

# Probabilistic Failure Analysis of Locking Compression Plating vs. Intramedullary Nailing for Treatment of Distal Femur Fractures

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## INTRODUCTION:

Post-operative damage accumulation of the implant/bone interface can result in a major effect on the stability, integrity, and recovery time of injured bones. It is well recognized that the level of damage is highly dependent on bone quality and choice of implant used by the surgeon. In order to determine which of these factors has the highest significance on the bone it would be necessary to conduct a large number of experimental studies. This would require resources (specimens, implants, time and financial resources) that are beyond the capabilities of most research facilities. Probabilistic mechanics have been developed to overcome such challenges. This study compares the probability of fracture of bones implanted with distal Locking Compression Plates (LCP) and Intramedullary (IM) Nails using a probabilistic mechanics approach aided with the finite element (FE) method and a limited number of experimental tests.

## METHODS:

The cortical and cancellous regions of the bone were generated from the Standardized Femur model. The LCP and IM nail were created using SolidWorks® 3D CAD design software. The bone/implant constructs were then analyzed using the ANSYS® simulation environment (Figure 1). To validate the FE model, the bone was fixed and loaded in a way similar to a previous experimental study performed by the authors. The material properties for the LCP and screws match those for 316L stainless steel. The material properties for the IM nail, nuts and bolts match those for Titanium alloy (Ti6Al4V).

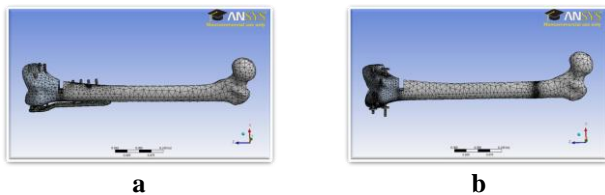


Figure 1) Finite element model of femur implanted with a) LCP and b) IM nail

The validated finite element model was then analyzed for the experimental failure load (101.9N) while the cortical and cancellous bone moduli of elasticity were varied to introduce uncertainty in the analysis. The moduli of elasticity (E) were assumed to follow a Gaussian (normal) distribution. Variation of E simulates the fluctuation of stiffness in the bone as damage is induced in the construct due to cyclic loading (i.e. post-operative movement). The mean and standard deviation (assumed to be 20% of mean) of both the cortical and cancellous bone moduli of elasticity as used in the probabilistic analysis are presented in Table 1.

Table 1: Mean and standard deviations (SD) of modulus of elasticity of cortical and cancellous bones used in probabilistic analysis

	Cortical		Cancellous	
	Mean (Pa)	SD (Pa)	Mean (Pa)	SD (Pa)
LCP	1.06E9	2.12E8	1.55E8	3.1E7
IMN	2.00E9	4.00E8	1.55E8	3.1E7

The mean values of the modulus of elasticity of cortical and cancellous bone were found from experimental testing. The probabilistic analysis was performed using principles of Monte Carlo simulation to solve the convolution integral of the probability functions of the bone stress and strength.

## RESULTS:

A deterministic finite element model of the LCP implanted bone showed the highest shear stress concentrations in the bone at the most proximal shaft screw as shown in Figure 2.

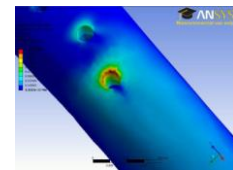


Figure 2) FE model of femur implanted with LCP showing highest shear stress concentration at most proximal shaft screw

The shear stress at that location exceeded the shear strength of the cortical bone (24-34 MPa) under the applied loading conditions indicating a possible failure at that location as observed experimentally. The probabilistic analysis allowed realization of the probability of failure for the LCP and IM nail as shown in Figure 3. Under the applied loading conditions, the LCP was found to have a higher probability of failure than the IM nail.

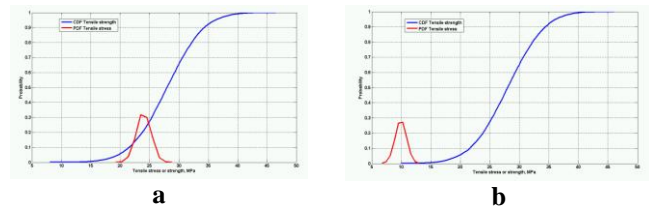


Figure 3) Probability of failure of the femur implanted with a) LCP showing a probability of failure of 21.8% and b) IM Nail showing a probability of failure of 1.9%

## DISCUSSION:

The use of a probabilistic analysis enables examining the uncertainty in the modeling parameters on the biomechanical behavior of distal femur fracture. Variation of the cortical and cancellous bone modulus of elasticity allowed computing the probability of failure of the implant. It is evident from the analysis that the use of IM nail for distal femur fracture will result in significantly lower probability of failure compared with LCP.