***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

Prediction of Osteoarthritis in the Knee by KOA Diagnosis Using Artificial Intelligence Based Techniques

Ramya Praba
PG Scholar, Department of Computer Science and Engineering
Panimalar Engineering College
Chennai, India
e-mail: ramyapraba005@gmail.com

Dr. K. Valarmathi
Professor, Department of Computer Science and Engineering
Panimalar Engineering College
Chennai, India
e-mail: valarmathi_1970@yahoo.co.in

N.Sivakamy
Assistant Professor, Department of Computer Science and Engineering
Panimalar Engineering College
Chennai, India
e-mail: sivakamyn@gmail.com

S.Muthukumarasamy
Associate Professor, Department of Computer Science and Engineering
S.A Engineering College
Chennai, India
e-mail: muthukumarasamy@saec.ac.in

Abstract—Knee Osteoarthritis is the most common form of knee arthritis. A healthy knee's articular cartilage, a smooth, slick tissue, allows for simple bending and straightening. The ends of the leg bones that make up your knee are covered, safeguarded, and cushioned by this material. Two c-shaped segments of meniscal cartilage between your bones serve as "shock absorbers" to cushion your knee joint. Osteoarthritis develops gradually. The cartilage becomes rough and ragged as it ages. It hurts to move the bones along this exposed area. The most prevalent signs and symptoms of knee osteoarthritis are pain and stiffness. After being inactive for a while or in the morning, symptoms typically worsen. The earlier you begin treatment, the better, as osteoarthritis gets worse with time. Your doctor may prescribe additional tests after reviewing your symptoms and medical history, such as X-rays, which can reveal bone and cartilage damage as well as the existence of bone spurs, and magnetic resonance imaging (MRI) scans. So, the KOA diagnosis will be based on two modalities: X-rays and MRIs. Depending upon the patient's opinion about their knee problems, the doctor will decide whether to take X-rays or MRIs for KOA diagnosis.

To avoid such severe knee issues, researchers used many various techniques for KOA diagnosis in the existing system in order to treat it at an early stage of knee problems. In order to do that, we conducted a survey of research articles based on the KOA diagnosis published in the years 2021 and 2022 for this work. From the conducted survey, the methodologies which are AI-based techniques used for KOA diagnosis are discussed and their performance metrics are compared. The current review paper's goal is to do research on the various KOA diagnosis approaches employed in the years 2021 and 2022. As a result of this study, the methodologies which are AI-based techniques used for KOA diagnosis achieves good efficiency in predicting the osteoarthritis in the knee.

Keywords-knee, osteoarthritis, AI-based techniques, KOA diagnosis, prediction

I. INTRODUCTION

Osteoarthritis is the greatest common form of arthritis, and the knee is one of the greatest commonly troubled joints. Everybody's joints experience a consistent cycle of injury and curative over the course of a lifetime, but occasionally, the body's attempt to restore our joints can result in alterations to their structure or form. Osteoarthritis is the medical term for these changes that take place in one or more of your joints. A joint is a place on the body where two or more bones touch, and in your knee, the thigh and shin bones combine. A little bone located in the front of the knee is called the patella, also referred to as the knee cap. The smooth, silky surface of cartilage protects the ends of our bones (car-ti-lidge). Your joint won't be put under tension, and the bones can move against one another without rubbing. Your knee also features cartilage beneath your kneecap and two additional rings of a particular type of cartilage known as menisci or meniscus that help the knee joint bear weight evenly.

As a result of osteoarthritis, the cartilage in your knee joint thins and the joint surfaces turn out to be rougher, which makes the knee move less evenly than it should and may make it feel unpleasant and inflexible. Osteoarthritis can attack at any age, however it is more common in women over 50. Osteoarthritis can increase a person's risk of injury or other joint issues, such gout. Our parental DNA may potentially enhance the likelihood of developing the illness. Another cause of osteoarthritis is being overweight, which places greater stress on weight-bearing joints like your knees. You may likely have occasional pain and stiffness in your knee if you have osteoarthritis of the knee. It might only be in one knee, especially if you've previously hurt it, or it might be in both. When you move your knee or towards the end of the day, the pain could feel worse, and it might get better when you take a nap. In the morning, you can feel stiff, but this normally passes after 30 minutes. Your knee may hurt all throughout or just in the front and sides, for example. Following a certain motion, such as ascending or descending stairs, your knee may hurt more. People occasionally experience pain that causes them to wake up at night. There's a good chance that the pain may change and that you'll have good and bad days. You might notice that your knee doesn't move as easily or as far as it typically does, or that it grunts or crunches as you do. On occasion, your knee may seem larger. There are two potential causes for this: • Hard swelling: osteophytes are bony spurs that occur when the bone at the edge of a joint raises outward (os-tee-o-fites). • Soft swelling: Also known as an effusion or "water on the knee," this condition occurs when a joint becomes inflamed and secretes additional fluid. Sometimes knee osteoarthritis might result in weakened thigh muscles, making your leg appear slimmer. Due to this weakening, the knee may give way when you put weightiness on it and the joint may seem unstable. People with osteoarthritis may have anxiety or depressive symptoms, and their relationships and sleep may also be affected. Tell your doctor if you have any issues like these since there are things they can do to help. Age is the prime factor in knee osteoarthritis. Osteoarthritis will eventually affect nearly everyone in some way.

However, a number of factors grows the possibility of severe arthritis at a younger age, including: Age - As a person ages, their cartilage's capacity for healing declines, Weight: Carrying extra burden puts more strain on all joints, but particularly the knees. For every pound you gain, your knees will carry an additional 3–4 pounds. Due to genetics, genetic mutations may raise a person's risk of getting knee osteoarthritis. It could also be the result of genetic variations in the way the bones surrounding the knee joint are built. Age-related osteoarthritis of the knee is more general in women than in males between the ages of 55 and 64. Repetitive stress disorders: People often get these conditions as a result of the jobs they have. People who work in certain sectors that demand a lot of kneeling, squatting, or moving large goods (55 pounds or more) are more prone to develop osteoarthritis of the knee because of the persistent stress on the joint. Athletics - Tennis players, soccer players, and long-distance runners may be more susceptible to developing knee osteoarthritis. That suggests that players should take precautions to avoid getting hurt. It's important to keep in mind that regular, moderate exercise can reduce the risk of osteoarthritis while strengthening joints. In actuality, weak knee muscles might contribute to osteoarthritis. Other ailments - Rheumatoid arthritis, the second most common type of arthritis, increases the risk of developing osteoarthritis. Additionally, osteoarthritis is more prevalent in those with particular metabolic issues, such as an overabundance of growth hormone or iron.

Your doctor will perform a physical examination to begin the process of diagnosing knee osteoarthritis. In addition, your doctor will record any symptoms and collect a medical history. To assist your doctor in determining whether osteoarthritis or another condition may be the source of your pain, be sure to keep track of what makes it worse or better. Identify any other family members with arthritis. Your doctor may request additional tests, including magnetic resonance imaging (MRI) scans and X-rays, which can reveal bone and cartilage damage as well as the existence of bone spurs. X-rays and MRIs are the two techniques used for KOA diagnosis. The research publications based on the KOA diagnosis that were published in the years 2021 and 2022 were surveyed for this paper. From the conducted survey, the methodologies which are AI-based techniques used for KOA diagnosis. The KOA is diagnosed by various methodologies which are AI-based techniques. The AI-based techniques used for finding the OA features in the X-rays and MRIs more accurately in order to predict whether the knee image (X-ray or MRI) has osteoarthritis or not. Our survey works on the research articles based on the KOA diagnosis are discussed in the section of related work.

II. RELATED WORKS

In this section, we have made a survey work on the research articles based on the KOA diagnosis in the year of 2021 and 2022. The Various methodologies which are AI-based techniques used for KOA diagnosis to predict osteoarthritis in the knee. With fine-grained clinical X-ray imaging data, *Hu, Kun, et al.* [1] applied the Adversarial Evolving Neural Network (A-ENN) technique for long KOA categorizing. An input image is compared to prototype images of various KL grades using convolution and deconvolution computations, and ENN uses the progression patterns to precisely define the disease as it evolves from a mild to severe degree. To obtain the evolution traces, a discriminator-based adversarial training strategy is also constructed. The evolution traces should be further integrated with the generic convolutional picture depictions for longitudinal grading, which serve as fine-grained domain knowledge. Remember that ENN can be used to a variety of learning tasks in conjunction with deep architectures that already exist, with results characterised by progressive

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

representations.

A GAN model with a hierarchical framework (HieGAN) was used by *Gan, Hong-Seng, et al.* [2] to create improved synthetic knee pictures that effectively served as an extension of training data for deep learning applications. In order to acquire salient information from knee images during training, the suggested framework used an attention mechanism prior to the 256 256 scale in the generator and discriminator. The training performance of HieGAN was then stabilised using an unique pixelwise-spectral normalisation setup. The Generative Adversarial Network is an effective unsupervised training technique (GAN). It creates novel outputs based on the basic structural information in the training data while learning the pattern of the incoming samples. Therefore, GANs are very beneficial for the synthesis of medical imagery. Artificial medical image-based augmentation may be able to address the rigidity of conventional augmentation and the absence of physically marked data. Furthermore, no particular patient image information is connected to fake medical photographs. Data privacy regulations are not broken when data is shared for repeatability.

Wang, Yifan, et al. [3] used the method of hybrid loss function focusing on the OA dataset's label uncertainty to aid CNN in learning from the highly reliable sample data. There are two stages to the suggested training plan. We first extract the label confidence data before moving on to the label confidence evaluation stage. We utilise it to clean the samples prior to model training. hybrid loss function that highlights the value of extremely reliable samples. To decrease the influence of experiential mistakes, we regulate the effects of the little assured samples using a weight parameter rather than deleting them. The results show that on the five-class OA evaluation job, we perform at a cutting-edge level. We can compete with the semi-automatic method without using a person in the early-stage OA detection challenge.

In order to determine the directional bias of the asymmetry between the medial and lateral compartment knee joint loads in healthy individuals, *Jeong, Hyeon Ki, et al.* [4] introduced the concept of joint acoustic emissions (JAE). This involved recording and analyzing knee acoustical emissions using a deep neural network in a subject-independent model. Acoustic signals may be able to decide the direction of medial to lateral load distribution, according to research by Jeong, Hyeon Ki, et al. [4]. This study has implications for the optimal rehabilitation activities to perform without stressing one side and wearable sensing devices that monitor cartilage health and elements that cause cartilage breakdown. Jeong, Hyeon Ki, et al. [4] investigated whether the acoustic emissions can be used to detect changes in the medial to lateral load distribution on healthy subjects without any known history of injuries in order to lessen the impact of the unknown parameters that could affect these load changes, such as age, since degeneration of the knee is a natural process that can happen as people age. Consequently, we have demonstrated for the first time that JAEs can be utilized to evaluate any imbalance or asymmetry between the medial and lateral compartment joint contact forces during squats in physically fit and healthy persons.

Yang, Hee Doo, et al. [5] present a wearable soft robotic exosuit that tests the reduction of KAM by applying a hip abduction torque. An adaptable cable actuation system allows the exosuit to produce torque when needed while being unrestrictive when powered off. The knee adduction moment can be utilized to evaluate the load on the medial compartment hypothesized to contribute to OA (KAM). Enhancing hip abduction instant, or the torque in the front plane about the hip joint, is another method for lowering KAM that has been discussed in the literature. During the single-support stance phase of walking, the hip abductor muscles produce a torque that prevents the pelvis from rotating about the femur in the front plane. These preliminary results demonstrate that the system can consistently alter walking biomechanics.

Smolle, Maria Anna, et al. [6]. introduce the software, called KOALA (Knee Osteoarthritis Labeling Assistant), provides metrics for evaluating anterior posterior (AP) or PA knee X-rays as well as recommendations for clinical OA grade. These suggestions ought to make it easier for medical professionals to assess whether adult patients have knee OA or are at risk of developing it. The deployment of AI-based KOALA software enhances the radiological judgment of senior orthopedic surgeons with regard to X-ray characteristics suggestive of knee OA and KL grade, as shown by the agreement rate and overall accuracy in contrast to the ground truth. Senior readers who used aided analysis also had accuracy and agreement rates that were equivalent to junior readers. As a result, expanding the usage of AI-based technologies could improve healthcare.

Liu, Weiqiang, et al. [7] used the method of FOL to overcome CEL and FPL's limitations in the Kellgren-Lawrence knee osteoarthritis grading task. By lowering the load of the simple-to-divide specimen at the subsequent epoch, the focused ordinal loss concentrates the challenging data in each training iteration. Additionally, CBAM is added to our model, and several data-increment techniques are used. The studies with a few traditional CNN network models demonstrate that the fixed penalty weights loss and cross-entropy loss are outperformed by the focused ordinal loss.

An approach for choosing features based on fuzzy logic that integrates the output of many FS algorithms is presented by *Kokkotis, Christos, et al*. [8]. (filter, wrapper and embedded). Multiple feature relevance scores are combined using fuzzy logic, producing a extra strong range of pertinent features. This method is used to handle the OAI dataset's multidimensionality, get rid of bias, and lessen the shortcomings of results from single feature selection. The suggested approach significantly lowers the dimensionality of the original OAI features and contributes to lowering the measurable difficulty of the used classification models. Each of the six FS strategies that were independently implemented and compared to the performance of the presented FLFS technique. Last but not least, another recently published FS approach that used the last characteristic was also chosen as a comparator.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

DeepKneeExplainer, a new explainable approach for diagnosing knee OA hinged on radiographs and magnetic resonance imaging, is presented by *Karim, Md Rezaul, et al.* [9]. (MRI). Prior to domain generalisation, we thoroughly pre-process MRIs and radiographs using the deep-stacked transformation method to eliminate any artefacts and sounds that might contain hidden images. A U-Net architecture with ResNet at its core is then used to obtain the ROIs. On the retrieved ROIs, we train DenseNet and VGG architectures to categorize the cohorts. We next highlight regions that distinguish between various classes using gradient-guided class activation mappings (Grad-CAM++) and layer-wise relevance propagation (LRP), and we explain the predictions in simple terms. Finally, rather than focusing solely on segmentation or classification accuracy, our strategy improved the interpretability of the OA diagnosis results, increased generalization through domain adaptation, and optimized each neural network design to reduce the computing cost. Additionally, we want to mention a few of our study's limitations: First off, some misclassifications are the result of excessive ROI area designations due to an absence of medical expertise. To improve performance, ROI calibration for decision visualization or even radiologists' recommendations may be helpful. Second, even though huge data sets are needed for training with DNN architectures, overfitting cannot be completely ruled out. Thirdly, the GradCAM++-identified class-discriminating regions do not necessarily reflect the grade attached to a region. Fourth, because of outside factors, we have not yet had radiologists confirm the accuracy of the diagnosis and localization.

Guan, Bochen, et al.[10] in order to forecast the evolution of pain using baseline knee radiographs, a DL model was created. An artificial neural network was utilized to create a conventional risk evaluation model that uses demographic, clinical, and radiological risk indicators to forecast how pain will progress. The DL analysis of baseline knee radiographs was coupled with demographic, clinical, and radiographic risk factors in a combination model.

III. METHODOLOGY

In the methodology section, we have compiled various methodologies which are used for KOA diagnosis and prediction that we surveyed and gives you the generalized or overall structured format about the prediction process in the KOA diagnosis. The data collection is the first step in the diagnosis and prediction of KOA, according to the study we conducted for the survey. As per study, it is viewed that the data collection process from various methodologies mostly involves two sources: MOST (Multicenter Osteoarthritis Study) and OAI (Osteoarthritis Initiative). Next process is data analysis and preprocessing. Data analysis is analyzing how the data is and preprocessing it by taking only necessary data from it by removing unwanted data like null values, noise, missing data etc from the images. The procedure begins by importing the required packages, such as numpy, pytorch, flask, matplotlib, pillow, torchvision, and numpy, which are used to create the arguments and parse them. Preprocessing is the process of modifying or altering data via a series of steps. Our data underwent this processing before being fed to an algorithm. The act of retrieving, transforming, or otherwise altering data is denoted to as data handling. It is a method for transforming unclean data into collections of clean data. To put it another way, when data are collected from numerous sources, they are unprocessed, which makes analysis impossible. Data cleaning, which is a component of data preprocessing, refers to methods for "cleaning" data by doing things like replacing missing values, smear out noise, smooth out noisy data, and fix inconsistent data. Each of these activities is carried out using a variety of approaches. Raw data are transformed into understandable and useful forms through the iterative process of data preparation. Original or raw datasets are regularly characterized by inaccuracies while also being irregular, missing in behavior and patterns, and being incomplete. To manage missing values and accord with discrepancies, pre-processing is necessary. Data preprocessing involves contrast improvement, edge enhancement, noise elimination and multi-slice integration.

Contrast improvement: Images with pronounced darker or brighter areas have a contact on the accuracy of the osteoarthritis evaluation. By extending the gap between dark and light areas without significantly distorting them, contrast enhancement can get clearer images in this situation. Edge enhancement: Unsharp masking and edge enhancement techniques that combine the spatial and frequency domains were discovered to be the most widely used techniques for sharpening images. To construct the fuzzy unsharp mask, the signal is combined with the weighted high-pass filtered original image. Convolution matrices are used in image filters to "sharpen" and "edge enhance" images. Due to its high propensity to amplify noise in real-world situations, the kernel method's "edge enhancement" was not taken into consideration. Single contrast enhancement was taken into consideration because HGE and picture sharpening are compatible. Noise elimination: Impulse and other types of noise are becoming less common in biomedical imaging because of technological developments. Therefore, median filters were not used in our study to quantify OA. Instead, PMF is used because it may reduce noise while preserving edges and intricate structures with the appropriate diffusion and gradient threshold. Multi-slice integration: In order to calculate the arithmetical mean of the associated pixels for multi-slices, an average filter is used. And also this includes, but is not limited to, changes in color, size, and direction. Pre-processing works to improve the image's quality so we can analyze it more thoroughly. Through preprocessing, we can eliminate undesired distortions and enhance particular qualities that are crucial for the application we are developing. Those qualities could alter based on the application. For software to work properly and deliver the required results, an image must be preprocessed.

After data preprocessing, here the vital role plays that the prediction process starts after the data gets prepared for the required task. From study, most of the methodologies employs AI-based algorithms (deep learning algorithms and machine

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

learning algorithms) to detect and extract the Osteoarthritis (OA) features such as osteophytes, joint space width (JSW) decreasing, subchondral sclerosis, cysts, & bone spurs from a knee picture input is required in order to forecast osteoarthritis in the knee if OA features present in the knee. It is observed that deep learning algorithms are more accurate in predicting osteoarthritis in the knee than the machine learning algorithms. As per study, most of the methodologies use radiographs (X-rays) for KOA diagnosis and few only using MRI for KOA diagnosis. And some methodologies using both X-rays and MRIs for KOA diagnosis for accuracy comparison in KOA diagnosis and prediction. In that, the modality of X-rays achieves more accuracy in KOA diagnosis. Here, the osteoarthritis in the knee were diagnosed and predicted by various methodologies are A-ENN (Adversarial evolving neural network), HieGAN (Generative adversarial network (GAN) model with hierarchical framework), Hybrid loss function, JAEs (Joint Acoustic Emissions), robotic exosuit devices to reduce KAM (Knee Adduction Moment), AI-based KOALA (Knee OsteoArthritis Labeling Assistant), FOL (Focal Ordinal Loss), FLFS (Fuzzy Logic-enhanced Feature Selection), DeepKneeExplainer and DL based risk assessment model. Therefore, the KOA diagnosis and prediction using these several algorithms and methodologies were effectively done which we studied earlier. The structural diagram for KOA prediction in a generalized perspective is the following of figure 3.1

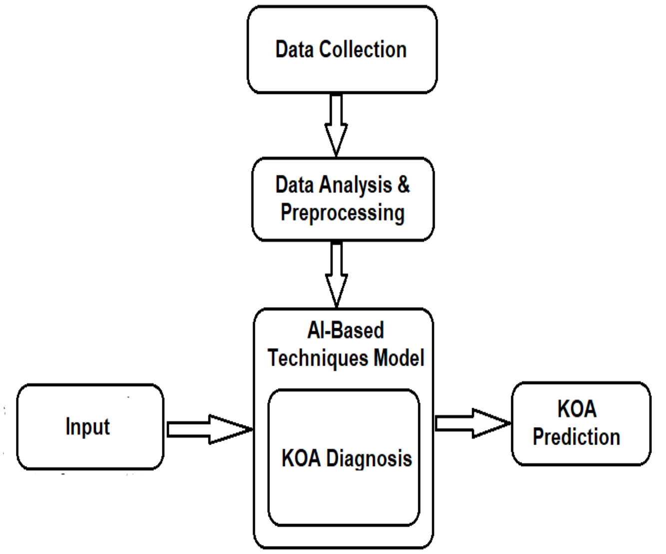

Figure 3.1 Structural diagram of KOA prediction

IV. PERFORMANCE METRICS

Based on the study of each algorithm and methodologies, we can observe that they have achieved their best level of performance in their methodologies according to their perspective. The performance metrics of several methodologies are ACC and MAE from [1], ACC and MCC from [3], ACC from [4], ACC, sensitivity and specificity from [6], MSE from [7], ACC, Precision, Recall and F1 Score from [8], ACC, precision, F1 score & recall from [9], and AUC from [10]. From which, we have obtained only one common performance metric from several methodologies is ACC (accuracy %). The simple ratio of correctly identified points to all points is known as the accuracy correlation coefficient (ACC). "Accuracy" is the most frequently used classification evaluation metric. Accuracy (ACC) describes how the model performs across all classes.

To calculate accuracy,

$$\text{Accuracy} = \frac{\text{Number of correct predictions}}{\text{Total number of predictions}}$$

Source adapted from [11]

$$Accuracy = \frac{TrueNegatives + TruePositive}{TruePositive + FalsePositive + TrueNegative + FalseNegative}$$

Source adapted from [12]

From the study which we made earlier, we have obtained accuracy from various methodologies are presented in the following table 4.1

METHOD	ACC
A-ENN	0.627
Hybrid Loss Function	0.7013
JAE	0.83
AI-Based KOALA	0.88
FLFS	0.7355
DeepKneeExplainer	0.6956

Table 4.1: Accuracy (ACC) comparison on various methodologies

The table format (Table 4.1) representation of Method and ACC is shown as the column chart below (Figure 4.1).

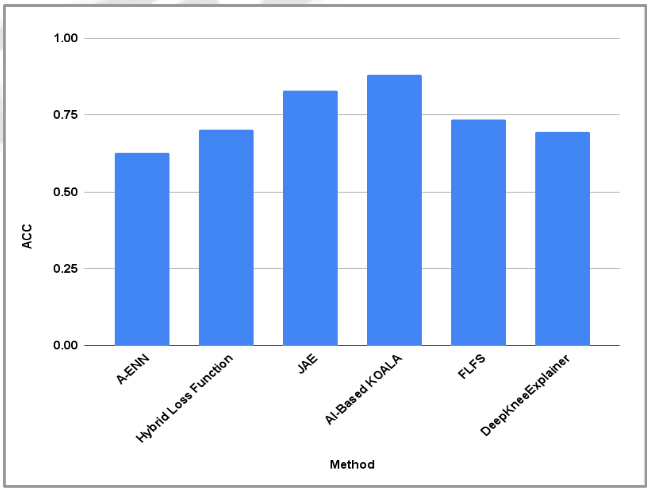

Figure 4.1: Bar chart for accuracy (ACC) comparison on various methodologies

From figure 4.1, we can compare and conclude that the method of AI-Based KOALA (Knee OsteoArthritis Labeling Assistant) has higher accuracy (ACC) than the others. Therefore, the AI-Based KOALA method has higher accuracy in diagnosis and prediction of knee osteoarthritis in the knee.

V. RESULTS AND DISCUSSION

Finally, we made a study on the various methodologies which are AI-based techniques used for KOA diagnosis in order to predict the osteoarthritis in the knee. The various methodologies which we studied in this paper were implemented with good efficiency. The OA features which are the causes for the knee osteoarthritis were predicted more accurately in each methodologies. But still there are some drawbacks in each methodologies. To overcome the drawbacks, we can provide the more robust algorithms in order to achieve the highest accuracy in diagnosis and prediction of osteoarthritis in the knee.

VI. CONCLUSION

In this paper, a comparative study was made among the several methodologies. This study proposes several methodologies and algorithms for KOA diagnosis to predict the osteoarthritis in the knee. Each and every methodologies which we studied earlier were implemented and worked in an efficient way. The summarized procedure for KOA diagnosis to predict OA in knee is data collection, data analysis and preprocessing, load the preprocessed data into the AI-based techniques model for KOA diagnosis in order to detect and extract the OA features such as Osteophytes, Joint Space Width (JSW) decreasing, Subchondral Sclerosis, cysts, and bone spurs from the knee and predict the osteoarthritis in the knee if the OA features present in the knee. Also, the performance metrics among various methodologies were compared and analyzed based on the accuracy (ACC) metric and concluded with the best methodology. Finally, this comparative study proposes the best methodology based on the AI-based techniques for KOA diagnosis to predict the osteoarthritis in the knee.

1. REFERENCES

[1] Hu, Kun, et al. "Adversarial Evolving Neural Network for Longitudinal Knee Osteoarthritis Prediction." IEEE Transactions on Medical Imaging (2022).

[2] Gan, Hong-Seng, et al. "Hierarchical Knee Image Synthesis Framework for Generative Adversarial Network: Data from the Osteoarthritis Initiative." IEEE Access (2022).

[3] Wang, Yifan, et al. "Learning From Highly Confident Samples for Automatic Knee Osteoarthritis Severity Assessment: Data From the Osteoarthritis Initiative." IEEE Journal of Biomedical and Health Informatics 26.3 (2021): 1239-1250.

[4] Jeong, Hyeon Ki, et al. "Quantifying Asymmetry Between Medial and Lateral Compartment Knee Loading Forces Using Acoustic Emissions." IEEE Transactions on Biomedical Engineering 69.4 (2021): 1541-1551.

[5] Yang, Hee Doo, et al. "A soft exosuit assisting hip abduction for knee adduction moment reduction during walking." IEEE Robotics and Automation Letters 7.3 (2022): 7439-7446.

[6] Smolle, Maria Anna, et al. "Artificial intelligence-based computer-aided system for knee osteoarthritis assessment increases experienced orthopaedic surgeons' agreement rate and accuracy." Knee Surgery, Sports Traumatology, Arthroscopy (2022): 1-10.

[7] Liu, Weiqiang, et al. "A Novel Focal Ordinal Loss for Assessment of Knee Osteoarthritis Severity." Neural Processing Letters (2022): 1-26.

[8] Kokkotis, Christos, et al. "Explainable machine learning for knee osteoarthritis diagnosis based on a novel fuzzy feature selection methodology." Physical and Engineering Sciences in Medicine 45.1 (2022): 219-229.

[9] Karim, Md Rezaul, et al. "DeepKneeExplainer: explainable knee osteoarthritis diagnosis from radiographs and magnetic resonance imaging." IEEE Access 9 (2021): 39757-39780.

[10] Guan, Bochen, et al. "Deep learning approach to predict pain progression in knee osteoarthritis." Skeletal Radiology 51.2 (2022): 363-373.

[11] https://hasty.ai/docs/mp-wiki/metrics/accuracy

[12] https://rukeshlekkala.medium.com/how-to-evaluate-classification-models-accuracy-precision-recall-f1-score-covariance-1e957f3be59a