# INFLUENCE OF ANISOTROPIC CORTICAL BONE PROPERTIES IN PERIPROSTHETIC HIP FRACTURES

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## Introduction

Periprosthetic femur fractures (PFFs) remain a major clinical challenge associated with increased mortality and morbidity [1]. Epidemiological studies show a relatively high number of PFFs during the early postoperative (EP) period, especially with cementless stems [2].

Recent experimental studies have reported crack propagations parallel to the femur axis under stance, and lateral fall loading conditions [3], which suggests a role of bone anisotropy on PFFs since the fracture direction aligns with osteon directions. However, the relative role of material anisotropy on early postoperative PFFs remains poorly understood.

Therefore, the main objective of this study was to investigate the influence of cortical bone anisotropy in periprosthetic hip fractures. To achieve this, finite element models (FEMs) of implanted femurs were developed and validated, considering anisotropic cortical bone material properties.

## Methods

In this study, femur-specific FEMs were created, using Zweymueller stem design, based on the pre-and post-operative computer tomography scans provided by Saemann et al. [3].

Corresponding trabecular and cortical bone segments were modeled depending on the bone density using crushable foam and composite material models, respectively. Elasto-plastic and asymmetric cortical bone properties were defined in primary direction based on the experiments reported by Mirzalli et al. [4]. Material properties in the secondary direction were calculated by scaling the primary properties using the experimental findings of Reilly and Burstein [5].

The developed modeling strategy was tested under lateral fall loading conditions against the ex-vivo experiments documented by Saemann et al. [3]. Results were evaluated based on the force-displacement behavior alongside the fracture patterns for isotropic and anisotropic material models.

## Results

Simulation results using the anisotropic material properties showed comparable force-displacement characteristics with the experiments. The ultimate force and displacement values before fracture resulted in respectively +13% and -10% differences compared with the experimental data. On the other hand, although following a similar force-displacement path initially, the simulation model with isotropic material properties clearly overpredicted the ultimate force and displacement values (Figure 1).

Regarding the fracture patterns, the simulation results using the anisotropic cortical bone properties showed similar fracture patterns as reported in the experiment.

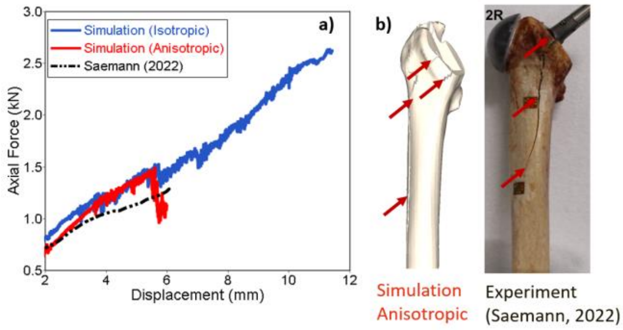


*Figure 1: Force-displacement results of the femur-specific lateral fall simulation (a). Fracture patterns of the simulation (indicated with red arrows) using anisotropic properties compared with the experimental results [3] (b).*

## Discussion

Periprosthetic bone fracture experiments have shown crack propagations parallel to the primary bone material direction, suggesting that the secondary material properties should play an important role. To test this hypothesis, we developed an anisotropic cortical bone modeling strategy and applied it to the FE models of ex-vivo PFF experiments.

Simulation results using anisotropic material properties predicted the ultimate force and displacement values compared to the experiments more accurately than the isotropic material properties. Additionally, the fracture patterns were also predicted realistically using the anisotropic material definition.

In the future, the modeling strategy presented in this study can help to predict PFFs more accurately and develop patient-specific strategies to mitigate such fractures.

## References

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2. Abdel et al., Bone Joint J, 2016.
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5. Reilly, Burstein, J. of Biomech, 1975.