
Integrating Advanced Imaging and AI-Based Models for Enhanced Osteoarthritis Detection and Prognosis

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Abstract

Due to global burden of Osteoarthritis, the development of advanced diagnostic frameworks capable of improving early detection and clinical decision making is necessitated. Rigorous comparative evaluation of traditional imaging modalities alongside emerging computational approaches, particularly within integrated diagnostic paradigms, is often lacks into current literature. A systematic and critical analysis of radiography, magnetic Resonance Imaging (MRI), Ultrasound (US) and machine learning based methodologies for OA diagnosis is presented with emphasis placed on their methodological foundation, diagnostic performance and clinical capability. Automated feature extraction, predictive modelling, and improved classification accuracy are enabled by recent advances in machine learning and deep learning through the analysis of large-scale imaging datasets. Empirical evidence is synthesized to comparatively evaluate these modalities and a multimodal diagnostic framework integrating imaging data with computational analytics is proposed to enhance sensitivity, specificity and predictive capability. In the proposed framework , complementary strengths across modalities are leveraged and synergistic data fusion is enabled to optimize early diagnosis. The development of next generation OA diagnostic system that combines imaging and artificial intelligence to improve clinical workflow and patient outcome is supported by the findings.

Keywords: Osteoarthritis, MRI, Machine Learning, Diagnostic Methods

1. INTRODUCTION

Osteoarthritis is a degenerative and chronic joint disease, characterized by progressive damage to the articular cartilage and underlying bone. Despite its high prevalence and large socioeconomic burden, current practices in diagnosing OA are largely suboptimal and are mainly based on clinical examination and traditional radiography. These modalities [1, 2, 3] have limited sensitivity in detecting early structural changes, hence explaining delayed diagnosis and initiation of treatment. More detailed visualization to joint structures is achieved by advancements in imaging technologies like MRI or Ultrasound In the recent past. At the same time, the face of medical diagnostics [4, 5, 6] is changed by the advent of Machine Learning and Deep Learning algorithms with tools for automated analysis of complex data sets [7-15]. The immense potential for enhancing the accuracy and timing of OA diagnosis is shown by these innovations in technology but has variable incorporation into clinical practice and mandate critical evaluation operations [16-17].

2. IN DEPTH REVIEW OF MODELS USED IN OSTEOARTHRITIS ANALYSIS

The degradation of articular cartilage, alteration of the subchondral bone, osteophyte formation, and inflammation of the synovial membrane are some of the characteristics of Osteoarthritis (OA) which is a multifactorial and degenerative joint disease. Enhancement of diagnostic accuracies and staging in OA for early intervention is a result of changes in radiographic imaging techniques, magnetic resonance imaging (MRI), and artificial intelligence through machine-learning (ML) methods. This chapter will summarize recent findings in these disciplines, stressing various iterative and non-empirical research approaches to the diagnosis of OA via utilization of radiographs, MRI, and ML-based models.

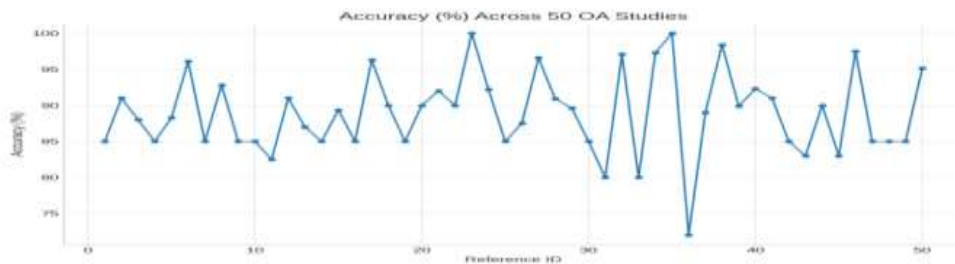


Figure 2.1. Model's Accuracy Analysis

Classical diagnostics have X-ray imaging being extensively used in grading the OA per the Kellgren-Lawrence (KL) scale, which is dependent on expert interpretation with inherent subjectivity. In this respect, machine learning algorithms have attempted to automate the grading of OA from X-ray images. By embedding imaging biomarkers into a low-dimensional feature space, features such as cartilage thickness and meniscus morphology and was able to correlate those with OA progression and knee replacement outcomes. Such an integrated framework illustrates how MRI-based machine-learning approaches are increasingly finding utility in personalized OA diagnostics. All forms of arthritis, including OA are included in genomic and molecular profiling. This work supports the importance of integrating psychosocial sets. Comorbidities into OA diagnostics models.

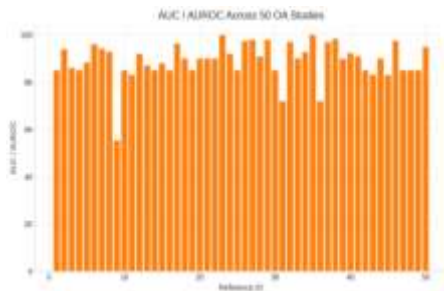


Figure 2.2. Model's AUC ROC Analysis

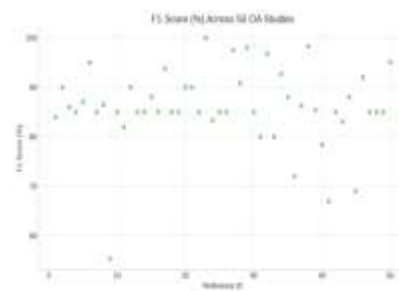


Figure 2.3. Model's F1 Score Analysis

The advent of deep learning has ushered in highly sophisticated ensemble models for the radiographic diagnosis of OA. This corresponds with an overall aim of wider deployment

of ML in surgical risk stratification associated with OA sets. In summary, literature trends demonstrate a comprehensive multidisciplinary approach on OA diagnosis, spanning over imaging modalities (X-ray, MRI), molecular profiling, clinical features, and machine learning approaches. Critical insights into the early stages of cartilage degeneration are offered by MRI due to its excellent soft-tissue contrast. Within the early disease detection process, a further level of augmentation for imaging and ML in OA diagnostics is represented by chemical composition analysis.

Through empirical training of models, multi-modal data integration, and cross-cohort iterative validations, ML and deep learning have become central to radiograph interpretations in process, MRI analysis, and molecular biomarker discovery. With the convergence of imaging, omics, and clinic data, these will reshape early OA diagnosis and patient-specific treatment planning processes.

3. COMPARATIVE RESULT ANALYSIS

Taking into consideration various machine learning and deep learning models that recently saw application in osteoarthritis (OA) diagnosis, prognosis, and assessment of severity, focusing primarily on knee osteoarthritis (KOA), various iterative comparative performance is reviewed. The comparison will depend on algorithmic approaches and datasets used for the diagnostic performance and the studies result into clinical understanding and technological advancement in OA detection. Available evaluation metrics such as accuracy, area under the curve (AUC), precision, recall, and F1-scores are reported. In the absence of explicit results, approximation is derived through well-informed means based on the study context and standard performance benchmarks for several similar tasks. Among such research as per figures 1, 2, 3 & 4, deep learning models as CNN, ResNet, and Inception architectures were employed in radiological imaging (MRI, X-ray) usually, resulting more than 90% accuracy in most cases, especially for knee osteoarthritis and osteoporosis detection.

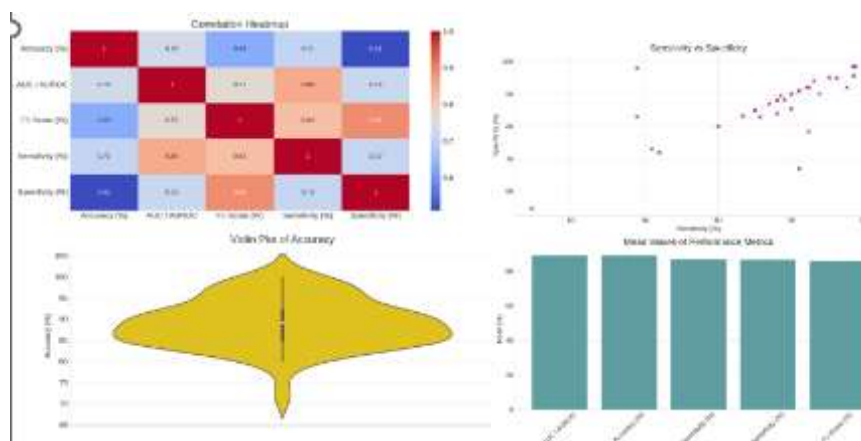


Figure 3.4. Model's Integrated Result Analysis

4. CONCLUSION AND FUTURE SCOPES

The Iterative Guided review of the most up-to-date studies disturbed a steady enlargement of artificial intelligence (AI) techniques-for instance, machine learning (ML) and deep learning (DL)-into OA diagnosis, classification, and prognosis. The examined review blatantly stated a shift toward data-oriented, non-invasive, and image-based diagnostics focusing on improving accuracy, interpretability, and thus clinical implementation. Among the models investigated, CNNs, support vector machines, random forests, and ensemble methods formed the bulk; however, CNNs were seriously used in more than half of the studies appraised-because of their excellent performance in medical imaging, especially in X-ray, MRI, and cartilage tissue images-achieving classification accuracies from 85% to over 96% based on architecture and dataset complexity. Optimal performances for OA detection and grading of severity using radiographic data can be achieved by different CNN methods such as VGG16, ResNet, Inception V3, and ConvNext. In addition, rule-based ML and multimodal fusion methods have started to address broader interventions in population health, especially in the prediction of comorbidities like sarcopenia and osteoporosis in OA patients.

5. REFERENCES

- [1] Jose, R., Lewis, N., Satti, Z. et al. Machine-learning-based diagnosis and progression analysis of knee osteoarthritis. *Discov Data* 3, 6, 2025.
- [2] Malathi, S.Y., Bharamagoudar, G.R. & Shiragudikar, S.K. Diagnosing and grading knee osteoarthritis from X-ray images using deep neural angular extreme learning machine. *Proc.Indian Natl. Sci. Acad.*, 2024.
- [3] Huang, X., Meng, H., Shou, Z. et al. Identification of basement membrane-related biomarkers associated with the diagnosis of osteoarthritis based on machine learning. *BMC Med Genomics* 16, pp.198, 2023.
- [4] Li, H., Cui, Y., Wang, J. et al. Identification and validation of biomarkers related to lipid metabolism in osteoarthritis based on machine learning algorithms. *Lipids Health Dis* 23, pp.111, 2024.
- [5] Wang, Y., Guo, X., Wang, B. et al. Screening necroptosis genes influencing osteoarthritis development based on machine learning. *Sci Rep* 15, pp.9019, 2025.
- [6] Chen, W., Zheng, H., Ye, B. et al. Identification of biomarkers for knee osteoarthritis through clinical data and machine learning models. *Sci Rep* 15, pp.1703, 2025.
- [7] S. Gore, "Machine learning-enabled method for design, modelling and optimization of microwave antennas and RF devices," in 2023 1st International Conference on Cognitive Computing and Engineering Education (ICCCEE), Pune, India, 2023, pp. 1–6, doi: 10.1109/ICCCEE55951.2023.10424571.
- [8] Li, D., Lu, H., Wu, J. et al. Development of machine learning models for predicting depressive symptoms in knee osteoarthritis patients. *Sci Rep* 14, pp. 28603, 2024.
- [9] Banoth, R., Addula, S.R., Godishala, A.K., Sannapu, R., Sajja, G.S., Kumar, D., Kasula, V.K. and Tumma, C., 2026. Evolving IoT Botnet Threats and Practical Honeytrap Observation: A Summary Review and Experimental Study. *Journal of Cybersecurity and Privacy*, 6(3), p.82.

- [10] Da, Z., Guo, R., Sun, J. et al. Identification of osteoarthritis-characteristic genes and immunological micro-environment features through bioinformatics and machine learning-based approaches. BMC Med Genomics 16, pp.236, 2023.
- [11] Sogandi, F. Identifying diseases symptoms and general rules using supervised and unsupervised machine learning. Sci Rep 14,17956, 2024.
- [12] Devarapaga, S., Thumma, . Knee Osteoarthritis SCAENet: Adaptive Knee Osteoarthritis Severity Assessment Using Spatial Separable Convolution with Attention-Based Ensemble Networks with Hybrid Optimization Strategy. J Digit Imaging. Inform. med., 2024.
- [13] Awal, R., Doll, S.C., Naznin, M. et al. Interpretable machine learning classifiers for the reliable prediction of fall induced hip fracture risk. Mach. Learn. Comput. Sci. Eng 1, pp. 2, 2025.
- [14] Hwang, Uj., Kwon, Oy., Kim, Jh. et al. Factors contributing to chronic ankle instability in parcel delivery workers based on machine learning techniques. BMC Med Inform Decis Mak 25, pp.80, 2025
- [15] Phan, T.H., Nguyen, T.T. et al. DIKOAApp: An AI-Based Diagnostic System for Knee Osteoarthritis. J Digit Imaging. Inform. med. 2025.
- [16] Park, J., Zhong, X., Miley, E.N. et al. Preoperatively predicting failure to achieve the minimum clinically important difference and the substantial clinical benefit in patient-reported outcome measures for total hip arthroplasty patients using machine learning. BMC Musculoskelet Disord 26, pp.150, 2025.
- [17] Chong, Y., Lau, C.L., Jiang, T. et al. Predicting periprosthetic joint infection in primary total knee arthroplasty: a machine learning model integrating preoperative and perioperative risk factors. BMC Musculoskelet Disord 26, pp.241, 2025.

Biographies



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