A was submitted to isolated medial meniscus root repair (n=20). Their mean age was 45.3 ±3.3. Group B was submitted to HTO alone. Their mean age was 43.6±4.2. Group C was treated with both HTO along with medial meniscus root repair. Their mean age was 45.5±4.3. The difference between the three groups was statistically insignificant denoting adequate matching of the groups. Patients' demographic data are included in Table 1.

Regarding ROM, there was no statistically significant difference between all groups (P>0.05). Regarding the patients' reported outcome measures, one-way ANOVA was calculated to compare means between the three groups. The results of isolated root repair were the worst and there was no statistically significant difference between groups B and C (Tables 2 and 3).

Regarding the Lysholm score at the end of follow-up, we computed a one-way ANOVA comparing the outcomes between the three groups. A significant difference was found among the groups with F-value of 68.7 with degree of freedom 2 and P-value 0.000. Tukey's HSD post-hoc comparison test was used to determine the source of the differences between the groups. This analysis revealed that group A (root repair alone) scored lower (79.7±2.9) than group B (HTO alone: 89.9±3.0) and group C (combined approach: 88.9±2.1) (P=0.000). However, the difference between groups B and C was not significant (P=0.635) (Fig. 8).

Table 1 Patients' demographic data

	Group A R (n=20)	Group B O (n=20)	Group C R+O (n=20)	Test of significance	P value
Age (years)	45.3±3.3	43.6±4.2	45.5±4.3	F=0.25	0.96
Sex					
Male	2	2	3	χ^2=0.516	0.472
Female	18	18	17		
Side affected					
Right	8	10	6	χ^2=0.045	0.832
Left	12	10	14		
BMI	30.4±2.3	31.4±2.0	30.5±2.3	F=0.93	0.32
Time before surgery (months)	4.7±1.8	4±2.7	4.5±1.7	F=1.34	0.07
HKA	4.1±1.5	5.5±1.2	5.6±0.9	F=1.25	0.92
MPTA	84.3±2.5	83.4±1.8	88.6±2.3	F=1.30	0.33
LDFA	89.0±1.5	89.6±3.1	94.3±2.1	F=0.80	0.30
Joint-space narrowing	3.5±0.6	3.8±0.7	4.1±0.9	F=0.25	0.96
Medial meniscus extrusion	3.7±0.9	4±0.6	3.8±0.8	F=0.26	0.90

F, one-way analysis of variance test; HKA, hip–knee varus angle; LDFA, mechanical lateral–distal femoral angle; MPTA, medial proximal–tibial angle; O, osteotomy; R, root repair; R+O, root and osteotomy. *P significant if <0.05.

Table 2 Patients' reported outcome measures

	Group A R (n=20)	Group B O (n=20)	Group C R+O (n=20)	df	Test of significance	P
Lysholm	79.7±2.9	89.9±3.0	88.9±2.1	2	F=68.7	0.000*
HSS	65.4±3.1	81±4.6	85±5.1	2	F=18.7	0.000*
VAS	6.8±0.9	2.4±0.2	2.5±0.6	2	F=199.2	0.000*
KL grading						
G1	0	0	3		χ^2=64.868	0.000*
G2	0	20	17			
G3	13	0	0			
G4	7	0	0			

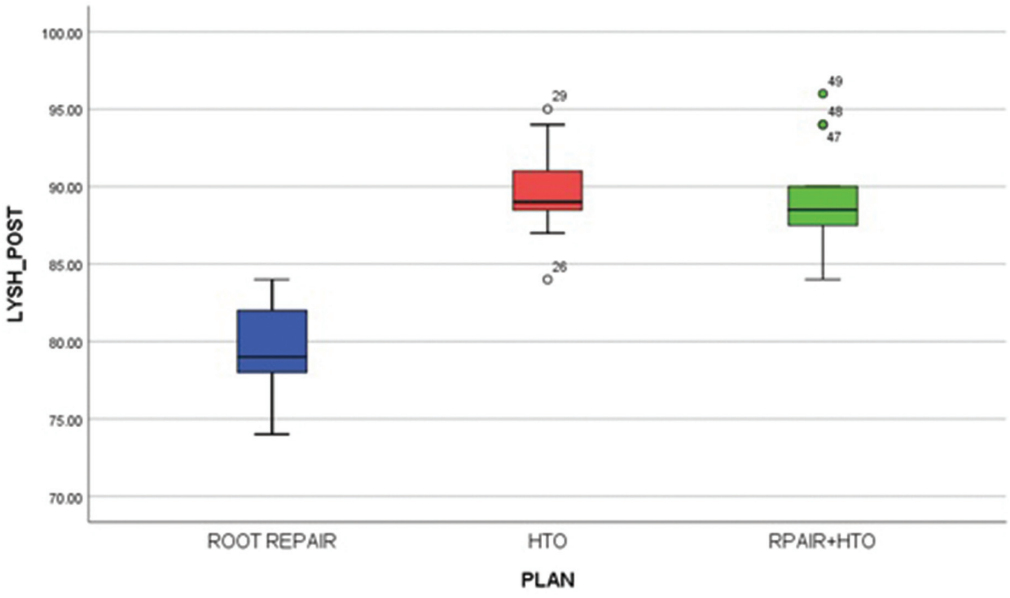
HSS, hospital for special surgery. F, one-way analysis of variance test. *P significant if <0.05.

Table 3 Turkey HSD post-hoc comparison between the three groups

Tukey HSD							
						95% confidence interval	
Dependent variable	Group	PLAN	Mean difference	SE	Significance	Lower bound	Upper bound
LYSH_POST	ROOT REPAIR	HTO	−9.80000-*	0.92575	0.000	−12.0277-	−7.5723-
		REPAIR+HTO	−8.95000-*	0.92575	0.000	−11.1777-	−6.7223-
	HTO	ROOT REPAIR	9.80000*	0.92575	0.000	7.5723	12.0277
		REPAIR+HTO	0.85000	0.92575	0.631	−1.3777-	3.0777
	REPAIR+HTO	ROOT REPAIR	8.95000*	0.92575	0.000	6.7223	11.1777
		HTO	−0.85000-	0.92575	0.631	−3.0777-	1.3777
HSS_POST	ROOT REPAIR	HTO	−15.05000-*	3.28499	0.000	−22.9551-	−7.1449-
		REPAIR+HTO	−19.05000-*	3.28499	0.000	−26.9551-	−11.1449-
	HTO	ROOT REPAIR	15.05000*	3.28499	0.000	7.1449	22.9551
		REPAIR+HTO	−4.00000-	3.28499	0.448	−11.9051-	3.9051
	REPAIR+HTO	ROOT REPAIR	19.05000*	3.28499	0.000	11.1449	26.9551
		HTO	4.00000	3.28499	0.448	−3.9051-	11.9051
VAS_POST	ROOT REPAIR	HTO	4.40000*	0.25305	0.000	3.7911	5.0089
		REPAIR+HTO	4.35000*	0.25305	0.000	3.7411	4.9589
	HTO	ROOT REPAIR	−4.40000-*	0.25305	0.000	−5.0089-	−3.7911-
		REPAIR+HTO	−0.05000-	0.25305	0.979	−0.6589-	0.5589
	REPAIR+HTO	ROOT REPAIR	−4.35000-*	0.25305	0.000	−4.9589-	−3.7411-
		HTO	0.05000	0.25305	0.979	−0.5589-	0.6589

HSS, hospital for special surgery. HT, high tibial osteotomy; HTO, high tibial osteotomy; VAS, visual analog scale. *The mean difference is significant at the 0.05 level.

Figure 8

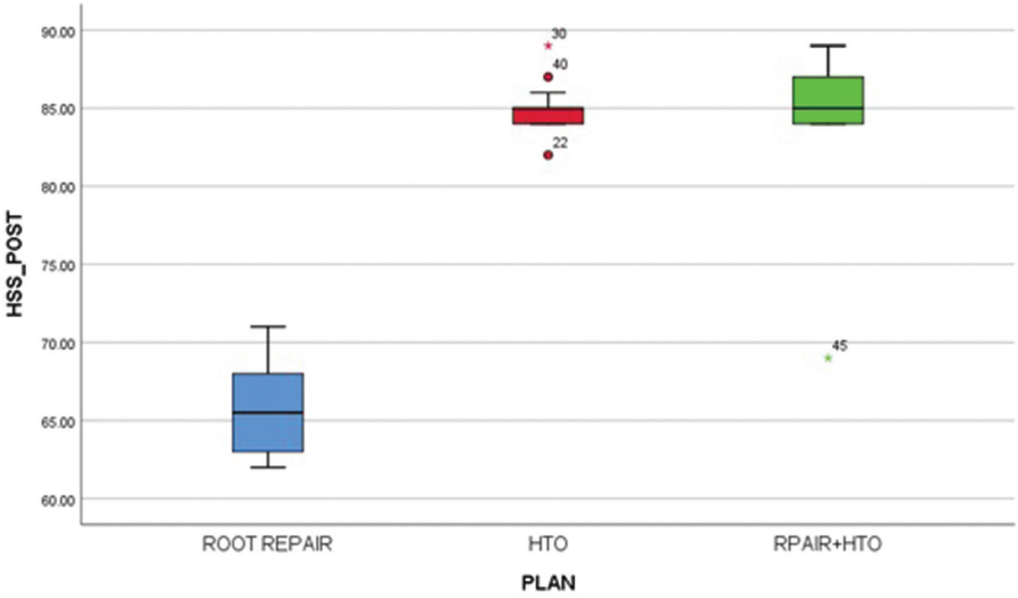


A box plot showing the difference between the three groups at the final follow-up regarding the Lysholm score.

Regarding the HSS score at the end of follow-up, we computed a one-way ANOVA comparing the outcomes between the three groups. A significant difference was found among the groups with *F*-value of 18.7 with degree of freedom 2 and *P*-value 0.000. Tukey's HSD post-hoc comparison test was used to determine the source of the differences between the groups. This analysis revealed that group A (root repair alone) scored lower (65.4±3.1) than group B (HTO alone: 81±4.6) and group C (combined approach: 85 ±5.1) (*P*=0.000). However, the difference between groups B and C was not significant (*P*=0.448) (Fig. 9).

Regarding the visual analog scale score at the end of follow-up, we computed a one-way ANOVA comparing the outcomes between the three groups.

Figure 9



A box plot showing the difference between the three groups at the final follow-up regarding the Hospital for Special Surgery score.

A significant difference was found among the groups with *F*-value of 199.2 with degree of freedom 2 and *P*-value 0.000. Tukey's HSD post-hoc comparison test was used to determine the source of the differences between the groups. This analysis revealed that group A (root repair alone) scored the worst (6.8±0.9) than group B (HTO alone: 2.4±0.2) and group C (combined approach: 2.5±0.6) (*P*=0.000). However, the difference between groups B and C was not significant (*P*=0.979) (Fig. 10).

Regarding the radiological outcome, χ^2 test was performed to compare grades of OA according to KL grading. Isolated root repair alone had progressed to grade 3 and grade 4 arthritis after years of follow-up in comparison with the other groups that had no cases with arthritis progression beyond grade 2 (χ^2=64.868, *P*=0.000).

Discussion

HTO unloads medial compartment overload that usually associates root tears of the medial meniscus. Unloading this failed compartment is pivotal for survival and healing of the medial root repair. Isolated medial root repair disregarding the real cause of root failure represents a great biomechanical ignorance. HTO unloads the overloads on the medial compartment, widens the medial joint spaces that might delay the progression of degenerative OA to prolong the conversion to total knee arthroplasty [25].

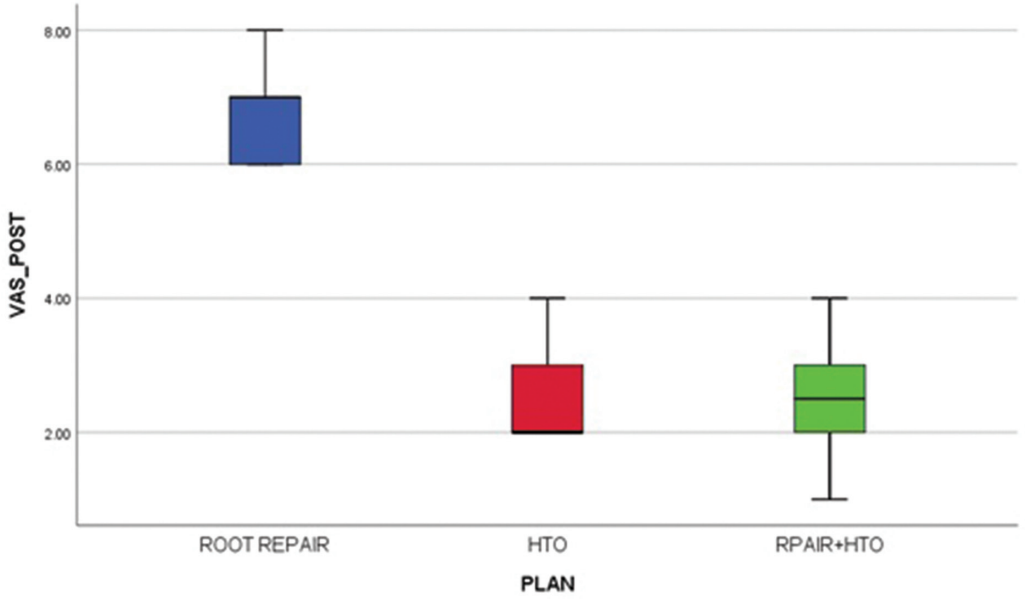
As a rule, to obtain a clear, complete picture of each meniscal condition, lower-limb alignment should be systematically assessed in all patients. A tailored approach for each patient is then recommended. Ignoring malalignment is inexcusable surgical illiteracy [26].

Root repair failures were reported to be related to varus malalignment greater than 5°, and it is recommended to correct the lower-limb axis in these situations [27,28]. Patients who have mechanical axis deviation in varus and mild OA associated with MMPRTs can benefit from tibial valgus osteotomy. This, even isolated, can provide significant improvement of symptoms and allows healing of the root tear without the need for repair [15].

De Faria *et al.* [29] reported posterior meniscal root repair combined with HTO. Nakamura *et al.* [13] performed medial meniscus root repair with HTO and they added medial meniscus centralization to distribute the meniscal hoop tension between the root repair site and the centralization site, which may reduce the retear risk. They reported that the deformity, whether primary or secondary to root damage, must be corrected before or together with root repair when it is greater than 5° of varus [13,29].

Nha *et al.* [15] evaluated the degree of meniscal healing of the posterior root, through an arthroscopic second-look evaluation, in patients undergoing isolated tibial osteotomy, without meniscal repair, and found 10

Figure 10



A box plot showing the difference between the three groups at the final follow-up regarding the visual analog scale score.

(50%) cases with complete healing, six (30%) with incomplete healing, and four (20%) with no healing without any meniscal repair.

A recently published study by Lee *et al.* [30] retrospectively compared 71 patients with posterior root tears of the medial meniscus and submitted to a medial opening valgus tibial osteotomy. The authors divided these patients into three groups. In the first group, only the osteotomy was performed and no treatment was performed on the meniscal root tear. In the second group, the tibial osteotomy was associated with a transosseous root repair, and, in the third group, the patients underwent osteotomy associated with the repair 'side by side' of the meniscal root. The authors evaluated patients with clinical questionnaires (Lysholm, IKDC, K–L, and Tegner), progression of joint degeneration assessed radiologically by the classification, and a second-look arthroscopy was performed 24 months after surgery (performed at the time of removal of osteotomy plate and screws) to assess the chondral status and the meniscal root healing. The authors found a clinical improvement of all scores in the three groups with no significant differences between them. They observed a better chondral quality in the group that osteotomy was associated with the transosseous meniscal reinsertion technique, but without a statistical difference between the other two groups. This same group had the greatest rate of meniscal healing of 24%. In the radiologic analysis, only one patient in the group in which the osteotomy was performed isolated presented OA progression, in the other groups, none of the patients worsened. The authors concluded that the association of posterior meniscal root repair of the medial meniscus with osteotomy seems to improve the quality of the chondral status during the second arthroscopic look, however, in the short term, the repair of the meniscal root did not present significant differences with the group in which meniscal root has not been addressed [30].

Ke *et al.* [16] performed a prospective comparative study to investigate the clinical benefits of meniscal repair during open-wedge high tibial osteotomies in 90 patients with MMPRTs. The patients in group A (n=30) underwent OWHTO and arthroscopic all-inside meniscal repair concurrently, those in group B (n=34) underwent OWHTO only, and those in group C (n=26) underwent arthroscopic partial meniscectomy. After a minimum follow-up of 24 months, no significant differences between groups A and B regarding the final Lysholm (P=0.689) or Hospital for Special Surgery (HSS) scores (P=0.256) were observed. There were significant differences among the three groups regarding the hip–knee–ankle angle, weight-bearing line ratio, medial proximal–tibial angle, and joint line convergence angle (P<0.001, respectively), but the differences between groups A and B were not significant. During second-look arthroscopy, the healing rate of the MMPRTs was significantly higher in group A (63.3%) than in group B (35.3%). They concluded that concurrent arthroscopic meniscal

repair during OWHTO did not lead to significant clinical benefits in the treatment of MMPRTs, except for an increased rate of meniscal healing, which was not associated with clinical outcomes [16].

Lee *et al*. [12] compared the radiologic, arthroscopic, and clinical outcomes between repaired versus unrepaired MMPRT during OWHTO. They found that repair of the medial meniscus posterior root was not related to the radiologic and clinical outcomes. Therefore, there is no clear evidence of the need for the MMPHRT repair during OWHTO [12].

Kyun? Ho *et al*. [31] in 2021 performed a systematic review and a meta-analysis on medial meniscal root repair with HTO. They concluded that concurrent MMPRT repair during HTO for medial OA with MMPRTs has little benefits on the clinical, radiological, and arthroscopic outcomes during short-term follow-up. Further accumulation of evidence is needed for long-term effects [31].

Kim *et al*. [14] found that MMPRT does not affect the clinical and radiologic outcomes of MOWHTO compared with those patients without MMPRT over a mid-term follow-up (average 82 months) [14].

Jing *et al*. [18] found that MM root repair with HTO only leads to a higher healing rate of MMPRT and regeneration of degenerated articular cartilage in the medial condyles after MOWHTO. However, healing of the MMPRT was not related to a better clinical or radiological outcome. Moreover, the outcome is usually inferred under BMI and malalignment [18]. The same conclusion was reported by Lee *et al*. [32] that there is no relation between meniscal root healing and patient clinical nor radiological outcome [32].

Astur *et al*. [33] found that medial opening-wedge HTO decreases medial meniscal extrusion and improves clinical outcomes and return to activity without root repair. On the contrary, Chung and colleagues performed a systematic review and a meta-analysis on long-term follow-up of medial meniscus root repairs alone without HTO. They found that with isolated medial meniscal root repairs, the meniscus extrusion was not reduced and it did not prevent the progression K–L grading of arthrosis and did not improve the cartilage status [34]. Moreover, Goshima *et al*. [35] found that OWHTO is an effective treatment strategy for patients with spontaneous osteonecrosis of the medial tibial plateau or medial femoral condyle, either primary or secondary to root tears.

Lubowitz [36] in his editorial commentary reported that when one has a hammer (which is a metaphor for a tool), everything looks like a nail. In conclusion, based on current evidence, realistic indications for meniscal root repair could be refined over time because salvage procedures may have substantial failure rates, so we may not want to hammer every nail. Hohmann [37] also in his editorial commentary reported that the logical conclusion seems that it makes no sense to repair medial meniscal root tears even with HTO. We should ask ourselves the following question: is it worthwhile to repair a torn medial meniscal root when patients undergo a HTO for medial compartment OA, considering that the approximate healing rate is only 20% with a similar percentage of 'some' cartilage recovery after 2 years? Current evidence is limited, and it again boils down to clinical judgment.

Our results highlighted the same debate. Isolated medial meniscal root repairs had the worst outcome. Moreover, there was no added benefit from root repair with HTO. However, our study has some limitations due to the small number of cases and lack of randomization and blinding during assessment.

In conclusion, our results recommend isolated HTO as a solo fast-attack procedure with reliable durable clinical and radiological outcomes for the treatment of root tears of the posterior horn of the medial meniscus.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 LaPrade CM, James EW, Cram TR, Feagin JA, Engebretsen L, LaPrade RF. Meniscal root tears: a classification system based on tear morphology. Am J Sports Med 2015; 43:363–369.

2 Faucett SC, Geisler BP, Chahla J, Krych AJ, Kurzweil PR, Garner AM, *et al.* Meniscus root repair vs meniscectomy or nonoperative management to prevent knee osteoarthritis after medial meniscus root tears: clinical and economic effectiveness. Am J Sports Med 2019; 47:762–769.

3 LaPrade CM, Foad A, Smith SD, Turnbull TL, Dornan GJ, Engebretsen L, *et al.* Biomechanical consequences of a nonanatomic posterior medial meniscal root repair. Am J Sports Med 2015; 43:912–920.

4 Pache S, Aman ZS, Kennedy M, Nakama GY, Moatshe G, Ziegler C, *et al.* Meniscal root tears: current concepts review. Arch Bone Jt Surg 2018; 6:250.

5 Bernard CD, Kennedy NI, Tagliero AJ, Camp CL, Saris DB, Levy BA, *et al.* Medial meniscus posterior root tear treatment: a matched cohort comparison of nonoperative management, partial meniscectomy, and repair. Am J Sports Med 2020; 48:128–132.

6 Lee DW, Ha JK, Kim JG. Medial meniscus posterior root tear: a comprehensive review. Knee Surg Relat Res 2014; 26:125.

7 Han SB, Shetty GM, Lee DH, Chae DJ, Seo SS, Wang KH, *et al.* Unfavorable results of partial meniscectomy for complete posterior

medial meniscus root tear with early osteoarthritis: a 5-to 8-year follow-up study. Arthroscopy 2010; 26:1326–1332.

8 Lim HC, Bae JH, Wang JH, Seok CW, Kim MK. Non-operative treatment of degenerative posterior root tear of the medial meniscus. Knee Surg Sports Traumatol Arthrosc 2010; 18:4. 9–535.

9 Krych AJ, Johnson NR, Mohan R, Hevesi M, Stuart MJ, Littrell LA, *et al.* Arthritis progression on serial MRIs following diagnosis of medial meniscal posterior horn root tear. J Knee Surg 2018; 31:698–704.

10 Ahn JH, Jeong HJ, Lee YS, Park JH, Lee JW, Park J-H, *et al.* Comparison between conservative treatment and arthroscopic pull-out repair of the medial meniscus root tear and analysis of prognostic factors for the determination of repair indication. Arch Orthop Trauma Surg 2015; 135:1265–1276.

11 Kim DH, Lee GC, Kim HH, Cha DH. Correlation between meniscal extrusion and symptom duration, alignment, and arthritic changes in medial meniscus posterior root tear. Knee Surg Relat Res 2020; 32: 8–1.

12 Lee OS, Lee SH, Lee YS. Comparison of the radiologic, arthroscopic, and clinical outcomes between repaired versus unrepaired medial meniscus posterior horn root tear during open wedge high tibial osteotomy. J Knee Surg 2019; 34:57–66. doi: 10.1055/s-0039-1692992. Epub 2019 Jul 9. PMID: 31288272.

13 Nakamura R, Takahashi M, Kuroda K, Katsuki Y. Suture anchor repair for a medial meniscus posterior root tear combined with arthroscopic meniscal centralization and open wedge high tibial osteotomy. Arthrosc Tech 2018; 7:e755–e761.

14 Kim K-I, Bae J-K, Jeon S-W, Kim GB. Medial meniscus posterior root tear does not affect the outcome of medial open-wedge high tibial osteotomy. J Arthroplast 2021; 36:423–428.

15 Nha K-W, Lee YS, Hwang D-H, Kwon JH, Chae DJ, Park YJ, *et al.* Second-look arthroscopic findings after open-wedge high tibia osteotomy focusing on the posterior root tears of the medial meniscus. Arthroscopy 2013; 29:226–231.

16 Ke X, Qiu J, Chen S, Sun X, Wu F, Yang G, *et al.* Concurrent arthroscopic meniscal repair during open-wedge high tibial osteotomy is not clinically beneficial for medial meniscus posterior root tears. Knee Surg Sports Traumatol Arthrosc 2021; 29:955–965.

17 Kim YM, Joo YB, Lee WY, Kim YK. Remodified Mason-Allen suture technique concomitant with high tibial osteotomy for medial meniscus posterior root tears improved the healing of the repaired root and suppressed osteoarthritis progression. Knee Surg Sports Traumatol Arthrosc 2021; 29:1258–1268.

18 Jing L, Liu K, Wang X, Wang X, Li Z, Zhang X, *et al.* Second-look arthroscopic findings after medial open-wedge high tibial osteotomy combined with all-inside repair of medial meniscus posterior root tears. J Orthop Surg 2019; 28:2309499019888836.

19 Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res 1985; 198:43–49.

20 Słupik A, Białoszewski D. A comparative analysis of the clinical utility of the Staffelstein-score and the hospital for special surgery knee score (HSS) in monitoring physiotherapy of total knee replacement patients-preliminary study. Ortop Traumatol Rehabil 2009; 11:37–45.

21 Mazzuca S, Le Graverand MPH, Vignon E, Hunter D, Jackson C, Kraus V, *et al.* Performance of a non-fluoroscopically assisted substitute for the Lyon schuss knee radiograph: quality and reproducibility of positioning and sensitivity to joint space narrowing in osteoarthritic knees. Osteoarthritis Cartilage 2008; 16: 1555–1559.

22 Slattery C, Kweon CY. Classifications in brief: outerbridge classification of chondral lesions. Clin Orthop Relat Res 2018; 476:2101.

23 Yin Y, Li S, Zhang R, Guo J, Hou Z, Zhang Y. What is the relationship between the 'Fujisawa point' and postoperative knee valgus angle? A theoretical, computer-based study. Knee 2020; 27:183–191.

24 Schiphof D, Boers M, Bierma-Zeinstra SM. Differences in descriptions of Kellgren and Lawrence grades of knee osteoarthritis. Ann Rheum Dis 2008; 67:1034–1036.

25 Katagiri H, Nakagawa Y, Miyatake K, Ohara T, Shioda M, Sekiya I, Koga H. Short-term outcomes after high tibial osteotomy aimed at neutral alignment combined with arthroscopic centralization of medial meniscus in osteoarthritis patients. J Knee Surg 2021. doi: 10.1055/s-0041-1731738. Epub ahead of print. PMID: 34261157.

26 Gelber PE, Barenius B, Perelli S. Role of alignment and osteotomy in meniscal injuries. Clin Sports Med 2020; 39:211–221.

27 Chung KS, Ha JK, Ra HJ, Kim JG. Prognostic factors in the midterm results of pullout fixation for posterior root tears of the medial meniscus. Arthroscopy 2016; 32:1319–1327.

28 Jiang EX, Abouljoud MM, Everhart JS, DiBartola AC, Kaeding CC, Magnussen RA, *et al.* Clinical factors associated with successful meniscal root repairs: a systematic review. Knee 2019; 26:285–291.

29 de Faria JLR, Pavão DM, de Castro Moreirão M, Titonelli VE, de Sousa EB, Minamoto STN, *et al.* Posterior root repair of medial meniscus combined with valgus opening wedge tibial osteotomy. Arthrosc Tech 2021; 10: e1373–e1382.

30 Lee DW, Lee SH, Kim JG. Outcomes of medial meniscal posterior root repair during proximal tibial osteotomy: is root repair beneficial? Arthroscopy 2020; 36:2466–2475.

31 Kyun-Ho S, Hyun-Jae R, Ki-Mo J, Seung-Beom H. Effect of concurrent repair of medial meniscal posterior root tears during high tibial osteotomy for medial osteoarthritis during short-term follow-up: a systematic review and meta-analysis. BMC Musculoskelet Disord 2021; 22:1–15.

32 Lee HI, Park D, Cho J. Clinical and radiological results with second-look arthroscopic findings after open wedge high tibial osteotomy without arthroscopic procedures for medial meniscal root tears. Knee Surg Relat Res 2018; 30:34.

33 Astur DC, Novaretti JV, Gomes ML, Rodrigues AG Jr., Kaleka CC, Cavalcante ELB, *et al.* Medial opening wedge high tibial osteotomy decreases medial meniscal extrusion and improves clinical outcomes and return to activity. Orthop J Sports Med 2020; 8:2325967120913531.

34 Chung KS, Ha JK, Ra HJ, Kim JG. A meta-analysis of clinical and radiographic outcomes of posterior horn medial meniscus root repairs. Knee Surg Sports Traumatol Arthrosc 2016; 24:1455–1468.

35 Goshima K, Sawaguchi T, Shigemoto K, Iwai S, Fujita K, Yamamuro Y. Open-wedge high tibial osteotomy for spontaneous osteonecrosis of the medial tibial plateau shows excellent clinical outcomes. J Exp Orthop 2020; 7:1–9.

36 Lubowitz JH. Editorial commentary: meniscal root avulsion repair outcomes are at the level of a salvage procedure. Arthroscopy 2015; 31:1817–1818.

37 Hohmann E. Editorial Commentary: Medial Meniscal Root Repair May Not Be Required During Knee Medial-Compartment Unloading High Tibial Osteotomy. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2020; 36:2476–2477.