# MULTI MODALITY APPROACH FOR OPTIMIZING PROPHYLACTIC AUGMENTATION OF THE PROXIMAL FEMUR FOR HIP FRACTURE PREVENTION

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## Introduction

Hip fractures in the elderly have severe consequences for the individual and are a major burden to the health care system. Hip fracture risk is affected by the load-bearing capacity of the femur which has been shown to decrease with low bone mineral density (BMD) [1]. The load that the femur is subjected to is multi-factorial, affected by biomechanical aspects of the fall, such as impact speed and impact direction [2]. The risk of fragility fractures can potentially be reduced by augmenting susceptible femora with injectable bone-strengthening hydrogel, which degrades and triggers new bone formation and a local BMD increase. The goal of the present study was (i) to estimate optimized augmentation patterns taking fall direction into account and (ii) to quantify the strength increase obtained by those patterns.

## Methods

The Bi-directional Evolutionary Structural Optimization (BESO) [3] algorithm was coupled with a Finite Element (FE) model of a femur in a sideways fall loading configuration (Figure 1a) [4]. The initial volume to be optimized was 50mL, shown in Figure 1b, corresponding to the volume of the entire trabecular bone of the proximal femur. A BMD increase of 20% was assumed for bone elements infiltrated by the hydrogel. This initial volume selection allows the final optimized volume to be distributed in the proximal femur without restriction. The target volume after optimization was set to 5mL. Five different optimized patterns were calculated corresponding to five fall angles (-30°, -15°, 0°, 15°, 30°) as shown in Figure 1c, and fracture strength of the femurs with and without the optimized augmentation patterns predicted.

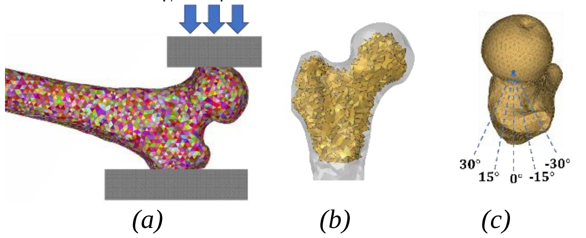


*Figure 1: (a) FE model for sideways fall loading of the femur, (b) initial volume selection to be optimized, (c) representation of femur subjected to different loading angles.*

## Results

Figure 2 shows a strength comparison before and after augmenting the optimized pattern for the different fall angles. As expected, the different fall angles resulted in five different optimized patterns. Relative to the unaugmented specimens, the strength increase was on average found to be 13.6% across fall angles.

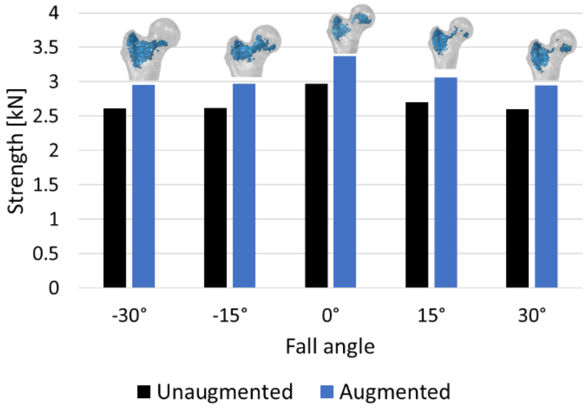


*Figure 2: Comparison of strength between unaugmented and augmented specimens. Optimized augmentation patterns for each fall angel are indicated.*

## Discussion

A topology optimization algorithm was developed that is capable of optimizing augmentation patterns of a bone-strengthening hydrogel that is assumed to increase the local BMD by 20%. Furthermore, the BESO algorithm was applied to FE simulations by examining different fall angles. The estimated patterns resulted in a strength increase for all examined fall angles compared to the unaugmented specimens. Overall, the outcome of this work could be used to design the injection strategy for the bone-strengthening hydrogel or other injectable biomaterials.

## References

1. Yang et al, J. Bone Min. Res. 35:2020, 1914-22.
2. Amin et al, J. Bone Miner. Res. 26:2011, 1593-1600.
3. Huang et al, Finite Elem Anal Des 43:2007,1039–49.
4. Galliker et al, Ann Biomed Eng, 50: 278-290, 2022.

## Acknowledgements

Funding from Innosuisse, project 54723.1 IP-LS.