Anatomically-Guided Patches for Joint KL and OARSI Grading of Knee Osteoarthritis

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1. Introduction

Knee osteoarthritis (OA) is a prevalent degenerative joint disease commonly assessed using radiographic grading systems such as Kellgren–Lawrence (KL) (Kellgren & Lawrence, 1957) and OARSI (Altman & Gold, 2007). KL grading provides a global severity assessment, whereas OARSI offers localized grading of OA features, including osteophytes and joint space narrowing (JSN). Although deep learning methods have shown promising performance for automated OA grading (Antony et al., 2017; Tiulpin et al., 2018), most existing approaches rely on coarse knee bounding boxes and overlook detailed anatomical structures critical for clinical assessment. Furthermore, automated OARSI grading remains relatively underexplored. In this work, we extend our previously proposed anatomically-focused patch framework (Chang & Lombaert, 2025) for simultaneous KL and OARSI grading from knee radiographs. We employ BoneFinder (Lindner et al., 2014) to extract anatomically consistent patches along the knee contour and aggregate patch-level information using an attention-based multiple instance learning (MIL) framework (Ilse et al., 2018). We further adopt a multi-task learning strategy (Crawshaw, 2020; Tiulpin & Saarakkala, 2020) to jointly predict KL and OARSI grades, enabling complementary supervision between global and local OA assessments. Experimental results show that our anatomy-guided approach achieves competitive KL grading performance while additionally supporting OARSI prediction with lower model complexity. The proposed method also produces more clinically meaningful attention maps, improving interpretability by focusing on relevant anatomical regions.

2. Methods

We propose an anatomically-guided multi-instance learning (MIL) framework for knee osteoarthritis grading from bilateral radiographs. Instead of using coarse regions, the method first detects anatomical landmarks along the tibiofemoral joint and extracts clinically relevant local patches. These patches are treated as instances in a bag and aggregated with an attention-based MIL model to produce knee-level predictions. To provide richer clinical assessment, the framework performs multi-task grading, jointly predicting KL grade together with OARSI for joint space narrowing and osteophytes. In addition, attention-weighted saliency maps are generated to visualize the model's attention with ensemble class activation mapping (e-CAM).

3. Results

We evaluated our proposed anatomically-guided MIL framework against two baselines: (1) a lightweight Siamese network (Tiulpin et al., 2018), a state-of-the-art patch-based OA grading model, and (2) a ResNet-34 (He et al., 2016) trained on a large ROI. Our method achieved competitive performance across multiple evaluation metrics, with Cohen's kappa improving from 0.772 to 0.808, demonstrating improved KL grading compared with baseline methods. Attention-weighted saliency maps further showed that the model focused on more localized explanations, supporting the interpretability of anatomically-guided multi-task MIL in OA grading. In addition, our method uses a substantially more compact input representation (21 KB vs. 65 KB and 245 KB for the Siamese network and ResNet-34, respectively) and fewer model parameters (248k vs. 595k and 21,287k, respectively), suggesting more efficient feature learning than ROI-based approaches. Overall, these findings indicate that anatomically focused local patch representations improve prediction performance, interpretability, and computational efficiency in OA grading.

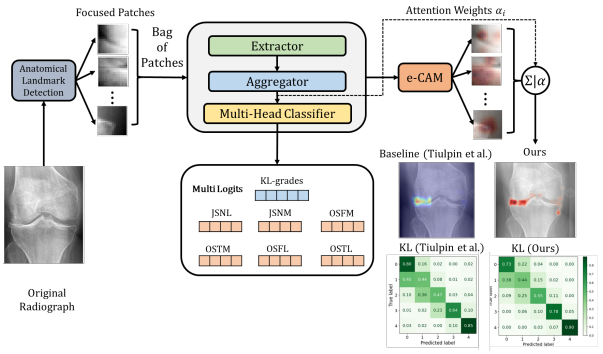

Figure 1. **A schematic overview.** An anatomically-guided attention-based MIL framework aggregates patch-level features into multi-task KL and OARSI predictions.

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