Menoufia Medical Journal

PRINT ISSN: 1110-2098 - ONLINE ISSN: 2314-6788

journal hompage: www.menoufia-med-j.com

Role of Dynamic Ultrasonography in Evaluation of Osteoarthritis in the Knee Joint

Mohammed Salah Eldeen Elzawawi

Hend Hamdy Elsayed Elsenbawy

Belal Said Hefny Soltan

ORIGINAL STUDY

Role of Dynamic Ultrasonography in Evaluation of Osteoarthritis in the Knee Joint

Mohammed S.E. Elzawawi[*], Hend H.E. Elsenbawy[**], Belal S.H. Soltan [***]

Radio-Diagnosis, Intervention and Imagining Department, Faculty of Medicine, Menoufia University, Egypt

Abstract

Objective: **The aim of the current study was to show the role of dynamic ultrasonography in diagnosis and assessment of medial type of the knee OA.**

Background: **Osteoarthritis (OA) is the most common form of arthritis that leads to chronic disability. The knee is one of the most frequently involved sites.**

Ultrasound (US) is valuable during the early detection of OA and monitoring its progression as it is much more sensitive to changes in cartilage, more reliable to assess meniscal extrusion and allows direct assessment of changes in soft tissues. In addition, it is useful to evaluate the rapid progression of OA changes in patients with OA seen on radiographs.

Patients and methods: **This cross-sectional study included 73 patients. Patients were 21 males and 52 females. Their ages ranged from 46 to 70 years old. All patients were referred from Rheumatology and Orthopedic Departments in Menoufia University Hospitals and Outpatient Clinic to Radiology Department in Menoufia University Hospitals by different clinical presentations suspecting knee joint disorder.**

Results: **This descriptive observational cross sectional study was carried out on 73 patients with clinical suspicion of knee OA referred from rheumatologic or orthopedic outpatient clinic.**

Conclusion: **In conclusion we have demonstrated that US is a simple and reproducible technique for the assessment of medial radial displacement of the medial meniscus and cartilage thickness of MFC. Furthermore, we have identified an association between MRD, cartilage thickness & and OA knees.**

Keywords: Anterior cruciate ligament, Antero-posterior, Knee osteoarthritis, Osteoarthritis, Ultrasonography

1. Introduction

Osteoarthritis (OA) is the most common form of arthritis that leads to chronic disability. The knee is one of the most frequently involved sites [1].

Its prevalence is increasing in aging populations worldwide, as it's reported that it has been doubled in prevalence since the mid 20th century [2].

Knee OA (KOA) is a disease of the entire joint, characterized by cartilage breakdown, subchondral bone alterations, formation of osteophytes, meniscal degeneration and synovial inflammation [3].

Traditionally, knee OA is primarily diagnosed by conventional radiography using Kallgren−Lawrence (K&L) grading by structural changes such as presences of osteophyte and joint space narrowing (JSN) which appear at relatively late stages. Also, conventional radiography (CR) provides little information about soft tissue structures [4].

In contrast, magnetic resonance imaging (MRI) may provide an accurate and reproducible evaluation of bone, articular cartilage, and soft tissues. It's not usually used as an initial imaging technique for knee OA due to practical and cost reasons [5].

Received 13 July 2022; revised 24 August 2022; accepted 27 August 2022.
Available online 1 November 2024

* Corresponding author.
** Corresponding author.
*** Corresponding author.

E-mail addresses: Mohamed.elzawawi@med.menofia.edu.eg (M.S.E. Elzawawi), hendelsenbawy@gmail.com (H.H.E. Elsenbawy), Belal.soultan@med.menofia.edu.eg (B.S.H. Soltan).

https://doi.org/10.59204/2314-6788.3266

Another modality used to visualize musculoskeletal disorders in research and clinical practice is high-frequency musculoskeletal ultrasound (MSK US). Musculoskeletal ultrasound possesses a high potential in assessment of knee OA among other imaging modalities as it allows qualitative and quantitative assessment of the articular cartilage and plays an important role in screening and follow-up [6]. In addition to noninvasiveness, it is quick to perform and relatively of low cost.

Unlike radiography, ultrasound (US) is valuable during the early detection of OA and monitoring its progression as it is much more sensitive to changes in cartilage, more reliable to assess meniscal extrusion and allows direct assessment of changes in soft tissues. In addition, it is useful to evaluate the rapid progression of OA changes in patients with OA seen on radiographs [6].

Ultrasound provides dynamic technique in which the patient exerts a certain movement while the physician holds the ultrasound probe relative to an anatomical landmark. Ultrasound provides functional assessment of muscles, tendons and ligaments and allows more precise identification and localization of tissue damage [7].

The aim of the current study was to show the role of dynamic ultrasonography in diagnosis and assessment of medial type of the knee OA.

2. Patients and methods

This cross-sectional study include 73 patients. Patients were 21 males and 52 females. Their ages ranged from 46 to 70 years old. All patients were referred from Rheumatology and Orthopedic Departments in Menoufia University Hospitals and Outpatient Clinic to Radiology Department in Menoufia University Hospitals, during the period from February 2020 to February 2022, by different clinical presentations suspecting knee joint disorder.

2.1. Ethical consideration

Ethical scientific committee of Menoufia University approved the study protocol and informed consents Before enrolling in the study.

2.2. Inclusion criteria

Patients with clinical suspicion of knee OA referred from rheumatologic or orthopedic outpatient clinic.

2.3. Exclusion criteria

- History of Trauma
- Infective conditions of the knee including septic arthritis
- Inflammatory condition e.g. RA
- Known patients with gouty arthropathy
- History of previous surgery

All patients were subjected to:

- Full history taking.
- Clinical examination with special emphasis on particular symptoms as pain, swelling, and limitation of movement was done in the orthopedic or the rheumatology clinic.

2.4. Clinical examination

- Patients were assessed by the outpatient physician then directed to the radiology unit.

2.5. Radiological assessment

- Conventional radiography
- Ultrasound examination

2.6. Conventional radiography

Conventional plain x-ray was taken of the knee Antero-posterior (AP) view in standing position was acquired with focus to film distance of 180 cm, 60 kV, and 50 mAs. The images were reviewed for:

- Narrowing of the joint space
- Osteophytes lipping
- Articular surface sclerosis
- Subchondral cysts
- Deformities as genu valgum

And the image was given a score according to KL score.

2.7. Dynamic US was used to examine the medial compartment of knee joint to diagnose

A. The medial radial displacement (MRD) of the medial meniscus with Longitudinal us in Complete extension in both the supine and standing positions.
B. Cartilage thickness at medial femoral condyle (MFC). with Horizontal us with fully flexion in supine position

The MRD was measured on longitudinal US images at the site at which the medial collateral

ligament (MCL) was most clearly visualized. Normal MCLs are observed to be two hyperechoic bands separated by a thin hypoechoic zone crossing over the medial femoral condyle, the margin of the medial meniscus and the medial tibial plateau. The deeper layer closely adheres to the peripheral edge of the meniscal body. In OA there is insufficient contrast between the two structures in US because the meniscus is frequently extruded and macerated and the MCL is displaced radially. The MRD was measured as the distance from the outer most edge of the medial meniscus to a line connecting the femoral and tibial cortices. When marginal osteophytes were present in the femur and tibia, the MRD was measured by line connected the clearly visualized normal cortical bone passing through the femoral and tibial marginal osteophytes. The distances were measured using electronic calipers (to an accuracy of 0.1 mm).

We defined the supine position MRD as the non-weight- bearing medial radial displacement (NWMRD) and the standing position MRD as the weight-bearing medial radial displacement (WMRD) respectively.

The cartilage thickness of medial femoral condyle was measured as patients lay in a supine position with their knees in maximum flexion. The transducer was placed axially above the patellar upper edge. Cartilage thickness measurements were taken from the mid-points of medial femoral condyle (MFC). The distance between the thin hyperechoic line at the synovial space–cartilage interface and the sharp hyperechoic line at the cartilage-bone interface ware measured as the cartilage thickness. Cartilage assessment was done by evaluation of sharpness, clarity and thickness of the cartilage band with knee in fully flexion on horizontal suprapatellar US images of medial femoral condyle (MFC) and measuring the cartilage thickness in mm.

2.8. Statistical analysis

The collected data will be, tabulated, and statistically analyzed using SPSS program (Statistical Package for Social Sciences) software version 26.0, and Microsoft Excel 2016. Descriptive statistics were done for numerical parametric data as mean ± SD (standard deviation) and minimum & maximum of the range and for numerical non parametric data as median and 1st& 3rd inter-quartile range, while they were done for categorical data as number and percentage. Inferential analyses were done for quantitative variables using independent t-test in cases of two independent groups with parametric data and Mann Whitney U in cases of two independent groups with non-parametric data. Inferential analyses were done for qualitative data using Chi square test for independent groups. The level of significance was taken at P value < 0.05 is significant, otherwise is non-significant. The p-value is a statistical measure for the probability that the results observed in a study could have occurred by chance.

3. Results

This descriptive observational cross sectional study was carried out on 73 patients; 21 males, 52 female with age range from 46 years to 70 years (mean age 56.68 years) all of them clinical suspicion of knee OA.

Fig. 1shows that the patients are divided into five groups according to K-L grading using knee radiographs. 9.6% of knees have grade 4 lesion as severe degree of knee OA, 24.7% knees had grade 1, 26% knees had grade 2 and 24.7% knees had grade 3 (see Figs. 2–5).

Ultrasound examination of the studied cases shows that the mean of NW_MRD was 5.69 ± 2.18 mm and median of 5.20 mm with its minimum value was 3.0, maximum value is 12.3 mm. The mean of W_MRD was 6.61 ± 2.35 mm and median of 6.20 mm with its minimum value was 3.30, maximum value was 13.5 mm. Also, the mean of the CARTIL was 1.55 ± 0.51 mm and median of 1.5 mm with its minimum value was 0.5 mm, maximum value was 2.40 mm Table 1.

Joint effusion was found in 60.3% of the subjects while Backer's cyst in 31.5% only Table 1.

Tables 2 and 3 shows that there was no significant difference was noted in the NW-MRD between the KL grade 0 and KL grade 1 knees and between the KL grade 3 and KL grade 4 knees, but significant difference between KL grade 0 and KL grade 2 or more severe grade knees were found. Also, there was no significant difference was noted in the W-MRD between the KL grade 0 and KL grade 1 knees and

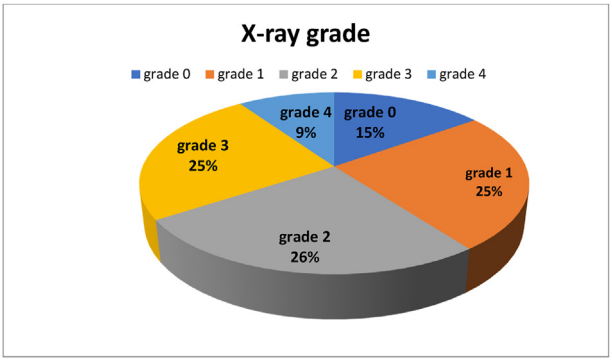

Fig. 1. Distribution of patients according to X-ray grade.

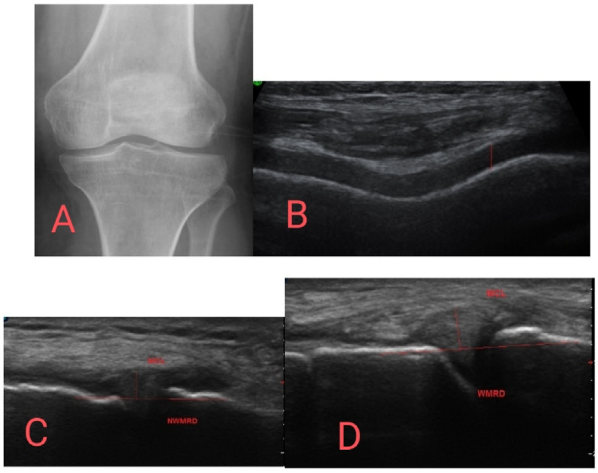

Fig. 2. Male patient 66 years old, complaining of pain at the medial aspect of the left knee. (A) Lt knee radiograph AP view KL grade 1 (non-osteoarthritis), (B) US of medial compartment in supine position with flexed knee, cartilage thinking of medial femoral condyle 2.1 mm. (C) US of medial compartment supine position NW-MRD = 3.7 mm. (D) US of medial compartment (standing) W-MRD = 4.0 mm.

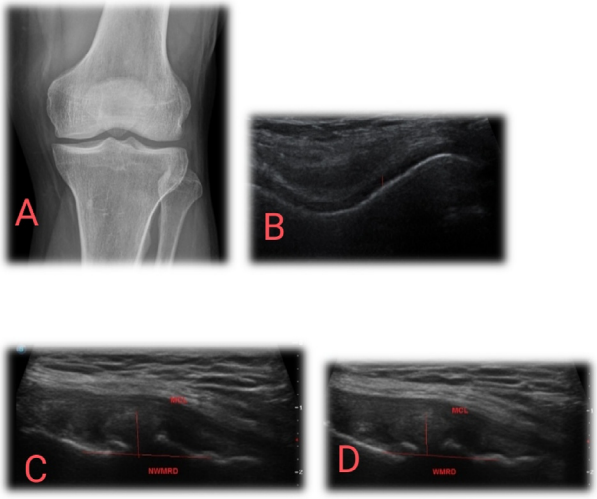

Fig. 3. Female patient 50 years old, complaining of pain at the medial aspect of the left knee. (A) Lt knee radiograph AP view KL grade 2 (osteoarthritis) with minimal osteophytes, (B) US of medial compartment in supine position with flexed knee, cartilage thinking of medial femoral condyle = 1.4 mm.(C) US of medial compartment supine position NW-MRD = 5.6 mm.(D) US of medial compartment (standing) W-MRD = 6.8 mm.

between the KL grade 3 and KL grade 4 knees, but significant difference between KL grade 0 and KL grade 2 or more severe grade knees were found.

Total 41 out of 44 knees were correctly diagnosed by ultrasonography with sensitivity of 93.18% and specificity of 86.21%. The predictive value positive was 91.11% and the predictive value negative was 89.29% with accuracy of 90.41% Table 4.

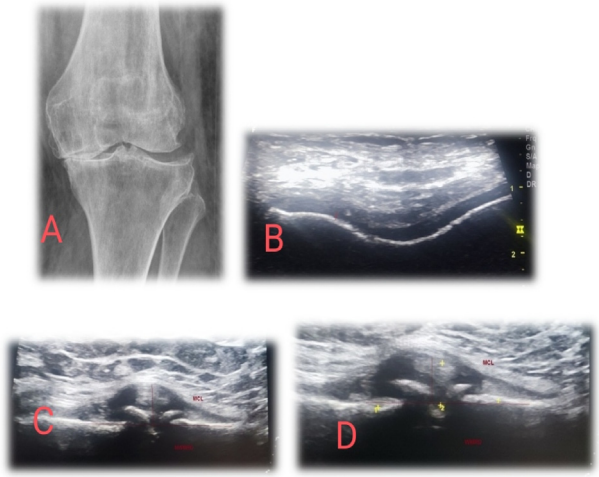

Fig. 4. Female patient 69 years old complaining of pain, stiffness and limitation of movement at the medial aspect of the left knee. (A) Lt knee radiograph AP view KL grade 3 (osteoarthritis) with marked osteophytes, (B) US of medial compartment in supine position with flexed knee, cartilage thinking of medial femoral condyle = 0.9 mm. (C) US of medial compartment supine position NW-MRD = 7.8 mm (D) US of medial compartment (standing) W-MRD = 9.2 mm.

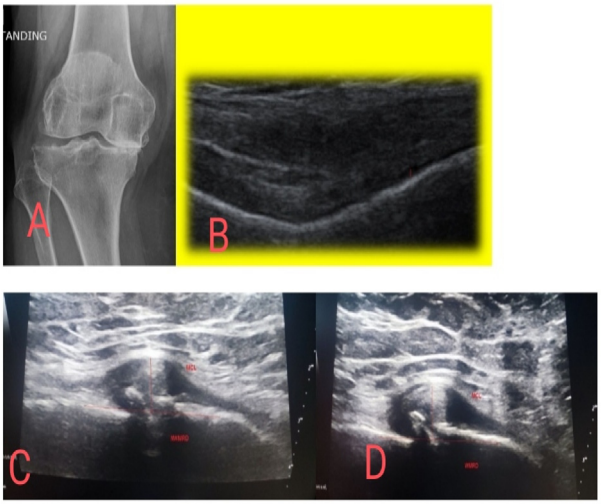

Fig. 5. Male patient 70 years old complaining of pain and stiffness at the medial aspect of the right knee. (A) Lt knee radiograph AP view KL grade 4 (osteoarthritis) with large osteophytes, (B) US of medial compartment in supine position with flexed knee, cartilage thinking of medial femoral condyle = 0.6 mm. (C) US of medial compartment supine position NW-MRD = 10.3 mm. (D) US of medial compartment (standing) W-MRD = 11.2 mm.

4. Discussion

Knee OA is the most common joint disease and more prevalent in the medial compartment than in the lateral compartment. During normal gait, there is a brief valgus moment after initial contact, and then the knee joint is subjected to an external varus moment throughout stance phase. This varus

Table 1. Distribution of studied patients as per ultrasound findings.

Parameters		Studied patients (n = 73)	
		N	%
NW-MRD (mm)	Mean ± SD	5.69 ± 2.18	
	Median	5.20	
	Range	3.0–12.3	
W-MRD (mm)	Mean ± SD	6.61 ± 2.35	
	Median	6.20	
	Range	3.30–13.5	
CARTILAGE THICKNESS (mm)	Mean ± SD	1.55 ± 0.51	
	Median	1.50	
	Range	0.50–2.40	
Joint effusion	No	29	39.7%
	Yes	44	60.3%
Baker Cyst	No	50	68.5%
	Yes	23	31.5%

NWMRD non-weight-bearing medial radial displacement, WMRD weight-bearing medial radial displacement, CARTILAGE THICKNESS SD = standard deviation.

Table 2. Comparison between each x-ray grade as regards NWMRD, WMRD and cartilage thickness.

Parameters		NW-MRD	W-MRD	CARTIL
Grade 0	Mean	3.72	4.13	2.19
	± SD	0.36	0.42	0.21
Grade 1	Mean	4.18	4.91	1.90
	± SD	0.70	0.73	0.33
Grade 2	Mean	5.25	6.27	1.53
	± SD	0.92	1.02	0.23
Grade 3	Mean	7.04	8.34	1.17
	± SD	1.43	1.23	0.20
Grade 4	Mean	10.37	11.33	0.64
	± SD	1.30	1.36	0.10

SD = standard deviation.

Table 3. P-values between groups.

Parameters		NW-MRD	W-MRD	CARTIL
Grade 0	Grade 1	0.261	0.130	0.155
	Grade 2	**0.001**	**<0.001**	**0.001**
	Grade 3	**<0.001**	**<0.001**	**<0.001**
	Grade 4	**<0.001**	**<0.001**	**<0.001**
Grade 1	Grade 2	**0.01**	**0.01**	**0.033**
	Grade 3	**<0.001**	**<0.001**	**<0.001**
	Grade 4	**<0.001**	**<0.001**	**<0.001**
Grade 2	Grade 3	**0.022**	**0.015**	**0.011**
	Grade 4	**0.001**	**0.001**	**<0.001**
Grade 3	Grade 4	0.120	0.155	0.112

$p \leq 0.05$ is considered statistically significant, $p \leq 0.01$ is considered highly statistically significant.
The values in (bold) are either significant or highly significant and the non-bold are insignificant.

moment and the subsequent increased loads in the medial compartment are thought to be responsible for the greater incidence of medial compartment osteoarthritis [8].

Knee radiographs is the most widely used method for the diagnosis of knee OA by using the Kellegren –Lawrence (K -L) grading system, that focuses on osteophytes and/or joint space narrowing but

Table 4. Contingency table showing the result of the ultrasonography and radiographic evaluation of knee OA.

		X-ray				
		Negative		Positive		Total
		No.	%	No.	%	
Ultrasound	Negative	25	34.2%	3	4.1%	28
	Positive	4	5.5%	41	56.2%	45
	Total	29	39.7%	44	60.3%	73 (100%)

cannot characterize cartilage damage, including that of the meniscus, so the medial radial displacement (MRD) cannot be detected by radiography, while it can be examined by US [9].

High-resolution ultrasonography is being applied increasingly to musculoskeletal medicine. It has proved to be valuable in the morphological and structural assessment of soft tissue in patients with arthritis [10].

Ultrasound can assess changes of internal structures as osteophytes, cartilage (near the joint surface) and the superficial components of the menisci (including detecting extrusion) in the knee. Ultrasound offers a relatively simple way to assess meniscal extrusion with the patient both supine (at rest) and standing (weight bearing), therefore it could be applied to the assessment of static and dynamic displacement of menisci [11].

The current study was performed to diagnose and evaluate medial type of the knee osteoarthritis (OA) by measuring the medial radial displacement at the level of the MCL and cartilage thickness of medial femoral condyle.

The study included 73 Patients. The age of patients ranging from 46 to 70 years old and mean age is 56.6 years. These results matched with the study of Loeser et al. [12] who stated that the prevalence of osteoarthritis (OA) rises directly with age and it is the most common cause of chronic disability in older adults. The prevalence of the disease increase dramatically among persons elder than 50 years, likely because of age related alternation in collagen and proteoglycans.

Also, our study confirmed what Chu and Andriacchi [13], described in 2015 that aging is the main risk factor for OA. Age-related changes occur in cartilage matrix and contributing to OA development. US studies showed that knee cartilage thins during aging, suggesting a gradual loss of cartilage matrix with age. This could be due to reduce growth factor activity as well as reduced water content.

In the current study, females were affected with OA more than males, (28.8% males and 71.2% females). This matched with the study of Hafez et al. [14] who describe that women are at greater risk for

developing knee osteoarthritis (OA) compared to men. Menopause has been associated with an increased production of interleukin-1 which is the part of the cytokine response in OA. In post-menopausal women as the level of estrogen decreases, interleukin-1 levels can increase which leads to OA. Also, other issues like anatomical differences, previous trauma and genetic effect should be considered. Women with OA have also been found to have greater levels of knee pain and lower function.

Hill et al. [15] stated that high prevalence of joint effusion is present in patients with knee OA who have knee pain and this was in agreement with our study in which we found that joint effusion was present in 60.3% of cases and all of them had knee pain.

In the current study baker cyst was found only in 31.5% of patients and this partially agreed with the study of Pouders et al. [16] who considered Baker cyst as a common finding in patients with knee OA.

Regarding OA grading, we found that the most common grade was grade II seen in 26% of cases followed by grade I and III each is 24.7% of cases. This result agreed with Maaly [17], who found that the most common grade was grade II seen in 32% of cases, but disagreed with Basuki et al. [18] who stated that grade III was the highest distribution of OA patients.

In our study, meniscal displacement was found to be significant in symptomatic OA cases in both weight bearing and non-weight bearing positions.

According to Kijima et al. [19], medial meniscus extrusion detected by ultrasound has been shown to be linked to the development and progression of knee osteoarthritis.

In the current study the degree of displacement was significantly higher in the weight-bearing standing position than in the non-weight-bearing supine position (dynamic displacement) ($P < 0.0001$).

In agreement to Ko et al. [8], Meniscal subluxation is a prominent feature on weight-bearing sonographic imaging in patients with radiographic osteoarthritis and could be considered as a risk factor for the development of knee osteoarthritis. By using musculoskeletal ultrasonography, one can detect this occult meniscal derangement early before the appearance of radiographic signs of osteoarthritis.

In agreement with the study of Kawaguchi et al. [20] who measured the medial radial displacement (MRD) of the medial meniscus with US. The displacement of medial meniscus increase in the weight bearing position.

In our study, US parameters between osteoarthritic and non-osteoarthritic groups were significantly different. Our results showed that the non-weight bearing medial radial displacement (NWMRD) and the weight bearing medial radial displacement (WMRD) increased in subjects with OA than non-OA ($P < 0.0001$).

In agreement to our results Yanagisawa et al. [9] reported that NWMRD and WMRD values were significantly lower in the non-OA group than in the OA group ($P < 0.001$).

In the current study we found that in early OA there was local reduction of cartilage thickness, loss of normal sharpness of cartilage interface, and increased echogenicity. In advanced stages, the cartilage narrows asymmetrically.

In agreement to Audisio et al. [21] the US has a predictive value in detecting the severity of cartilage degenerative alterations with high sensitivity at the femoral medial condyle and the sulcus areas.

In the current study we found that there is correlation between US values of cartilage thickness and joint space narrowing which was detected by x-rays (KL score).

This agrees with Naredo et al. [22] who had found a moderate correlation between radiographic joint space narrowing and loss of hyaline articular cartilage.

5. Conclusion

In conclusion we have demonstrated that US is a simple and reproducible technique for the assessment of medial radial displacement of the medial meniscus and cartilage thickness of MFC. Furthermore, we have identified an association between MRD, cartilage thickness & and OA knees.

Funding

None.

Conflict of interest

None.

List of abbreviation

OA	Osteoarthritis
KOA	Knee OA
CR	Conventional Radiography
US	Ultrasound
MRI	Magnetic Resonance Imaging
MFC	Medial femoral Condyle
MRD	Medial Radial Displacement
K&L	Kellegren–Lawrence
MSK-US	Musculoskeletal Ultrasound
MCL	Medial Collateral Ligament
NWMRD	Non-Weight-Bearing Medial Radial Displacement
WMRD	Weight-Bearing Medial Radial Displacement

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