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MUSCULOSKELETAL

Natural history of new horizontal meniscal tears in individuals at risk for and with mild to moderate osteoarthritis: data from osteoarthritis initiative

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Abstract

Objectives To study the natural history of new horizontal meniscal tears and their association with progression of cartilage degeneration in individuals at risk for or with mild to moderate knee osteoarthritis over 4 years.

Methods Individuals who developed a new meniscal tear in the right knee over 2 years were selected from the Osteoarthritis Initiative 3T MRI studies. Knee structural changes were analyzed at the time of tear appearance (baseline), and after 4 years using a modified Whole-Organ Magnetic Resonance Imaging Score (WORMS). Meniscal tears were classified as either horizontal tears or non-horizontal tears. Individuals without a meniscal tear were 1:3 frequency matched according to BMI, gender, race, and age and served as the control group. Linear regression analysis was used to compare cross-sectional and longitudinal changes in cartilage WORMS scores.

Results Forty-one subjects developed horizontal tears, including one indiviudal who developed a tear in both menisci, and 34 developed non-horizonal tears. We found that (29/41 (70.7%)) of horizontal and (20/34 (58.8%)) of non-horizonatal tears were stable during follow-up ($p = 0.281$). Although knees with an incident tear had higher than controls WORMS MAX total knee scores at baseline (coef. = 0.47, $p = 0.044$, 95% CI = 0.01 to 0.93), there were no significant differences between the horizontal subgroup and knees without tears in overall cartilage scores at baseline and in progression over 4 years of follow-up.

Conclusions New horizontal meniscal tears tended to be stable over 4 years and presented no significant differences in progression of cartilage degeneration when compared with knees without tears.

Key Points

- *Most of horizonal meniscal tears were stable over 4 years.*
- *There were no statistically significant differences in overall progression of cartilage degenerative changes between knees with horizonal meniscal tears and control knees without tears*
- *Horizontal tears most often occurred at the posterior horn of the medial meniscus and at the body of the lateral meniscus.*

Keywords Meniscus · Osteoarthritis · Risk factor

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Abbreviations

DES	Dual-echo steady state
FSE	Fast spin echo
KOA	Knee osteoarthritis
OAI	Osteoarthritis Initiative
WORMS	Whole-Organ Magnetic Resonance Imaging Score

Introduction

Knee osteoarthritis (KOA) is a heterogenous disabling joint disease with reported gradually increasing prevalence since the mid-twentieth century [1] affecting almost 250 million people worldwide [2]. Etiology is considered to be multifactorial, depending on both individual predisposition and environmental determinants [3]. The interactions between menisci, cartilage, and ligaments have been identified as drivers for disease progression [4–12].

Population-based studies find incidental meniscal findings on MRI are present in more than 30% of the middle-aged and elderly population [13]. Meniscal abnormalities include a wide spectrum of pathologies, starting from intrasubstance signal alterations [14], which are in most cases asymptomatic [13], to advanced structural degeneration with severe loss of meniscal function with documented association with progression of KOA [9, 12, 15, 16]. Horizontal meniscal tears are considered as degenerative in nature and are a highly prevalent tear pattern in individuals older than 40 years [17, 18]. Degenerative tears are the result of cumulative stress forces with loss of meniscal cellularity and collagen fiber disruption [19, 20]. They tend to be found in patients presenting with more advanced cartilage degeneration [21]; however, a debate concerning cause-and-effect between cartilage and menisci is still open [22] aggravated by inconsistent results found in the literature [21, 23].

In clinical practice, it is very challenging to determine the natural evolution of new horizontal meniscal tears and to understand the interaction between meniscal tears and cartilage degeneration. To the best of our knowledge, there is limited data on the natural evolution of non-surgically treated newly detected horizontal tears. The purpose of this study was to investigate the development of new horizontal meniscal tears over 2 years and to evaluate (1) associations with baseline joint morphology and (2) how those tears impact progression of knee degenerative changes in individuals at risk for or with mild to moderate knee osteoarthritis over a period of 4 years.

Materials and methods

Subject selection

Participants were selected from the Osteoarthritis Initiative database (OAI, which is available for public access at http://www.oai.ucsf.edu/) a multicenter longitudinal, prospective observational study of KOA in persons aged 45–79 years at recruitment, sponsored by the US National Institutes of Health (NIH) [24, 25]. Over 9 years, both clinical and imaging data were acquired at four clinical centers (Ohio State University, Columbus, OH; University of Maryland, Baltimore, MD; University of Pittsburgh, Pittsburgh, PA; Memorial Hospital of Rhode Island/Brown University, Pawtucket, RI). Informed consent was collected from all participants. Local institutional review boards of all participating centers reviewed and aproved this HIPAA-compliant study protocol in accordance with the Helsinki Declaration and the later amendments.

From the total number of 4796 enrolled subjects, we selected participants who developed a new meniscal tear in the right knee over a 2-year time period. Right knees were selected because the complete MRI protocol including the T_2 mapping sequences was only performed for the right knees.

We selected subjects who had a new tear at the 2-year or 4-year follow-up and normal menisci or intrasubstance degeneration 2 years before, at baseline or the 2-year follow-up of the OAI. The visit when the tear first appeared was set as the baseline for this study as shown in Fig. 1. The 2-year time period has been chosen based on previous studies that analyzed the natural history of meniscal signal changes developing into tears [14]. The exclusion criteria were (i) presence of a meniscal tear 2 years before the baseline, (ii) previous cruciate ligament reconstruction and (iii) previous partial or total meniscectomy. The comparison group included patients who did not present meniscal tears at any of the timepoints, 1:3 frequency matched according to BMI, gender, race, and age.

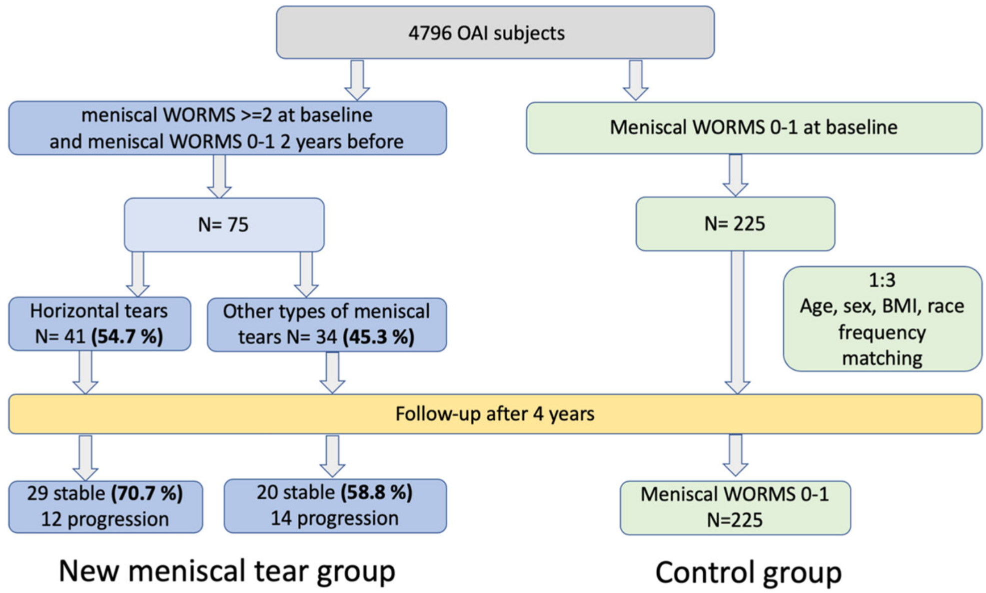
MR imaging

MR images were obtained on 3.0 Tesla MRI scanners (Siemens Magnetom Trio; Siemens) with the use of standard transmit-receive coils (USA Instruments, Aurora). The imaging protocol of the study has been published elsewhere [24]. The main sequences used for analysis were 2D sagittal intermediate-weighted fast spin echo (FSE) with fat-suppression (3200/30 milliseconds (ms), repetition time (TR)/echo time (TE); 3 mm slice thickness), coronal intermediate-weighted FSE (3700/29 ms; 3 mm slice thickness), and sagittal 3D dual-echo in steady state (DESS) with selective water excitation (16.3/4.7 ms; 0.7 mm slice thickness).

MR image analysis

Right knee baseline and 4-year follow-up MR studies were reviewed by a board-certified radiologist (M.P. with 10 years of experience in musculoskeletal imaging) after training and consensus readings to calibrate thresholds for gradings with a senior radiologist (T.M.L. with 27 years of experience in musculoskeletal imaging respectively). Cartilage and meniscal

Fig. 1 Study sample selection



lesions were graded using the UCSF modified Whole-Organ MRI Scoring (WORMS) system [26, 27].

Cartilage abnormalities were scored from 0 to 6 in six subregions (medial femoral condyle (MFC), medial tibia (MT), lateral femoral condyle (LFC), lateral tibia (LT), patella (P), and trochlea (T)) with modification described elsewhere [27]. The Maximum (MAX) WORMS score was defined as the highest WORMS score in the total knee joint (among all compartmental subscores: MFC, LFC, LT, MT, P, and T), medial (MFC and MT), lateral (LFC and LT), and patello-femoral (P and T) compartments. To describe meniscal pathology, five grades were used: grade 0 (normal), grade 1 (intrasubstance signal abnormalities not reaching the articular surface), grade 2 (simple, non-displaced tear), grade 3 (displaced or complex tear without deformity), and grade 4 (meniscal maceration). The morphology of all meniscal tears was defined as horizontal, vertical longitudinal and radial, flap, bucket handle, menisco-capsular separation, and root tear; additionally, discoid meniscal variants were also recognized. Readings were performed for each of the meniscal parts (the anterior horn, the body, and the posterior horn) for both medial and lateral menisci. A meniscal tear was defined as increased signal communicating with the free edge or any of its articular surfaces seen on at least two consecutive images.

Inter-/intrareader reproducibility

Inter- and intrareader reproducibility of WORMS scoring has been performed in previous studies [28, 29]. Reproducibility for WORMS subscores for menisci and cartilage was based on calculation of intraclass correlation coefficients (ICC). For menisci, it ranged from 0.80 [28] to 0.96 [29] for intra- and 0.81 [28] to 0.97 [29] for interreader reproducibility. Cartilage ICC for intrareader reproducibility ranged between 0.81 [28] and 0.99 [29] and 0.79 [30] and 0.97 [29] for interreader reproducibility, respectively.

Statistical analysis

Differences in subject characteristics between those with and without a new meniscal tear were assessed using chi-squared tests (categorical variables) and linear regression (continuous variables). Linear regression models were used to assess the differences in (a) baseline WORMS scores and (b) 4-year changes in WORMS scores in subjects with and without new meniscal tears and with horizontal vs non-horizontal tear vs. no tear. Case and control cohort were frequency matched and analyses were adjusted for age, gender, BMI, and race. Given that our analyses were considered exploratory we did not perform any multiple hypotheses testing. Outcome measures included the longitudinal change of cartilage MAX scores over 4 years in the total knee joint and in its three compartments (medial (MFC and MT), lateral (LFC and LT), patello-femoral (P and T)) and the individual subregional analysis (MFC, LFC, MT, LT, P, and T) presented in Supplementary materials (cross-sectional and longitudinal). Statistical analysis was performed with Stata v.14 software (StataCorp). Linear regression models were used to assess the association between BMI (predictor) and both (a) meniscal tear incidence, (b) WORMS scores.

Results

Subject characteristics

Table 1 lists the subject characteristics, including age, BMI, gender, and race for both case and control cohorts. The right

Table 1 Demographic subject characteristics

	subjects with new meniscal tear	control group	P value
total number	75	225	
sex (% of subgroup)	Male: 25 (33.3%) Female: 50 (66.7%)	Male: 75 (33.3%) Female: 150 (66.7%)	1
average BMI (kg/m^2) [STDEV]	28.51 [4.53]	28.51 [4.28]	0.99
race (% of subgroup)	White & Caucasian: 63 (84%) Black & Afro-American: 11 (14.7%) Asian: 1 (1.3%)	White & Caucasian: 190 (84.4%) Black & Afro- American: 33 (14.7%) Asian: 2 (0.9%)	0.945
average age (years) [STDEV]	61.10 [7.82]	61.04 [8.45]	0.96

knees of 75 case subjects and 225 controls were 1:3 frequency matched according to gender, age, BMI, and race. No significant differences ($p > 0.05$) were found in the subject characteristics between groups.

Incidence of meniscal tears and their progression over 4-year follow-up

Among the total number of 75 knees with a new meniscal tear, 41 knees (54.7%) presented with a horizontal tear; 24 knees had a horizontal tear in the medial meniscus, 16 tears were located in the lateral meniscus, and in one knee we found a new horizontal tear in both menisci (the posterior horn of medial meniscus and the body of lateral meniscus). Among the new horizontal tears in the medial meniscus, 21/25 (84%) were found in the posterior horn, 17/25 (68%) were restricted only to this subregion, and 4/25 (16%) knees presented with a new tear in both the body and posterior horn. A new horizontal tear in the lateral meniscus most frequently involved the body (15/17; 88.2%) and was restricted only to this subregion in 11/17 (64.7%) cases (Fig. 2). The subregional distribution of non-horizontal tears is presented in Supplementary materials (Figure 1 in Supplementary materials). Thirty-four knees (45.3%) developed a non-horizontal tear, and many of these had advanced stages of meniscal degeneration. In most cases, these were complex tears 9/34 (26%) followed by flap tears 8/34 (23%). One knee had a discoid meniscus, although it is an anatomical variant, it was classified as a meniscal abnormality using the meniscal grading system (Table 2).

Two years before development of a new meniscal tear in 15/75(20%), knees menisci had normal MRI signal (WORMS grade 0). Intrameniscal signal abnormalities (WORMS grade 1) were present in 60/75 (80%) participants 2 years before a new tear.

Over 4 years, the new horizontal tears remained stable in 29/41 (70.7%) knees, without progression to more advanced stages of meniscal degeneration (Fig. 3). Twelve knees demonstrated progression of horizontal tears; of these, 9 developed horizontal flap tears (9/41; 21.9%) and 3 maceration of the meniscus (3/41; 7.3%) (Fig. 1 and Table 2).

Of all non-horizontal tears 20/34 (58.8%) remained stable over 4 years. Knees with progression of non-horizontal tear types presented in the majority of cases maceration over 4 years 8/14 (57%); the detailed distribution of meniscal tear progression is presented in Table 2.

Baseline cartilage WORMS cross-sectional analysis

At baseline, knees that developed a new meniscal tear had more advanced overall structural cartilage abnormalities than controls, with significantly higher total knee MAX WORMS score (coef. = 0.47, $p = 0.044$, 95% CI = 0.01 to 0.93) (Table 3). In individual subregional WORMS scores analysis, we found significantly higher scores in meniscal tear group for MFC (coef. = 0.58, $p = 0.001$, 95% CI = 0.24 to 0.92), LCF (coef. = 0.36, $p < 0.001$, 95% CI = 0.17 to 0.56), and MT (coef. = 0.44, $p < 0.001$, 95% CI = 0.20 to 0.68) (Table 1a in Supplementary materials). Interestingly, baseline cross-sectional analyses of meniscal tear type subgroups showed statistically significantly more advanced cartilage damage of the non-horizontal group when compared with either horizontal or controls in total knee MAX WORMS scores (Table 3) and in 4/6 subregions (Table 1a in Supplementary materials). At baseline, compared with the control group, the horizontal tear group showed only significantly higher WORMS scores in LFC cartilage subregion (coeff. = − 0.24, $p = 0.049$, 95% CI = -0.49 to 0.001). The baseline analysis of the association between BMI and the

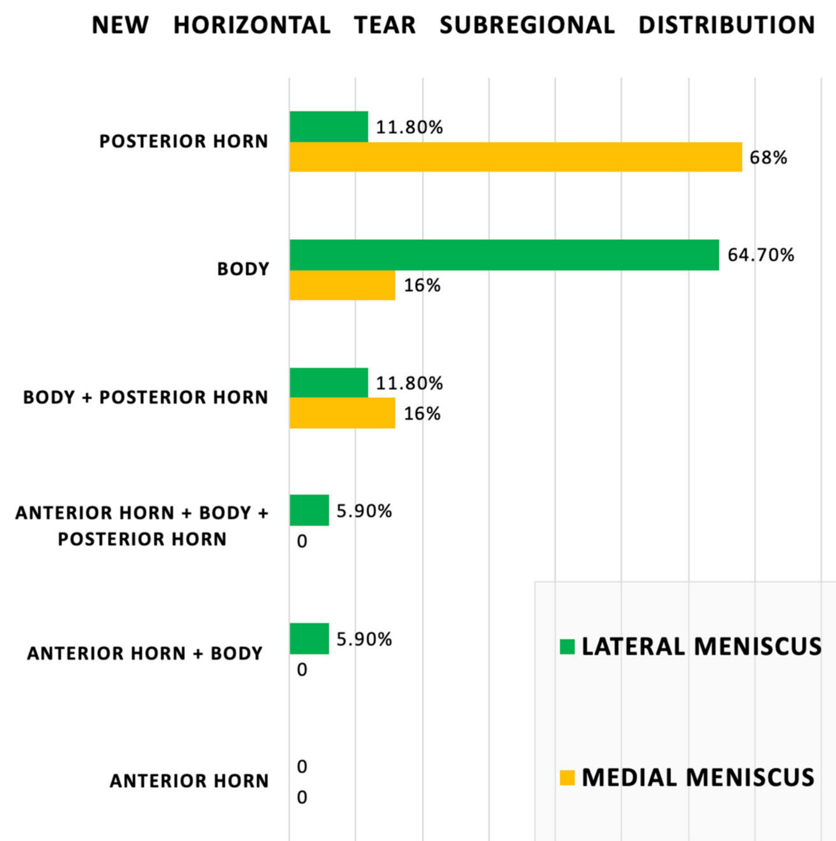


Fig. 2 Subregional distribution of new meniscal horizontal tears

incidence of meniscal tears and between BMI and the tear type (horizontal vs. non-horizontal) did not show statistically significant results ($p > 0.05$). However, we found a statistically significant correlation with BMI and baseline WORMS scores for both, tear group and control group in most of the subregions (Table 1b in Supplementary materials).

Table 2 New meniscal tear types baseline prevalence and 4-year follow-up

Meniscal tear type at baseline	Total N= 75		4-years follow-up	
HORIZONTAL	N=41 (54.67%)		Stable	N=29
			Unstable	N=12
			flap	N=9
			maceration	N=3
NON-HORIZONTAL	N=34 (45.33%)		Stable	N=20
			Unstable	N=14
	complex	N=9	complex to maceration	N=5
	flap	N=8	complex to flap	N=1
	vertical longitudinal	N=7	flap to maceration	N=3
	maceration	N=4	vert. long. to maceration	N=1
	vertical radial	N=3	vert. long to complex	N=3
	root	N=2	vert. long to flap	N=1
	*discoid meniscus without tear	N=1		

*Discoid meniscus was included in meniscal WORMS grading system as a meniscal abnormality, which remained stable over 4-year follow-up

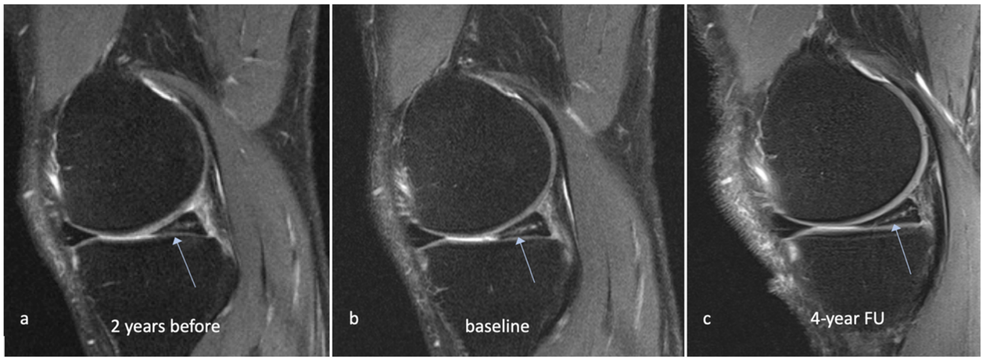


Fig. 3 Development and 4-year follow-up of new horizontal tears within the posterior horn of medial meniscus. **a** Sagittal IW TSE fat-suppressed MRI of the right knee presenting intrameniscal signal changes in the posterior horn 2 years before baseline/time of the occurrence of tear. **b** Baseline sagittal IW TSE fat-suppressed MRI of the right knee of the same subject showing a new horizontal tear in posterior horn of medial meniscus (arrow). **c** 4-year follow-up sagittal IW TSE fat-suppressed MRI of the right knee of the same participant presenting no progression of horizontal meniscal tear (arrow)

Longitudinal 4-year changes in cartilage WORMS

Over the 4-year follow-up period, we did not find a statistically significant difference in overall cartilage progression between the new meniscal tear group and controls in total knee MAX WORMS scores (coef. = − 0.23, p = 0.06, 95% CI = − 0.48 to 0.01) (Table 4). In individual subregional WORMS scores analysis, the new tear group had more progression than controls in MT (coef. = 0.27, p = 0.002, 95% CI = 0.10 to 0.45) and in LT (coef. = 0.33, p = 0.001, 95% CI = 0.12 to 0.54) but less progression in the trochlea (coef. = − 0.21, p = 0.033, 95% CI = − 0.40 to − 0.01) (Table 2 in Supplementary materials). The

Table 3 Differences in baseline MAX WORMS scores between subjects with a new meniscal tear and controls and between subgroups of horizontal and non-horizontal tear compared with controls (all values presented as adjusted means; ± standard error) (lower 95% confidence interval (CI); upper 95% CI; coef.) statistically significant p values are bold with fields marked in gray

Cartilage subregion/ compartment	BASELINE WORMS score (adjusted means; ± Standard Error)		p value [95% Conf. Interval]; Coef.	BASELINE WORMS score (adjusted means; ± Standard Error)			p value [95% Conf. Interval]; Coef.		
	new meniscal tear group	control group		horizontal tear group	non-horizontal tear group	control group	horizontal vs non-horizontal	horizontal vs control	non-horizontal vs control
MAX score total knee	3.12 ± 0.20	2.64 ± 0.11	**0.044** [0.01, 0.93] 0.47	2.66 ± 0.27	3.67 ± 0.30	2.64 ± 0.11	**0.014** [0.20; 1.80] 1.00	0.946 [-0.60; 0.56] -0.02	**0.002** [-1.65; -0.38] -1.02
MAX score medial compartment (MFC +MT)	1.38 ± 0.15	0.68 ± 0.08	**p<0.001** [0.35; 1.04] 0.69	0.74 ± 0.20	2.16 ± 0.22	0.68 ± 0.08	**p< 0.0001** [0.82; 2.00] 1.41	0.797 [-0.48; 0.37] -0.05	**p< 0.0001** [-1.93; -1.00] -1.47
MAX score lateral compartment (LFC +LT)	0.89 ± 0.12	0.63 ± 0.07	0.066 [-0.01; 0.53] 0.25	0.73 ± 0.16	1.08 ± 0.18	0.63 ± 0.07	0.158 [-0.13; 0.83] 0.34	0.571 [-0.45; 0.25] -0.10	**0.021** [-0.83; -0.06] -0.45
MAX score patello-femoral joint (P+T)	2.71 ± 0.21	2.45 ± 0.12	0.297 [-0.22; 0.74] 0.25	2.25 ± 0.28	3.28 ± 0.31	2.45 ± 0.12	**0.017** [0.18; 1.87] 1.02	0.509 [-0.41; 0.82] 0.20	**0.016** [-1.49; -0.15] -0.82

Table 4 Differences in MAX WORMS scores change over 4-year follow-up between subjects with a new meniscal tear and controls and between subgroups of horizontal and non-horizontal tear compared with controls (all values presented as adjusted means; ± standard error) (lower 95% confidence interval (CI); upper 95% CI; coef.) statistically significant *p* values are bold with fields marked in gray

Cartilage subregion/ compartment	Delta 4 years follow-up WORMS score (adjusted means; ± Standard Error)		p value [95% Conf. Interval]; Coef.	Delta 4 years follow-up WORMS score (adjusted means; ± Standard Error)			p value [95% Conf. Interval]; Coef.		
	new meniscal tear group	control group		horizontal tear group	non-horizontal tear group	control group	Horizontal vs non-horizontal	Horizontal vs control	non-horizontal vs control
MAX score total knee	0.34 ± 0.10	0.57 ± 0.06	0.06 [-0.48; 0.01]; -0.23	0.45 ± 0.14	0.20 ± 0.16	0.57 ± 0.06	0.263 [-0.68; 0.18] -0.24	0.434 [-0.19; 0.44] 0.12	**0.033** [0.03; 0.72] 0.37
MAX score medial compartment (MFC +MT)	0.29 ± 0.08	0.26 ± 0.04	0.718 [-0.15; 0.22] 0.03	0.31 ± 0.11	0.27 ± 0.12	0.26 ± 0.04	0.807 [-0.37; 0.29] -0.04	0.664 [-0.29; 0.19] -0.05	0.926 [-0.27; 0.25] -0.01
MAX score lateral compartment (LFC +LT)	0.41 ± 0.08	0.27 ± 0.04	0.136 [-0.04; 0.34] 0.14	0.52 ± 0.11	0.29 ± 0.12	0.27 ± 0.04	0.178 [-0.57; 0.10] -0.23	**0.045** [-0.50; -0.005] -0.25	0.883 [-0.29; 0.25] -0.02
MAX score patello-femoral joint (P+T)	0.28 ± 0.10	0.56 ± 0.06	**0.024** [-0.52; -0.03] -0.28	0.35 ± 0.14	0.18 ± 0.16	0.56 ± 0.06	0.443 [-0.59; 0.26] -0.16	0.197 [-0.10; 0.51] 0.20	**0.031** [0.03; 0.71] 0.37

changes in WORMS total knee MAX scores over 4 years were not significant for group with horizontal tears when compared with controls (Table 4); however, in individual subregional WORMS score analysis, we found more progression in LT in horizontal tear group than in controls (coef. = − 0.42, p = 0.0.002, 95% CI = − 0.68 to − 0.14) (Table 2 in Supplementary materials)**.** The non-horizonal group showed more progression than controls in MT (coef. = − 0.39, p = 0.002, 95% CI = − 0.63 to − 0.14); however, over the 4-year follow-up period, less progression in patello-femoral compartment was also noted for this group when compared with controls.

Discussion

In this study, we found that new horizontal meniscal tears are mostly stable over a period of 4 years. Meniscal intrasubstance signal abnormalities were preceding an incident tear in the majority of cases. The posterior horn of the medial meniscus and the body of the lateral meniscus were the most frequent locations for horizontal tears. The WORMS cartilage gradings at the time of tear occurrence were higher in the group which developed new meniscal tear than the control group without meniscal tears at any timepoint. However, those baseline differences were greater in the non-horizontal tear group rather than the horizontal tears. There were no statistically significant differences in overall progression in total knee MAX scores of cartilage degenerative changes in knees with horizonal meniscal tears when compared with other types of tears and control knees without tears over the 4-year follow-up period.

Meniscal tears are one of the most frequently recognized pathologies in both traumatic and degenerative knees [31, 32] with proven strong associations with incident KOA [11] even in knees at "preradiographic" stages [16]. Degenerative meniscal tears occur in patients without reported joint trauma [22] and in many cases are found incidentally together with cartilage structural changes. Our results showed that women have a higher rate of degenerative tears which is consistent with some previous studies [33]. However, other studies have reported a male predilection for meniscal tears due to traumatic lesions [34] and non-horizontal tears [35]. Our study results confirmed that the posterior horn is the most affected region for meniscal degeneration [13, 18, 19, 36] and anterior horn is less often affected [19].

The association between horizontal tears and KOA has been previously reported [37]; however, despite the meniscal tear types, the key functional role of meniscal circumferential fibrous bundles are preserved [6]. This explains that from biomechanical point of view horizontal tears are not related to severe alterations in pressure applied to cartilage [38, 39]. A recent retrospective analysis from knee arthropscopies determined that horizontal tears identified in lateral menisci are related to less cartilage damage compared with other types of tears [40] and our baseline comparison confirms those findings. Interestingly, overall cartilage alterations did not show increased progression over the 4-year follow-up when comparing the horizontal tear subgroup and the controls. We assume that these findings represent a relatively constant pace of knee degenerative disease advancement both in subjects with and without horizontal tears. This finding suggests that horizontal tears are "low-risk" in terms of impact on KOA progression. On the other hand, non-horizontal tears were related to more advanced cartilage abnormalities at the time of tear occurence. However, after 4 years, no statistically significant differences in KOA progression were found when comparing non-horizontal and horizontal tear groups.

We believe that recognition of tear type is crucial in assessing the KOA prognosis and it is not commonly reported in previous studies [41]. Based on our findings, we recommend that future knee MRI studies categorize meniscal tears and determine how each type is associated with knee OA progression [42].

We found that 2 years before an incident meniscal tear, 80% of our subjects demonstrated intrameniscal signal changes, which is consistent with previous studies [14]. A wide spectrum of meniscal intrasubstance abnormalities can be seen in daily clinical practice. Those MR signal alterations do not fulfill criteria of meniscal tear recognition, however, are considered as precursor to an incident tear [43]. Advancing meniscal aging on microstructural level represents a gradual loss of both cellular components and collagen fiber organization with predominance of fibrous and cystic changes as well as intrasubstance calcium deposition [19, 44]. Linear intrameniscal signal intensity is unlikely to regress and is related to higher risk of progression to degenerative tear within the same meniscal segment [14]. Those signal changes turn out to be meaningful signs of overuse and degeneration, and a precursor for developing an incident tear in the course of KOA confirmed in our results as well.

The diagnosis of a new horizonal tear may significantly impact patient management. According to new trends in orthopedic surgery, saving the meniscus is a priority and partial meniscectomies are considered as potentially promoting progressive knee joint degeneration [43]. Surprisingly, repair of horizontal cleavage tears show higher complication rates than meniscectomy [45]. Although some studies suggest that surgeons still favor an arthroscopic approach and partial meniscectomy, despite the reported lack of its long-term benefits in degenerative knees [46], the trend to change clinical practice towards a conservative approach has been reported in the last decade [47]. However, the ability to predict the outcome after degenerative meniscal surgery is still poor [43]. Our results show that simple, horizontal meniscal tear without concomitant abnormalities tends to be stable over time with no progression of meniscal and cartilage degeneration over 4 years of follow-up. Moreover, compared with a control group, there was no increase in overall progression of OA within the same timeframe. Our results support a conservative approach when dealing with patients presenting with degenerative horizontal tears. Furthermore, some previous studies on middle-aged and elderly populations showed that the majority of incidentally found non-traumatic meniscal tears were not accompanied by any clinical symptoms [13] or did not differ in pain scores from patients without meniscal tears [48]; thus, the etiology of pain in OA knees should be investigated with particular clinical awareness.

Although for our study we used a large database, counting almost five thousand patients, our inclusion criteria were restricted only to subjects who developed meniscal tears within a 2-year time frame. However, our cohort is also unique as we only focus on new tears and there is limited knowledge about the natural evolution of meniscal tears. Also, our group included middle-aged and elderly individuals without associated history of major knee trauma, which are mostly seen in a younger population [49] and are more likely treated surgically. Another limitation of our study is that the group with other than incident horizontal tears was very heterogenous and presented mostly with a broad spectrum of different stages of more advanced meniscal degeneration. A limitation of this study is that we relied on previously published intra- and interreader reproducibilities performed for WORMS cartilage and menisci. In our study, we only focused on the natural history of meniscal tears and the correlation with cartilage changes without including how the tear may impact other tissues around the knee joint, which is a limitation of our study but may be an interesting topic for future studies.

Conclusion

Horizontal tears in the majority of patients tended to be stable over 4 years. Our results suggest that horizontal tears represent a stable phenotype of degenerative meniscal abnormalities which is not related to statistically significant progression in cartilage outcome over 4 years compared to a control cohort without meniscal tears. At the time of meniscal tear occurrence, non-horizontal tears were related to significantly more advanced structural cartilage abnormalities than controls and horizontal tears.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Thomas M. Link.

Conflict of interest The authors of this manuscript declare no relationships with any companies whose products or services may be related to the subject matter of the article.

Statistics and biometry Two of the authors has significant statistical expertise.

Informed consent Written informed consent was obtained from all subjects (patients) in this study.

Ethical approval Institutional Review Board approval was obtained.

Study subjects or cohorts overlap Data used in the preparation of this article were obtained from the Osteoarthritis Initiative (OAI) database, which is available for public access at http://www.oai.ucsf.edu/. This specific study design of horizontal tear cohort from OAI has not been used in previous publications.

Methodology
- Prospectively collected database with retrospective analysis of meniscal tears
- Longitudinal case-control study
- Multicenter study

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