Austin Medical Sciences

Open Access

Austin Publishing Group

Research Article

A Radiological Study for Assessment of Cartilage Abnormalities in Patients with Osteoarthritis of Knee

Singh B[1]*, Raj G[1] and Gupta H[2]

[1]Department of Radiodiagnosis, Dr. Ram Manohar Lohiya Institute of Medical Sciences, Lucknow, Uttar Pradesh, India

[2]Leeds MSK Imaging, Department of Radiodiagnosis, Leeds Teaching Hospitals, NHS, UK

***Corresponding author:** Bhanupriya Singh, Assistant Professor, Department of Radiodiagnosis, Dr. Ram Manohar Lohiya Institute of Medical Sciences, Lucknow, UP 226010, India

Received: August 05, 2021; **Accepted:** August 19, 2021; **Published:** August 26, 2021

Abstract

Present study evaluates spectrum of abnormalities and severity of cartilage injury in patients with Osteoarthritis (OA) of knee by comparing plain radiograph and MRI. This retrospective study with 50 patients as sample that underwent MRI (on 3T scanner) and weight bearing radiograph (on 800mA & 1000mA machine) of the knee at our institution. The included patient population was clinically suspected osteoarthritis of the knee. Kellgren-Lawrence grades and proposed MR grade scale was applied. The standard was based mainly on cartilage injury and additional findings.

Results: Present study obtained significant result correlation while assessing the disease severity of patients on Kellgren-Lawrence score (on radiograph) and cartilage abnormality (On MRI). Distributions of associated degenerative changes were also documented.

Conclusions: Plain radiographs are still important in evaluating osteoarthritis of knee. MRI plays a vital role in imaging the bony and soft tissues of knee as a whole organ. There is significant correlation between plain radiograph and MRI findings.

Keywords: Cartilage; MRI; Osteoarthritis; Plain radiograph

Abbreviations

OA: Osteoarthritis; MRI: Magnetic Resonance Imaging; JSN: Joint Space Narrowing; JSW: Joint Space Width; KL-Score: Kellgren-Lawrence Score; AMADEUS: Area Measurement and Depth, and Underlying Structures; MERGE: Multi Echo Recombined Gradient Echo; CROAKS: Cartilage Repair Osteoarthritis Knee Score; MOAKS: MRI Osteoarthritis Knee Score; WORMS: Whole Organ MRI Score; BLOCKS: Boston Leeds Osteoarthritis Knee Score

Background

Osteoarthritis (OA), also known as degenerative joint disease, is diagnosed based primarily on the history and physical examination, is one of the leading cause of disability worldwide [1-3]. Radiographic findings, including asymmetric joint space narrowing, subchondral sclerosis, osteophyte formation, subluxation and distribution patterns of osteoarthritic changes, can be helpful. Cartilage damage is an important component of Osteoarthritis (OA) and is associated not only with disease symptoms, but with progression of cartilage lesions [1-5] (Chart 1). Characterized by degenerative changes in the bones, cartilage, menisci, ligaments, and synovial tissue, Osteoarthritis (OA) has evolved to be considered a disease of the whole joint. Using imaging, OA has traditionally been diagnosed with radiographs that demonstrate Joint Space Width (JSW) and osteophytes [4-6]. The present study was conducted with the aim of semi quantitative evaluation of cartilage abnormalities and associated degenerative changes in patients with osteoarthritis of knee. Cartilage defects predispose to further cartilage loss, leading to development and progression of osteoarthritis [7,8].

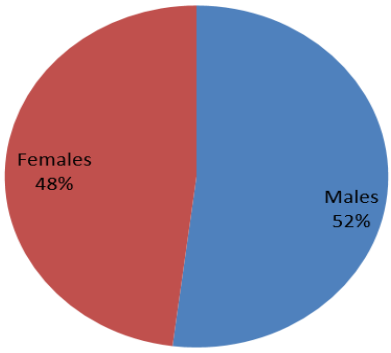

Chart 1: Gender distribution of study population.

Methods

Image acquisition

The present study was as commenced for assessing the cartilage abnormalities in patients with osteoarthritis of knee. A total of 50 patients with confirmed diagnosis of OA of knee were enrolled. A Performa was made complete clinical as well demographic details of all the patients were recorded.

Weight bearing poster-anterior knee radiographs (70kV, 16mAs) were acquired on 800mA and 1000mA Prognosis X-ray machine. Radiographic examination was done followed by categorization of patients based on radiographic findings as per Kellgren-Lawrence score (Table 1).

Citation: Singh B, Raj G and Gupta H. A Radiological Study for Assessment of Cartilage Abnormalities in Patients with Osteoarthritis of Knee. Austin Med Sci. 2021; 6(2): 1049.

Table 1: Distribution of patients according to Kellgren-Lawrence score (on Radiography).

Kellgren-Lawrence Score (on Radiography)	Parameter	Number of Patients	Percentage of Patients
Grade 0	Normal	24	48
Grade 1	Doubtful Osteoarthritis	8	16
Grade 2	Minimal Osteoarthritis	14	28
Grade 3	Moderate Osteoarthritis	4	8
Grade 4	Severe Osteoarthritis	0	0
Total		50	100

Table 2: Kellgren-Lawrence Grading System for Assessment of Radiographic OA [12].

0	No feature of OA
1	Doubtful JSN and possible osteophytic lipping
2	Definite osteophytes and possible JSN
3	Moderate multiple osteophytes, definite JSN, and some sclerosis and possible deformity of bone ends
4	Large osteophytes, marked JSN, severe sclerosis, and definite deformity of bone ends

Table 3: Distribution of patients according to cartilage abnormality (On MRI).

Grade (On MRI)	MRI Findings	Number of Patients	Percentage of Patients
Grade 0	Normal	4	8
Grade I	High T2 signal intensity alteration	4	8
Grade II A	Defect of cartilage of less than 50%	8	16
Grade II B	Defect of cartilage of 50% to 99%	16	32
Grade III A	100% defect of cartilage with no bone erosion	16	32
Grade III B	100% defect of cartilage with subjacent bone erosion.	2	4
Total		50 patients	100%

MR imaging was performed using GE SNIGMA 3T MR system, using a dedicated knee coil (8 channel). Knee was placed in extension in middle of the coil. After obtaining basic set of localizers, coronal plain T1 weighted images were obtained; fat saturated PD (proton density), 3D PD and MERGE (Multi Echo Recombined Gradient Echo) images were obtained. MRI evaluation for cartilage abnormality, menisci, ligament, osteophyte, loose bodies, cysts, and altered soft tissue intensities were done. Based on MRI findings, grading of the cartilage abnormalities was done according to severity of cartilage abnormalities (Table 2).

Statistical analysis

All the results were recorded in Microsoft excel sheet and were analysed. IBM SPSS Statistics for windows version 17.0(SPSS, Chicago, IL, USA) was used for all statistical evaluation. Chi-square test was used for assessment of level of significance.

Results

In the present study, a total of 50 patients with OA of knee were analysed. Mean age of the patients was found to be 52.8 years. There were 26 males and 24 females. According to Kellgren-Lawrence score, normal findings were observed in 48% of the patients while minimal to moderate findings were seen in 36% of the patients. In the present study, according to MRI findings, defect of cartilage of 50% to 99% and 100% defect of cartilage with no bone erosion were seen in 32% of the patients each. In the present study, significant results were obtained while assessing the distribution of patients Kellgren-Lawrence score [12] (On Radiography) and cartilage abnormality (On MRI [1]) (Chart 2). Similar to semi quantitative studies in past, like MOAKS (MRI osteoarthritis knee score), WORMS (Whole Organ MRI Score) and BLOCKS (Boston Leeds Osteoarthritis Knee Score) [13-15] we tried to access functional integrity of knee joint and changes in spectrum of OA (Chart 3). Evaluated features included cartilage involvement, medial and lateral menisci, anterior and posterior cruciate ligaments, medial and lateral collateral ligaments, popliteal, ganglion and para meniscal cyst, supra and infra patellar synovitis, osteophyte, loose bodies, iliotibial band involvement and pes anserine bursitis. We did not sub compartmentalize involvement of specific articular sub regions. Effusion was scored from 0 to 3, as absence of fluid, mild, moderate, severe joint effusion. Menisci and

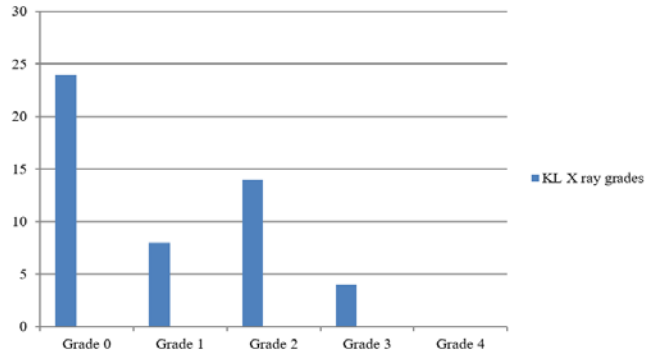

Chart 2: Distribution of patients according to Kellgren-Lawrence score (on Radiography).

Table 4: Comparison of Kellgren-Lawrence score (On Radiography) and according to cartilage abnormality (On MRI).

Cartilage Abnormality (On MRI)	Kellgren-Lawrence Score (On Radiographic)				Total	Fisher's Exact Test p-value
	Grade 0	Grade 1	Grade 2	Grade 3		
Grade 0	2	2	0	0	4	0.018 (Significant)
Grade I	2	0	2	0	4	
Grade II A	4	2	2	0	8	
Grade II B	12	2	2	0	16	
Grade III A	4	2	8	2	16	
Grade III B	0	0	0	2	2	
Total	24	8	14	4	50	

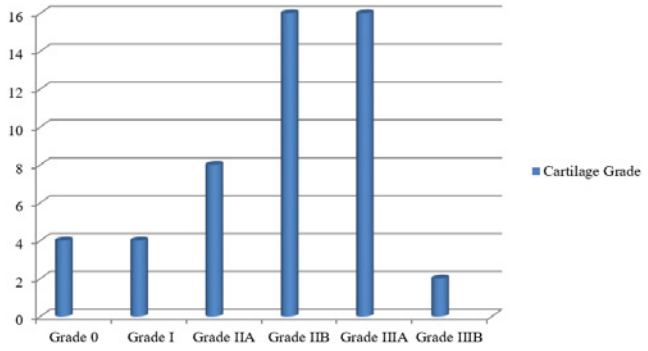

Chart 3: Distribution of patients according to cartilage abnormality (On MRI).

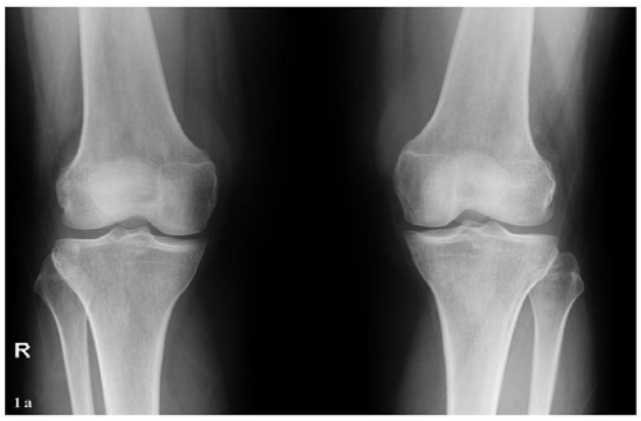

Figure 1a: Frontal weight bearing normal radiograph with no features of Osteoarthritis.

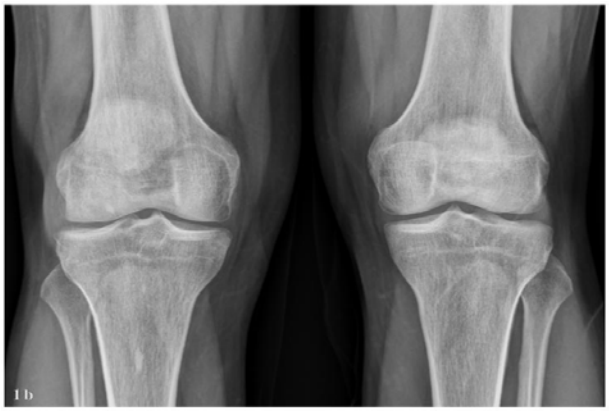

Figure 1b: Doubtful joint space narrowing seen in KL grade 1 Osteoarthritis (OA).

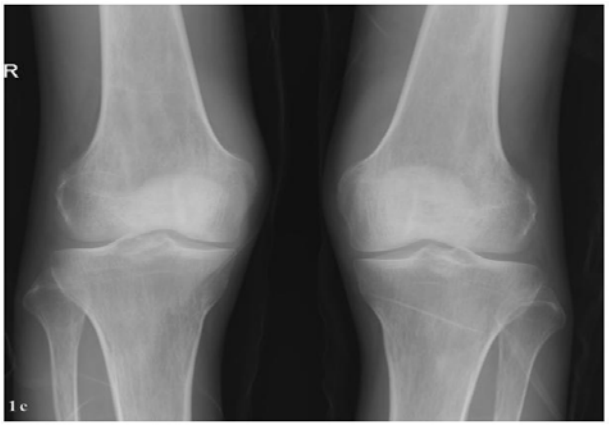

Figure 1c: Definite osteophyte with possible joint space narrowing in KL grade 2 OA.

ligaments were scored as involved in disease process for any grade of tear. Cartilage involvement was graded by a proposed scoring system mentioned in Table 3.

Discussion

Osteoarthritis (OA) is the most common form of arthritis and one of the leading causes of disability. This degenerative and progressive joint disease affects around 250 million people worldwide. Technologic advances and implementation of sophisticated post-processing instruments and analytic strategies have resulted in imaging playing an important role in understanding the disease process of OA [1-5]. Radiography is still the most commonly used imaging modality for establishing an imaging-based diagnosis of OA. The need for an effective non-surgical OA treatment is highly desired, but despite on-going research efforts, no disease-modifying OA drugs have been discovered or approved to date [5-7]. MR imaging-based studies have revealed some of the limitations of radiography [8-11] (Figure 1, Table 4). In the present study, significant results were obtained while assessing the distribution of patients Kellgren-Lawrence score (On radiography) [12] and according to cartilage abnormality (On MRI) [8-11] (Figure 2,3).

Figure 1d: Multiple definite osteophytes with medial joint space narrowing and subchondral sclerosis in KL grade 3 OA.

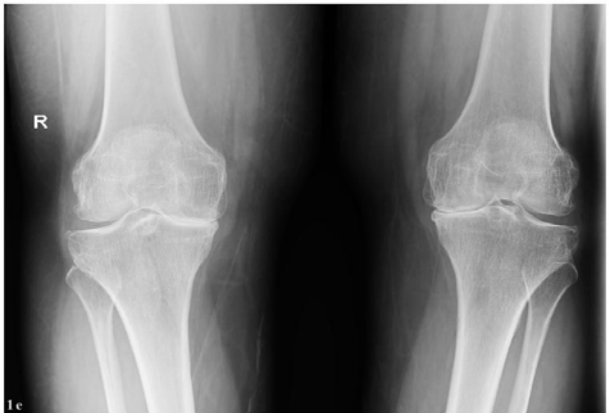

Figure 1e: Marked joint space narrowing (medial more than lateral) with multiple large osteophytes and subchondral sclerosis in KL grade 4 OA.

Figure 2a: Axial MERGE sequence of 55-year-old osteoarthritic female shows multiple large femoro-patellar and posterior femoral osteophytes (curved arrow). Large ganglion cyst (straight arrow) in popliteal fossa.

Figure 2b: Coronal PDFS image shows extrusion of medial meniscus (white arrowhead) with multiple osteophytes (curved arrow) in central sub region of medial and lateral, femoral and tibial aspects.

Figure 2c: Coronal PDFS image shows near total cartilage loss with cortical erosion (Grade IIIB) at anterior aspect of lateral tibial plateau (elbow arrow connector). Hyper intensity noted in lateral meniscus and deep fibers of lateral collateral ligament (curved arrow).

In the present study, a total of 50 patients with OA of knee were analysed. Mean age of the patients was found to be 52.8 years. There were 26 males and 24 females. According to Kellgren-Lawrence score, normal findings were observed in 48% of the patients while minimal to moderate findings were seen in 36% of the patients. Our results were in concordance with the results obtained by Hayes CW et al., who also reported similar findings in their study [27]. They reported that 17.2%, 8.2%, 19.5%, 19.8%, 20.8% and 14.7% of the patients had normal, Grade I, Grade IIA, Grade IIB, Grade IIIA and Grade IIIB defect of cartilage [27] (Figure 4,5). In another study conducted by Cubukcu D et al., authors reported that on the radiographic assessment with Kellgren-Lawrence score, 12 patients (10.5%) were of grade 1, 39 (34.2%) were of grade 2, 57 (50.0%) were of grade 3, and 6 (5.3%) had grade 4, showing that the subjects were mostly categorized as mild to moderate disease on radiographic assessment [28] (Figure 6,7).

In the present study, according to MRI findings, 4 patients (8%) showed intra cartilage high T2 signal intensity. 8 (16%) and 16 (32%) patients showed less than 50% and more than 50% cartilage defect with smooth underlying cortical bone. Near complete defect of cartilage of 100% with no bone ulceration were seen in 16 (32%) patients. Complete cartilage loss with underlying cortical irregularity was seen in 2 patients (4%). MRI imaging of the articular cartilage is particularly important, as articular cartilage degeneration is often cited as the structural hallmark of OA progression [29-31] (Table

Figure 2d-2f: Axial, coronal and sagittal PDFS images show Multiple small cysts adjacent to femoral attachment of medial head of gastrocnemius noted (straight arrow) and supra patellar synovitis (arrowhead). Multiple osteophytes (curved arrow).

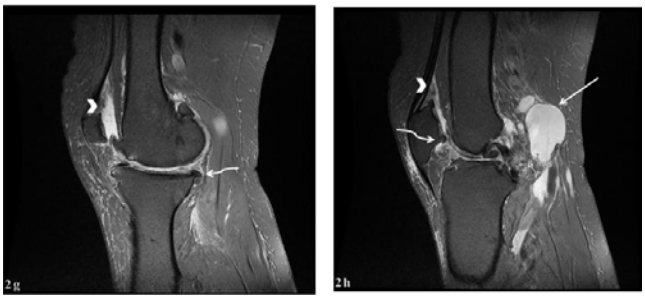

Figure 2g and 2h: Sagittal PDFS images show large ganglion cyst (straight arrow), supra patellar synovitis (arrowhead) and multiple osteophytes (curved arrow) along antero medial, postero medial aspect of tibia and femur and articular surface of patella. Chronic anterior cruciate ligament tear and moderate knee joint effusion also noted.

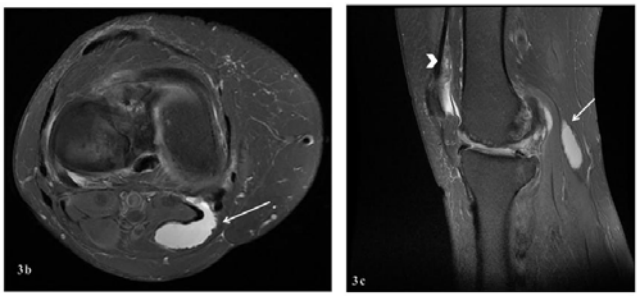

Figure 3b and 3c: Axial and sagittal PDFS image shows popliteal cyst (white arrow) between medial head of gastrocnemius and semimembranosus tendon, showing communicating neck with knee joint space. Hyper intensity in supra patellar fat with synovitis-effusion complex (white arrowhead).

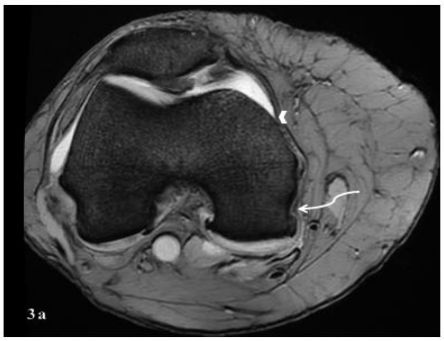

Figure 3a: Axial MERGE sequence shows large osteophytes on posterior aspect of medial femoral condyle (curved arrow). Moderate knee joint effusion (white arrowhead) with supra patellar synovitis and hyper intensity in medial patellar retinaculum.

Figure 3d: Coronal PDFS image shows osteophytes in central portion of medial and lateral femoral condyle with hyper intensity in medial meniscus, extending into medial collateral ligament (curved arrow).

5). A 2005 study by Amin et al. revealed that a significant number of symptomatic patients show cartilage loss on MRI even when joint space narrowing or disease progression is not visualized on radiography. In their study, radiographic progression was 91% specific but only 23% sensitive for cartilage loss [27,29].

MRI technology has evolved to provide quantitative information about the physiological content of articular cartilage. These developments have been useful in identifying early damage and breakdown. In OA, proteoglycan and collagen content are reduced. This disrupts the collagen network and results in increased water content and matrix degradation. Newer methods of MRI exploit these macromolecule changes to provide a quantitative understanding of the breakdown process. In general, fat suppression is useful in cartilage imaging because it results in a higher dynamic range of signal intensities in the articular cartilage and reduces or eliminates chemical shift artifacts [28-30].

Figure 3e: Sagittal PD shows near total cartilage destruction with subcortical bone irregularity (Grade IIIB) along anterior and central aspect of tibia (elbow arrow connector).

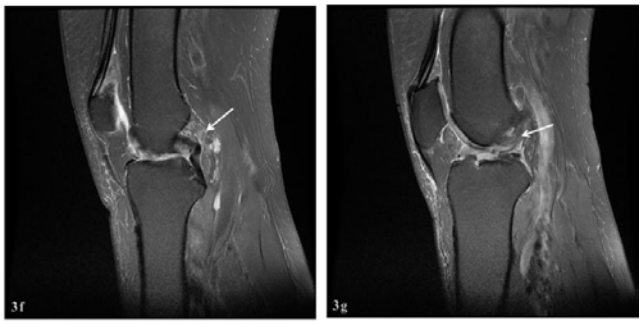

Figure 3f and 3g: Sagittal PDFS shows intra substance hyper intensity and irregularity in anterior and posterior cruciate ligament (white arrow) suggestive of tear.

Figure 4a: Coronal PDFS image shows extrusion of medial meniscus (curved arrow) and lateral meniscus (straight arrow) with hyper intensity in anterior cruciate ligament. Overall cartilage is thinned out, with smooth underlying cortex (Grade IIIA) (curved arrow).

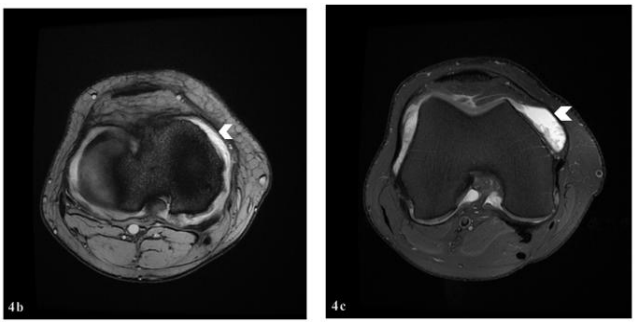

Figure 4b and 4c: Axial MERGE and PDFS image shows multiple osteophytes (predominantly along posteromedial aspect) with moderate knee joint effusion and supra patellar synovitis (arrowhead).

Figure 4d: Sagittal PDFS image shows moderate knee joint effusion with supra patellar synovitis (arrowhead). Intra substance hyper intensity noted in anterior cruciate ligament (elbow arrow connector).

Figure 5a and 5b: Sagittal PDFS images show moderate cartilage loss (50-99%) with smooth underlying cortex (Grade IIB). Intra substance hyper intensity noted in anterior cruciate ligament (straight arrow) and supra patellar fat pad (curved arrow).

Fernandez-Madrid et al published a study of 97 knees in 52 subjects with OA of the knee in which MRI imaging findings and radiographic evidence of OA of the knee were compared. They found a significant correlation between the MRI imaging parameters of synovial proliferation, meniscal abnormalities, defects of cartilage, effusion, subchondral lesions, and osteophytes and the radiographically determined Kellgren-Lawrence score [31]. Felson DT et al. determined whether bone marrow lesions on Magnetic Resonance Imaging (MRI) are associated with pain in knee osteoarthritis. They studied 401 patients (mean age, 66.8 years) with knee osteoarthritis on radiography. The prevalence of lesions in subjects with and without knee pain was compared. In participants with knee pain, the presence of lesions was correlated with severity of pain. Bone marrow lesions were found in 272 of 351 subjects (77.5%) with painful knees compared with 15 of 50 (30%) subjects with no

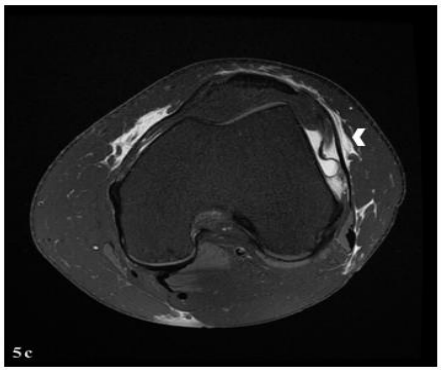

Figure 5c: Axial PDFS image shows partial tear of inner fibers of medial patellar retinaculum (arrowhead) with moderate knee joint effusion and edema in surrounding muscles.

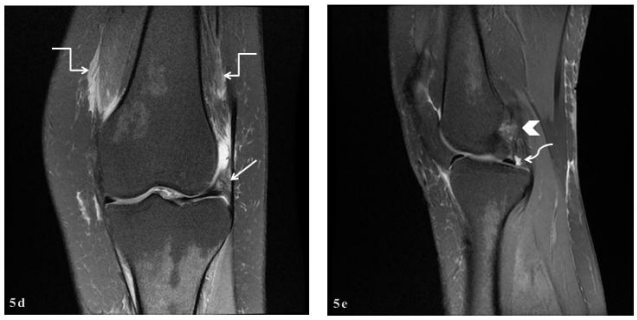

Figure 5d and 5e: Coronal and sagittal PDFS image shows hyper intensity in posterior horn of medial meniscus (straight arrow) with associated small para meniscal cyst (curved arrow). It is extending into deep fibers of medial collateral ligament. Soft tissue edema noted in muscle belly of vastus medialis, vastus lateralis (elbow arrow connector) and gastrocnemius.

Figure 6a and 6b: Sagittal and coronal PDFS image shows full thickness anterior cruciate ligament tear (straight arrow).

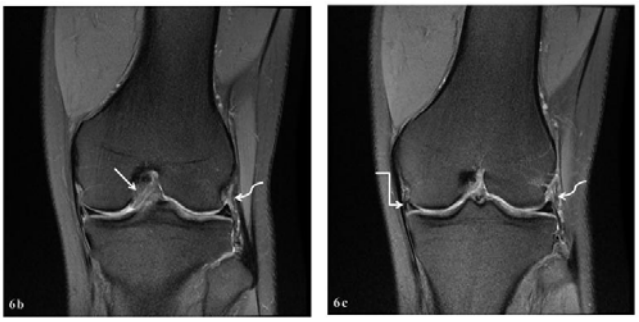

Figure 6b and 6c: Coronal PDFS images show intra substance hyper intensity noted in lateral collateral ligament (curved arrow) extending into lateral meniscus.

Figure 6c: Coronal PDFS image shows less than 50% thinned out cartilage (Grade IIA). Posterior horn of medial meniscus shows intrasubstance hyperintensity reaching upto articular surface (elbow arrow connector).

Figure 6d and 6e: Sagittal PDFS image shows few tiny ganglion cysts noted (arrowhead) at femoral attachment site of gastrocnemius muscle.

knee pain (P<0.001). Large lesions were present almost exclusively in persons with knee pain (35.9% *vs.* 2%; P<0.001). After adjustment for severity of radiographic disease, effusion, age and sex, lesions remained associated with the occurrence of knee pain. Among persons with knee pain, bone marrow lesions were not associated with pain severity. Bone marrow lesions on MRI are strongly associated with the presence of pain in knee osteoarthritis [4,13,29,30]. The ability of MRI to image all relevant joint tissues within the knee and to visualize cartilage morphology and composition has resulted in MRI playing a key role in understanding the natural history of the disease and in the search for new therapies [26,27].

Conclusions

OA is one of the most common pathologic conditions, causing pain and compromising on quality of life. From the above results, we conclude that and plain radiographs are still important in evaluating osteoarthritis of knee. Our institutional experience has provided better insight in local population subset, development of successful strategies for detection and prevention of progression. MRI plays a vital role in imaging the bony and soft tissues of knee as a whole organ. MRI is sensitive and specific tool in cases of OA and confirms

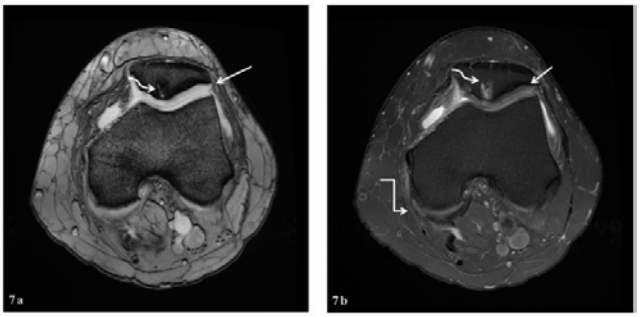

Figure 7a and 7b: Axial MERGE & PDFS image shows intra cartilage hyper intensity (Grade I) (straight arrow). However, no thinning or intra cartilage intensity noted. Bone marrow edema with intra osseous cyst noted in medial patellar facet (curved arrow) with moderate knee joint effusion.

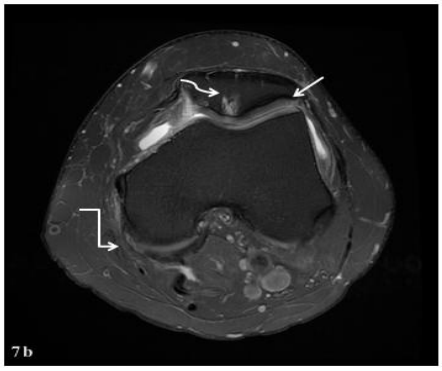

Figure 7b: Pes anserine bursitis is seen in axial PDFS image (elbow arrow connector) along medial aspect of medial femoral condyle.

Figure 7c: Coronal PDFS image shows intra osseous ganglion cyst (elbow arrow connector). Ill-defined hyper intensity in lateral collateral ligament (arrowhead) noted.

the percentage of degeneration, features and cartilage abnormality known in literature. With availability of disease-modifying interventions, and palliative procedures imaging plays an important role in clinical decision-making and practice.

Declarations

Ethics approval and consent to participate: Granted; Observational Study. The patients' information was kept confidential.

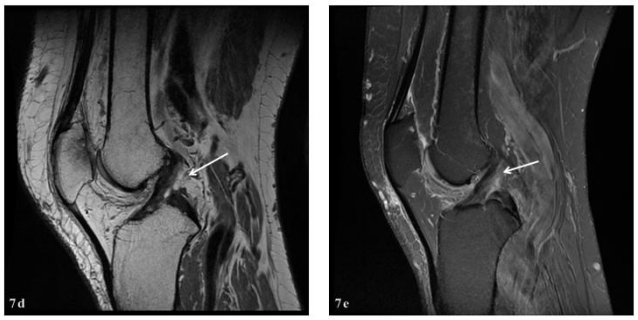

Figure 7d and 7e: Sagittal PD and PDFS images show intra substance hyper intensity and thinning of anterior cruciate ligament with complete tear of posterior cruciate ligament (straight arrow).

Table 5: Degenerative features distribution.

Joint feature	Number of Patients	Percentage of patients
Cartilage Degeneration	34	68%
Medial Menisci Tear	22	64%
Lateral Menisci Tear	20	59%
Anterior Cruciate Ligament Tear	30	88%
Posterior Cruciate Ligament Tear	12	35%
Medial Collateral Ligament Tear	10	29%
Lateral Collateral Ligament Tear	18	36%
Effusion	44	90%
Osteophytes	32	64.70%
Loose Bodies	12	24%
Supra Patellar Synovitis	40	82%
Infra Patellar Synovitis	32	64%
Poplitial Cyst	8	17%
Ganglion Cyst	20	41%
Parameniscal Cyst	8	17%
Pes Arserinus Bursitis	8	17%
Iliotibial Band Hyperintensity	6	12%

Consent for publication: The written informed consent was obtained from all research participants after a full explanation of the study.

Availability of data and materials: The datasets during and/or analysed during the current study are available from the corresponding author on a reasonable request.

Author's contributions: All the authors contributed in study design, data collection and contributed in drafting the manuscript. All authors have contributed in manuscript revision, read the manuscript, and approved its final version.

Acknowledgements: We would like to thank the Radiodiagnosis Department and Research Faculty for supporting this study.

References

1. Park HJ, Kim SS, Lee SY, et al. A practical MRI grading system for osteoarthritis of the knee: association with Kellgren-Lawrence radiographic scores. Eur J Radiol. 2013; 82: 112-117.

2. Chu CR, Millis MB, Olson SA. Osteoarthritis: From palliation to prevention: AOA critical issues. J Bone Joint Surg Am. 2014; 96: e130.

3. Heidari B. Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part I. Caspian J Intern Med. 2011; 2: 205-212.

4. Lawrence RC, Felson DT, Helmick CG, et al. National Arthritis Data Workgroup. Estimates of the prevalence of arthritis and other rheumatic conditions in the United States: Part II. Arthritis Rheum. 2008; 58: 26-35.

5. Hill CL, Gale DG, Chaisson CE, Skinner K, Kazis L, Gale ME, et al. Knee effusions, popliteal cysts, and synovial thickening: association with knee pain in osteoarthritis. J Rheumatol. 2001; 28: 1330e7.

6. Esser S, Bailey A. Effects of exercise and physical activity on knee osteoarthritis. Curr Pain Headache Rep. 2011; 15: 423-430.

7. Tanaka R, Ozawa J, Kito N, Moriyama H. Efficacy of strengthening or aerobic exercise on pain relief in people with knee osteoarthritis: a systematic review and meta-analysis of randomized controlled trials. Clin Rehabil. 2013; 27: 1059-1071.

8. Schreiner MM, Raudner M, Marlovits S, et al. The MOCART (Magnetic Resonance Observation of Cartilage Repair Tissue) 2.0 Knee Score and Atlas. Cartilage. 2019; 1947603519865308.

9. Jungmann PM, Welsch GH, Brittberg M, et al. Magnetic Resonance Imaging Score and Classification System (AMADEUS) for Assessment of Preoperative Cartilage Defect Severity. Cartilage. 2017; 8: 272-282.

10. Roemer FW, Guermazi A, Trattnig S, et al. Whole joint MRI assessment of surgical cartilage repair of the knee: Cartilage repair osteoarthritis knee score (CROAKS). Osteoarthritis Cartilage. 2014; 22: 779-799.

11. Hunter DJ, Guermazi A, Lo GH, Grainger AJ, Conaghan PG, Boudreau RM, et al. Evolution of semi-quantitative whole joint assessment of knee OA: MOAKS (MRI Osteoarthritis Knee Score). Osteoarthritis and cartilage. 2011; 19: 990-1002.

12. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957; 16: 494-502.

13. Felson DT, Lynch J, Guermazi A, et al. Comparison of BLOKS and WORMS scoring systems part II. Longitudinal assessment of knee MRIs for osteoarthritis and suggested approach based on their performance: data from the Osteoarthritis Initiative. Osteoarthritis Cartilage. 2010; 18: 1402-1407.

14. Roemer FW, Hunter DJ, Crema MD, Kwoh CK, Ochoa-Albiztegui E, Guermazi A. An illustrative overview of semi-quantitative MRI scoring of knee osteoarthritis: lessons learned from longitudinal observational studies. Osteoarthritis Cartilage. 2016; 24: 274-289.

15. Hunter DJ, Lo GH, Gale D, et al The reliability of a new scoring system for knee osteoarthritis MRI and the validity of bone marrow lesion assessment: BLOKS (Boston-Leeds Osteoarthritis Knee Score) Annals of the Rheumatic Diseases. 2008; 67: 206-211.

16. Hill CL, Hunter DJ, Niu J, Clancy M, Guermazi A, Genant H, et al. Synovitis detected on magnetic resonance imaging and its relation to pain and cartilage loss in knee osteoarthritis. Ann Rheum Dis. 2007; 66: 1599e603

17. Bacon K, LaValley MP, Jafarzadeh SR, et al .Does cartilage loss cause pain in osteoarthritis and if so, how much? Annals of the Rheumatic Diseases. 2020; 79: 1105-1110.

18. Wluka AE, Hanna F, Davies-Tuck M, et al. Bone marrow lesions predict increase in knee cartilage defects and loss of cartilage volume in middle-aged women without knee pain over 2 years. Ann Rheum Dis. 2009; 68: 850-855.

19. V Joshi, R Singh, N Kohli, U Parashari, A Kumar, V Singh. Evaluation of Osteoarthritis of The Knee With Magnetic Resonance Imaging And Correlating It With Radiological Findings In The Indian Population. The Internet Journal of Orthopedic Surgery. 2008; 14.

20. Akseki D, Pinar H, Oziç U. Cartilage defects of the knee joint: evaluation, classification, and natural course. Acta Orthop Traumatol Turc. 2007; 41: 25-31.

21. Crema MD, Roemer FW, Marra MD, Guermazi A. MR imaging of intra- and periarticular soft tissues and subchondral bone in knee osteoarthritis. Radiol Clin North Am. 2009; 47: 687-701.

22. Teichtahl AJ, Wluka AE, Davies-Tuck ML, Cicuttini FM. Imaging of knee osteoarthritis. Best Pract Res Clin Rheumatol. 2008; 22: 1061-1074.

23. Baranyay FJ, Wang Y, Wluka AE, et al. Association of bone marrow lesions with knee structures and risk factors for bone marrow lesions in the knees of clinically healthy, community-based adults. Semin Arthritis Rheum. 2007; 37: 112-118.

24. Bennell KL, Hinman RS. A review of the clinical evidence for exercise in osteoarthritis of the hip and knee. J Sci Med Sport. 2011; 14: 4-9.

25. Beckwée D, Vaes P, Cnudde M, Swinnen E, Bautmans I. Osteoarthritis of the knee: why does exercise work? A qualitative study of the literature. Ageing Res Rev. 2013; 12: 226-236.

26. Morrison JB. The mechanics of the knee joint in relation to normal walking. J Biomech. 1970; 3: 51-61.

27. Hayes CW, Jamadar DA, Welch GW, Jannausch ML, Lachance LL, Capul DC, et al. Osteoarthritis of the knee: comparison of MR imaging findings with radiographic severity measurements and pain in middle-aged women. Radiology. 2005; 237: 998-1007.

28. Cubukcu D, Sarsan A, Alkan H. Relationships between Pain, Function and Radiographic Findings in Osteoarthritis of the Knee: A Cross-Sectional Study. Arthritis. 2012: Article ID 984060.

29. Amin S, LaValley MP, Guermazi A, Grigoryan M, Hunter DJ, Clancy M, et al. The relationship between cartilage loss on magnetic resonance imaging and radiographic progression in men and women with knee osteoarthritis. Arthritis Rheum. 2005; 52: 3152-3159.

30. Felson DT, Chaisson CE, Hill CL, et al. The association of bone marrow lesions with pain in knee osteoarthritis. Ann Intern Med. 2001; 134: 541-549.

31. Fernandez-Madrid F, Karvonen RL, Teitge RA, Miller PR, Negendank WG. MR features of osteoarthritis of the knee. Magn Reson Imaging. 1994; 12: 703-709.