

Altered meniscal shape and maceration are associated with knee osteoarthritis severity and progression: data from the Osteoarthritis Initiative



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Benny Antony, Driban JB, Price LL, Lo GH, Ward RJ, Nevitt MC, Lynch J, Eaton CB, Ding C, McAlindon TE

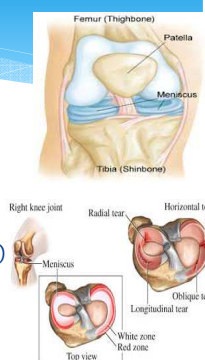
Meniscus

Anatomy

- * crescent-shaped fibrocartilaginous structure
- * structural integrity to the knee

Meniscal damage

- * common among older adults
- * increases the risk for the incidence and progression of knee osteoarthritis (OA)
- * only weakly related to knee pain.



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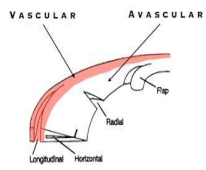
Introduction

Meniscal pathology

- * associated with subchondral bone pathologies including increased bone marrow lesions (BMLs).
- * primarily been analysed based on the presence or absence of meniscal pathology
- * Different types of meniscal pathology may have differential effects on meniscal function

MENISCAL INJURY CONCEPTS

VASCULAR AVASCULAR



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Aims

- * The aims of this study were to explore the association of different types of knee meniscal pathology with
 1. knee pain cross-sectionally and with change in knee pain over 2 years
 2. BML volume cross-sectionally and change in BML volume over 2 years
 3. End-stage knee OA (a proxy for total knee arthroplasty based on published algorithms).


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Methods

Study population

- * Osteoarthritis Initiative (OAI)
 - * OAI is a multi-center, longitudinal (4 years), prospective observational study (n=4800) of knee health. (public domain research resource)
 - * Progression cohort (1,300) or incidence cohort (3,500)
- * Bone Ancillary Study (n=629) from Progression Cohort conducted during 30- or 36- month OAI visit
 - * The aims of the ancillary project are to determine if periarticular BMD (measured by DXA) and apparent bone volume fraction (measured by MRI) are predictors of the rate of knee OA progression (cartilage loss)



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Meniscal pathology scoring

24-month OAI MR images

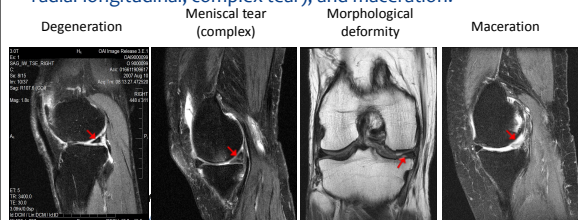
- * read by a experienced trained musculoskeletal radiologist
- * Modified International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS) meniscal tear classification system at 3 regions within each meniscus (i.e., anterior, body, and posterior horn)
- * 10 classifications were made: normal, degenerative signal, morphological deformity, horizontal tear, horizontal flap tear, longitudinal-vertical tear, radial tear, vertical flap tear, complex tear, and maceration.

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Meniscal pathology analysis

- 10 types of meniscal pathology was collapsed into 5 categories: normal, degenerative signal, morphological deformity, discrete tear (i.e., horizontal, horizontal flap, vertical-longitudinal, radial, radial-longitudinal, complex tear), and maceration.



Subchondral BML volume

24- and 48-month OAI MRI

- A semi-automated segmentation (n=386)
- Cross sectional analysis:
 - 1) no BML (volume < 1cm³)
 - 2) small BML volume (volume > 1cm³ volume < 2.5cm³)
 - 3) large BML volume (volume > 2.5cm³)
- Longitudinal analysis:
 - 1) No BML volume at both time points
 - 2) regression of BML volume
 - 3) no BML volume change
 - 4) progression of BML volume



Knee pain evaluation

- WOMAC scale at 24 and 48 month visit of OAI.
- Assessed in a 5-point likert scale where 0 indicated no pain and 4 indicated severe pain
- Cross-sectional analysis: WOMAC knee pain at 24 month was collapsed into 3 categories:
 - 1) no or little pain, 2) mild pain 3) moderate-severe pain
- Longitudinally, change in WOMAC knee pain was collapsed to 3 categories:
 - 1) no pain or a meaningful decrease in pain (reference category),
 - 2) pain but no change over time, and 3) meaningful increase in pain.



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End-stage knee OA

- Proxy for total knee arthroplasty
- Used an algorithm developed by Escobar et al and adapted to OAI by Riddle et al to define end-stage knee OA at the 36- and 48-month OAI visits
 - appropriate
 - inconclusive
 - inappropriate
- The modified algorithm accounts for a participant's age, radiographic severity, localization of OA, knee symptoms, range of motion, and varus/valgus laxity assessments.



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Results

Table 1. Baseline characteristics

Variable	Mean (SD) or n (%)
Age (years)	63 (9)
Body mass index (kg/m ²)	29.6 (4.6)
Male	245 (53%)
Kellgren-Lawrence Grade ≥ 2	329 (71%)
Presence of any meniscal pathology	398 (86%)
Meniscal degeneration	259 (55%)
Meniscal morphological deformity	142 (30%)
Meniscal maceration	100 (20%)
Any discrete tear of Meniscus	222 (47%)
Presence of any knee pain*	337 (73%)
Presence of tibial BML**	103 (27%)
Presence of end-stage knee OA***	42 (11%)

* n=463
** n=386
*** n=416



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Meniscal pathology and BML: cross-sectional

Table 2. Association between different types of meniscal pathology and tibial bone marrow lesion volume at baseline.

Menisci (Overall n = 386)	No BML n(%)	Small BML n(%)	Large BML n(%)	Univariable OR (95% CI)	Multivariable* OR (95% CI)
Type of Pathology**					
Degeneration (n=212)	154(73)	31(15)	27(13)	1.09(0.69,1.71)	1.25 (0.76,2.08)
Morphological Deformity (n=117)	68(58)	25(21)	24(21)	2.80(1.76,4.47)	2.47(1.49,4.09)
Maceration (n=77)	33(43)	12(16)	32(42)	7.04(4.22,11.76)*	5.85(3.40,10.06)
Any Discrete Tear (n=183)	137(75)	26(14)	20(11)	0.85(0.54,1.33)	0.95(0.58,1.58)
Maceration: Number of Regions Affected**					
0 (n=309)	251(81)	39(13)	19(6)	Reference	Reference
1 (n=37)	20(54)	6(16)	11(30)	4.18(2.12,8.23)	3.86(1.94,7.68)
2 (n=22)	8(36)	3(14)	11(50)	10.09(4.36,23.29)	8.19(3.48,19.29)
3 and above (n=18)	5(28)	3(17)	10(56)	13.89(5.42,35.59)	14.48(5.56,37.66)

* Ordinal regression models were used and adjusted for age, gender and BMI
**Types of pathology were further adjusted for each other in multivariable analysis



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Meniscal pathology and BML: longitudinal

Table 3. Association between different types and combination of meniscal pathology at baseline and total tibial bone marrow lesion volume change over 2 years.

Menisci (Overall n = 386)	No BML at both times n(%)	Regress on of BMLs n(%)	No Change in BMLs n(%)	Progress ion of BMLs n(%)	Univariable OR (95% CI)	Multivariable* OR (95% CI)
Type of Pathology**						
Degeneration (n=212)	138(65)	19(9)	34(16)	21(10)	1.09(0.72,1.64)	1.21(0.77,1.90)
Morphological Deformity (n=117)	60(51)	13(11)	30(26)	14(12)	2.33(1.52,3.60)	2.17(1.37,3.45)
Maceration (n=77)	26(34)	17(22)	24(31)	10(13)	3.81(2.39,6.07)*	3.12(1.87,5.19)
Any Discrete Tear (n=183)	116(63)	17(9)	34(19)	16(9)	1.19(0.79,1.79)	1.19(0.76,1.87)
Maceration: Number of Regions Affected**						
0 (n=309)	227(73)	17(6)	43(14)	22(7)	Reference	Reference
1 (n=37)	17(46)	8(22)	8(22)	4(11)	2.58(1.37,4.87)*	2.28(1.17,4.47)
2 (n=22)	6(27)	4(18)	10(45)	2(9)	4.49(2.12,9.53)*	3.28(1.45,7.43)
3 and above (n=18)	3(17)	5(28)	6(33)	4(22)	6.40(2.719,14.68)*	6.62(2.72,16.13)

* Ordinal logistic regression models were used and adjusted for age, gender and BMI

**Types of pathology were further adjusted for each other in multivariable analysis

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Meniscal pathology and knee pain: cross-sectional

Table 4. Association between different types of meniscal pathology and total WOMAC knee pain at baseline.

Menisci (n = 463)	No-Little Pain n(%)	Mild Pain n(%)	Moderate to Severe Pain n(%)	Univariable OR (95% CI)	Multivariable* OR (95% CI)
Type of Pathology**					
Degeneration (n=259)	100(39)	57(22)	102(39)	1.10(0.79,1.55)	1.12(0.79,1.60)
Morphological Deformity (n=142)	48(34)	34(24)	62(42)	1.34(0.93,1.93)	1.13(0.78,1.67)
Maceration (n=100)	23(23)	24(24)	53(53)	2.35(1.54,3.58)	2.82(1.79,4.43)
Any Discrete Tear (n=222)	86(39)	51(23)	85(38)	1.02(0.73,1.44)	1.30(0.91,1.86)
Maceration: Number of Regions Affected**					
0 (n=363)	154(42)	89(24)	121(33)	Reference	Reference
1 (n=49)	11(22)	9(18)	29(59)	2.83(1.58,5.08)	2.99(1.65,5.42)
2 (n=27)	7(26)	7(26)	13(48)	1.97(0.94,4.11)	2.55(1.20,5.34)
3 and above (n=51)	5(21)	8(33)	11(46)	2.03(0.93,4.42)	2.54(1.15,5.60)

* Ordinal logistic regression models were used and adjusted for age, gender and body mass index

**Types of pathology were further adjusted for each other

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Meniscal pathology and knee pain: longitudinal

Table 5. Association between types of meniscal pathology at baseline and WOMAC knee pain change over 2 years.

Menisci (n = 463)	No pain or Decreased pain n(%)	Pain but no Change n(%)	Increase in pain n(%)	Univariable OR (95% CI)	Multivariable* OR (95% CI)
Type of Pathology**					
Degeneration (n=259)	114(44)	61(24)	84(32)	1.19(0.84,1.67)	1.24(0.87,1.76)
Morphological Deformity (n=142)	54(38)	39(27)	49(35)	1.44(1.00,2.08)	1.44(0.99,2.09)
Maceration (n=100)	41(41)	30(30)	29(29)	1.10(0.73,1.66)	1.02(0.66,1.57)
Any Discrete Tear (n=222)	105(47)	56(25)	61(27)	0.82(0.58,1.15)	0.82(0.58,1.17)
Maceration: Number of Regions Affected**					
0 (n=363)	166(46)	89(25)	108(30)	Reference	Reference
1 (n=49)	24(49)	13(27)	12(24)	0.84(0.48,1.47)	0.84(0.47,1.47)
2 (n=27)	8(30)	10(37)	9(33)	1.53(0.74,3.14)	1.57(0.75,3.27)
3 and above (n=24)	9(38)	7(29)	8(33)	1.30(0.61,2.79)	1.32(0.61,2.85)

* Ordinal logistic regression models were used and adjusted for age, gender and BMI

**Types of pathology were further adjusted for each other in multivariable analysis

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Meniscal pathology and end-stage knee OA

Table 6. Association between different types of 24 month meniscal pathology and prevalence of end-stage knee osteoarthritis at 36 and 48 month visits using an Osteoarthritis Initiative adapted version of Escobar algorithm.

Menisci (n = 416)	End-stage KOA Absent n(%)	Present n(%)	Univariable OR (95% CI)	Multivariable* OR (95% CI)
Type of Pathology**				
Degeneration (n=231)	203(88)	28(12)	1.37(0.73,2.59)	1.48(0.73,2.98)
Morphological Deformity (n=125)	102(82)	23(18)	2.78(1.47,5.16)	2.16(1.09,4.28)
Maceration (n=86)	61(71)	25(29)	6.35(3.32,12.16)	5.71(2.84,11.50)
Any Discrete Tear (n=197)	175(89)	22(11)	1.07(0.58,1.99)	1.47(0.74,2.93)
Maceration: Number of Regions Affected**				
0 (n=330)	310(94)	20(6)	Reference	Reference
1 (n=43)	33(77)	10(23)	4.70(2.03,10.88)	4.21(1.79,9.89)
2 (n=24)	16(67)	8(33)	7.75(2.96,20.27)	6.96(2.53,19.10)
3 and above (n=19)	12(63)	7(37)	9.04(3.21,25.48)	9.65(3.35,27.81)

* Binary logistic regression models were used and adjusted for age, gender and BMI

**Types of pathology were further adjusted for each other in multivariable analysis

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Conclusions

- Among the five categories of meniscal pathologies
 - meniscal maceration was associated with knee pain.
 - Disruptive pathology (i.e., morphologic deformity and maceration) rather than degenerative or discrete tear was associated with structural changes such as BMLs and a later clinical state that is proxy for end-stage knee OA.
 - Pathologies that impair normal load distribution properties of meniscus can cause knee pain and damage to knee joint.
 - This suggests that clinicians should be wary of pathologies that impair normal load distribution properties of meniscus because they may or may not relate to knee OA severity and progression.

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