# USING A STATISTICAL SHAPE MODEL TO ESTIMATE THE KNEE JOINT CENTER FOR ALIGNING FEMORAL FINITE ELEMENT MODELS

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## Introduction

Patients with advanced cancer and femoral bone metastases can have an increased fracture risk. Patients with an expected low fracture risk are generally treated with radiotherapy to relieve pain, whereas patients with an expected high fracture risk are considered for prophylactic stabilizing surgery. However, fracture risk assessment is challenging when using the currently available methods. Therefore, we developed the BOne Strength (BOS) score, which aims to be an easy-to-use objective score for fracture risk assessment of patients with femoral bone metastases based on a patient-specific finite element (FE) model [1,2]. QCT scans are used as input to the FE models. Although only the proximal femur is included in the FE model, the complete femur must be scanned as the model is aligned based on the knee joint center (KJC). In some cases, the femur is not completely scanned, which makes it impossible to calculate the BOS score. In this study, we want to investigate whether a statistical shape model (SSM), which represents an average shape as well as its shape variations, can be used to estimate the KJC location. Therefore, our aim is to determine the accuracy of the KJC based on an SSM, and the effect of the SSM-fitted KJC on the BOS score.

## Methods

We included 117 femurs from our BOS database [2], containing femurs of patients with femoral bone metastases who were treated with radiotherapy. The radiotherapy planning CT scan was used to generate a patient-specific non-linear isotropic FE model of the proximal femur, which was aligned to mimic stance by aligning the KJC with the femoral head center [1,2]. On the FE model, an axial load was simulated until failure and the failure load was normalized by body weight to calculate the BOS score.

To determine the KJC based on the SSM, we removed the distal half of the femoral mesh. We used an SSM that was previously created based on 79 CT scans of patients with vascular disease [3]. The number of points in the proximal part of the femoral mesh was downsampled by randomly selecting sample points on the surface of the mesh. An iterative closest point (ICP) algorithm was applied to fit the SSM to the proximal femur. Next, the KJC was determined from the fitted distal femur. A new FE model was created and aligned based on the SSM-fitted KJC.

We determined the difference between the location of the SSM-fitted KJC and the original KJC location, and tested this using a t-test. Additionally, we determined the correlation between the original and SSM-fitted BOS-score, and tested the difference between both BOS scores using a paired t-test.

## Results

The average difference between the SSM-fitted KJC and the original KJC was 0.4 mm (SD 12.1, range [-37.8 28.9], p=0.7) in mediolateral direction, 0.5 mm (SD 9.4, range [-23.8 17.4], p=0.6) in anteroposterior direction, and -2.6 mm (SD 24.5, range [-64.0 64.5], p=0.2) in distal-proximal direction.

The correlation between the original BOS score and the SSM-fitted BOS score was very high ($R^2$=0.99, p<0.001, Fig. 1A) and there was no significant difference between the original and SSM-fitted BOS scores (p=0.3, Fig. 1B).

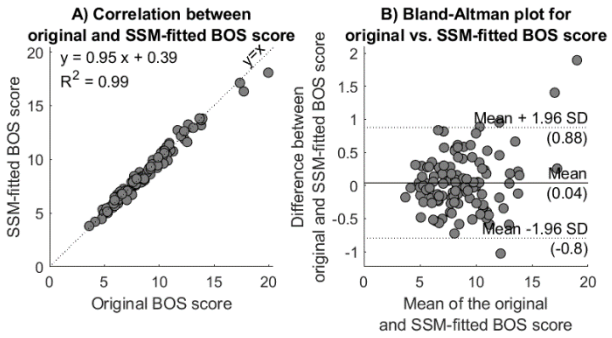


*Figure 1: Correlation (A) and Bland-Altman plot (B) for original vs. SSM-fitted BOS score.*

## Discussion

In this study, we determined whether the KJC can be accurately estimated using a SSM and we assessed the effect on the BOS score. In another preliminary study, we saw that KJC displacements in mediolateral and anteroposterior direction had the largest effect on the BOS scores, whereas the effect of changes in distal-proximal direction were small. Although the ranges of the differences between the original and SSM-fitted KJC location were large, the effect on the BOS score was limited. Hence, we conclude that it is possible to estimate the KJC and calculate the BOS score using a SSM in case the femur is not completely scanned. However, one should be careful, as also a small difference in BOS score could result in a different fracture risk assessment and a subsequent change in treatment plan.

## References

1. Eggermont et al, Bone. 130:115101, 2020.
2. Eggermont et al, Cancers. 14:5904, 2023.
3. Dunning et al, Med Eng Phys. 102:103781, 2022.