

Accurate wear determination in clinical radiographs after total knee arthroplasty using 2D-3D registration and artificial intelligence - In vivo validation

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INTRODUCTION: Polyethylene wear represents a significant risk factor for the long-term success of knee arthroplasty [1]. This work aimed to develop and in vivo validate an automated algorithm for accurate and precise AI based wear measurement in knee arthroplasty using clinical AP radiographs for scientifically meaningful multi-center studies.

METHODS: Twenty postoperative radiographs (knee joint AP in standing position) after knee arthroplasty were analysed using the novel algorithm. A convolutional neural network-based segmentation is used to localize the implant components on the X-Ray, and a 2D-3D registration of the CAD implant models precisely calculates the three-dimensional position and orientation of the implants in the joint at the time of acquisition. From this, the minimal distance between the involved implant components is determined, and its postoperative change over time enables the determination of wear in the radiographs. The measured minimum inlay height of 335 unloaded inlays excluding the weight-induced deformation, served as ground truth for validation and was compared to the algorithmically calculated component distances from 20 radiographs. Using early results from the clinical multi-center study creep of the polyethylene inlays after 3 months was compared to geometric creep results from a previously performed knee wear simulation study.

RESULTS SECTION: With an average weight of 94 kg in the studied TKA patient cohort, it was determined that an average inlay height of 6.160 mm is expected in the patient. Based on the radiographs, the algorithm calculated a minimum component distance of 6.158 mm (SD = 81 μ m), which deviated by 2 μ m in comparison to the expected inlay height. Creep of the polyethylene inlays after 3 months in vivo service was comparable to the measured creep results from in vitro knee wear simulation.

DISCUSSION: An automated method was presented that allows accurate and precise determination of the inlay height and subsequently the creep and wear in knee arthroplasty based on a clinical radiograph and the CAD models. Precision and accuracy are comparable to the current gold standard Radio Stereometric Analysis (RSA) [2], but without relying on special radiographic setups.

SIGNIFICANCE/CLINICAL RELEVANCE: The developed method can therefore be used to objectively investigate novel implant materials with meaningful clinical cohorts, especially for larger multi-center post market clinical follow-up studies according to the new Medical Device Regulation in Europe [3] thus improving the quality of patient care.

REFERENCES: [1] AOA NJRR 2021 [2] Kaptein 2007 [3] Overgaard & Grupp 2023

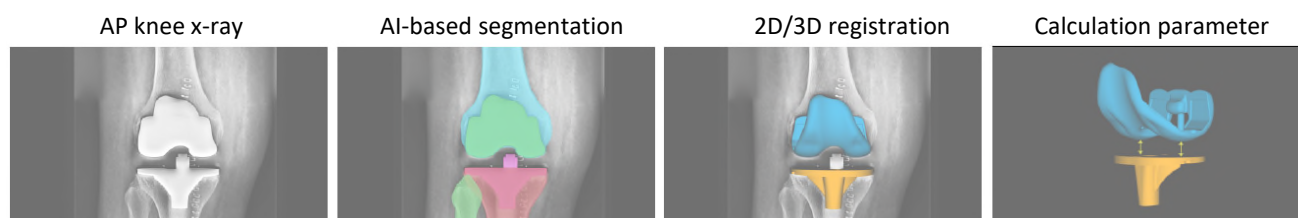


Figure 1: Graphical overview on the new 2D/3D convolutional neural network AI-based segmentation based on standardized AP knee radiographs

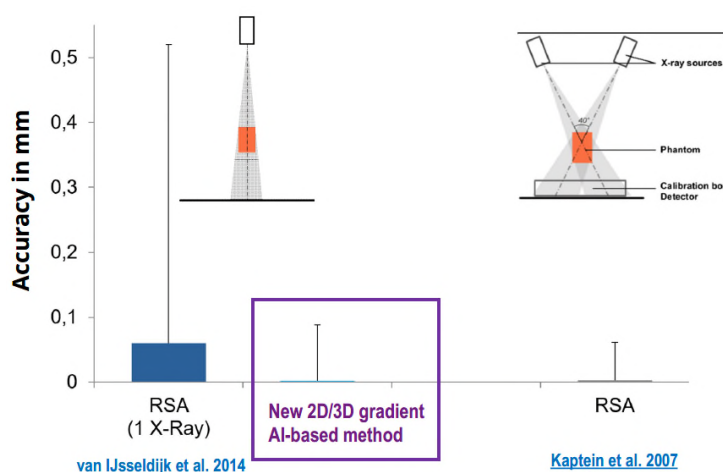


Figure 2: Accuracy of the new 2D/3D convolutional neural network AI-based segmentation method in comparison to dual plane RSA