PREDICTION OF KNEE OSTEOARTHRITIS USING MACHINE LEARNING ENHANCED FINITE ELEMENT MODELING APPROACH – DATA FROM OSTEOARTHRITIS INITIATIVE

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Introduction

Osteoarthritis (OA) is the most common degenerative joint disease, and its prevalence increases with aging population. Currently, there is no cure and only the symptoms, e.g., pain and inflammation, are treated. The problem with OA is its inevitable progression with time. The best option for reducing the number of OA patients would be disease prevention, which would, however, require identification of the patients with risk of OA.

During recent years, artificial intelligence solutions based on, e.g., machine learning (ML) have developed rapidly and are used for various purposes, including prediction of diseases. Several ML based approaches on prediction of OA have also been suggested [1]. Finite element modeling (FEM) -based prediction of OA development has also been introduced [2]. There are no studies that compare these approaches equally or try to combine them. The aim of this study was to provide first insights into the classification accuracies between those two approaches (FEM vs. ML) to predict knee OA and future potential when merging these novel approaches.

Methods

Knee shape and cartilage thickness (dimensions) and angles (Fig. 1) were measured from anteroposterior radiographs of 1222 radiographically healthy knees (exclusion criteria in Fig. 2) taken at baseline from Osteoarthritis Initiative Database (OAI, http://nda.nih.gov/oai). The knees were divided into three groups based on their OA severity (KL grade [3]) at 8-year follow-up: **KL01** (N=950): KL grades 0 and 1, **KL2** (N=140): KL grade 2, **KL34** (N=132): KL grades 3, 4, and total knee replacement. All measurements were done using an in-house Matlab (v. R2019b, MathWorks Inc.) graphical user interface.

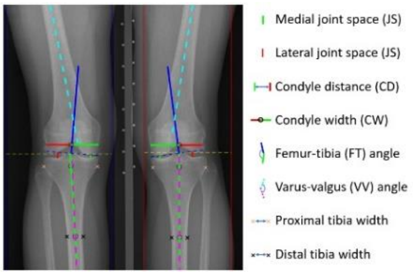

Figure 1: Knee dimensions and angles measured from the antero-posterior knee radiographs.

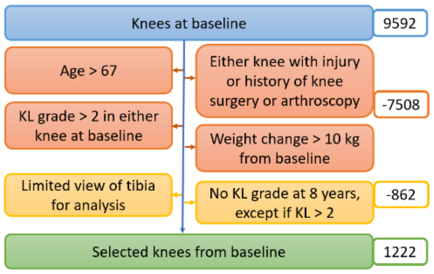

Figure 2: Exclusion criteria for selection and the number of the knees

The ML classification algorithm was trained utilizing two-fold balanced random forest classification ML approach with 5-fold cross-validation [4]. Subjects' age, weight, height, and the baseline KL grade and measurements indicated at Fig. 2 were used as the predictor variables. The data was split 70% (N=856) and 30% (N=366) between training and validation data, respectively. This division was done separately for each KL group. FEM based knee OA predictions were performed by using the FE atlas-based modeling approach, where the FE geometry was based on the measured joint dimensions [2]. Due to limitation of x-ray, anterior-posterior dimensions of medial and lateral condyles of femur, required in generation of 3D FE model, were evaluated by the joint size. To combine the ML classification and FEM, based on the ML classification the FEM results were multiplied with factors 0.5, 1, and 1.5 for KL01, KL2, and KL34 groups, respectively. Finally, receiver operating characteristic (ROC) curve and area under curve (AUC) were calculated for ML, FEM, and FEM+ML based predictions for validation data.

Results

The accuracies of the trained ML model were 93% for the training data and 68% for the validation data. The AUC for FEM+ML was higher than the AUCs for ML and FEM for KL01 vs KL34 knees (Fig. 3).

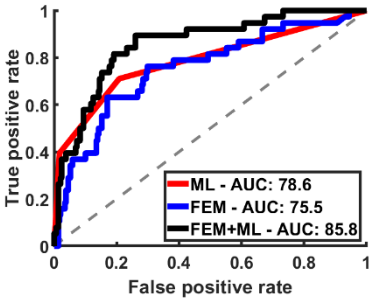

Figure 3: ROC curves and AUC of ML, FEM, and FEM+ML based knee OA predictions for KL01 (N=288) vs KL34 (N=38) validation data.

Discussion

ML classification and FEM simulations for the cartilage degradation are suitable for prediction of knee OA development. Overall, FEM+ML is superior compared to approaches that utilize solely ML or FEM. In conclusion, a ML enhanced FEM approach is promising for prediction of OA development.

References

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