**AI-Driven Patient-Specific Computational Modeling for Predicting Fracture Risk in Canine Osteosarcoma**

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## Summary

The goal of this study is to construct an Artificial Intelligence (AI)-driven computational framework for assessing fracture risk and evaluating the efficacy of novel minimally invasive IlluminOss (IS) [1] implants in stabilizing canine bones affected by Osteosarcoma (OSA), followed by Stereotactic Body Radiation Therapy (SBRT). The reconstructed bone models from Computed Tomography (CT) images were assigned Genetic Algorithm (GA) optimized mechanical properties derived from spherical nanoindentation data. Extended Finite Element Analysis (XFEA) was performed on a cohort of 18 patients to simulate mechanical response and fracture behavior in healthy, OSA-affected, and implant-treated bones, generating a dataset for training a reliable decision tree (DT)-based supervised Machine Learning (ML) model. The proposed model has the potential to predict fracture risk and IS implant effectiveness by utilizing patient-specific information in clinical settings.

## Introduction

The IS implant has shown promising results in humans by minimizing surgical trauma, reducing soft tissue damage and complications. However, a preliminary clinical study on 5 large-breed canines has shown a high failure rate. Therefore, rapidly predicting bone fracture risk and the success of the IS implant remains a significant challenge, which is essential for effective clinical decision-making. Developing high-fidelity finite element models and training a DT-based ML model could greatly facilitate this process, improving surgical planning and patient outcomes.

## Methods

The elastoplastic properties of canine bone were characterized for different regions of trabecular and cortical bones using spherical nanoindentation (Figure 1) and optimized with GA. The results were then calibrated against the findings from Steffy et al [2].

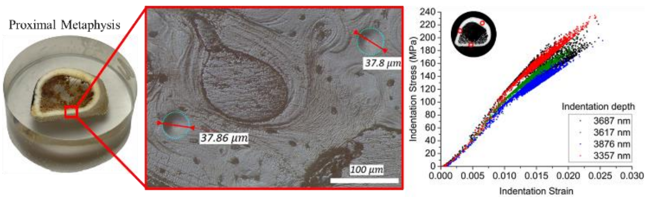


**Figure 1**: High-depth spherical nanoindentation performed on a sample from a canine femur.

The material model, correlated with grayscale values from CT images, was assigned to the meshed, reconstructed bone models. To replicate real-life scenarios, 25 distinct loading conditions were applied in the XFEA simulations to predict crack initiation and evolution. Additionally, the IS implants were designed to conform to the geometry of the medullary canal where the interaction between bone and implant was considered.

## Results and Discussion

The XFEA simulations were performed on various bone types. For instance, the results of a humerus (Figure 2) demonstrate that the IS implant provides an average fracture resistance improvement of 11.51%, with a maximum improvement of 23.14%. In comparison, a healthy bone exhibits an average of 63.28% higher resistance. The DT model developed based on the results shows promising potential but needs further evaluation in clinical settings to validate its effectiveness.

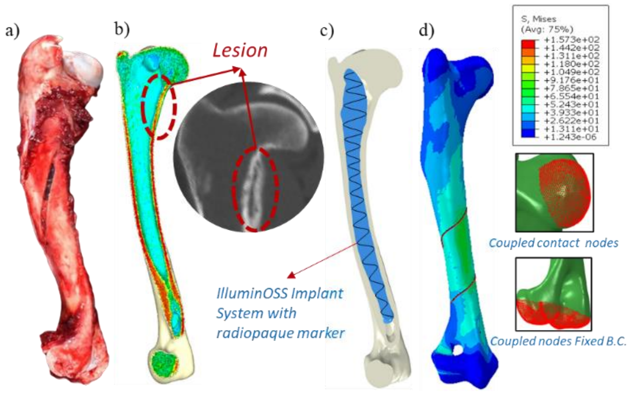


**Figure 2**: a) Gross anatomic image of proximal humerus after failure of IS implant, b) the reconstructed bone model from CT images with assigned mechanical properties, c) a conformally designed IS implant filled the medullary canal, and d) XFEA simulation results with imposed boundary conditions.

## Conclusions

This study developed a computational framework integrating XFEA and a DT-based ML model to expedite prediction of fracture risk and evaluation of IS implant efficacy in OSA-affected canine bones. The predicted fracture load results were comparable to existing literature, supported by early-stage bone characterization with nanoindentation conducted during the research. Feature importance analysis revealed that the most critical factors influencing predictions of ML model are the lesion ratio, bone mass density indicators, bone length, and imposed boundary conditions. Validation in clinical settings is currently underway in its early stages to confirm the model's broader applicability and ensure its effectiveness in real-world scenarios.

## References

[1] IlluminOss. (n.d.). *IlluminOss implant system*. Retrieved January 30, 2025, from https://illuminoss.com.
[2] Steffey, M. A. et al. (2017). *Vet. Surg.*, **46**, 539-548.