# Femoral Bone Diaphyseal Fracture Repair using Braided Structures: Biomechanical Modeling & Finite Element Analysis

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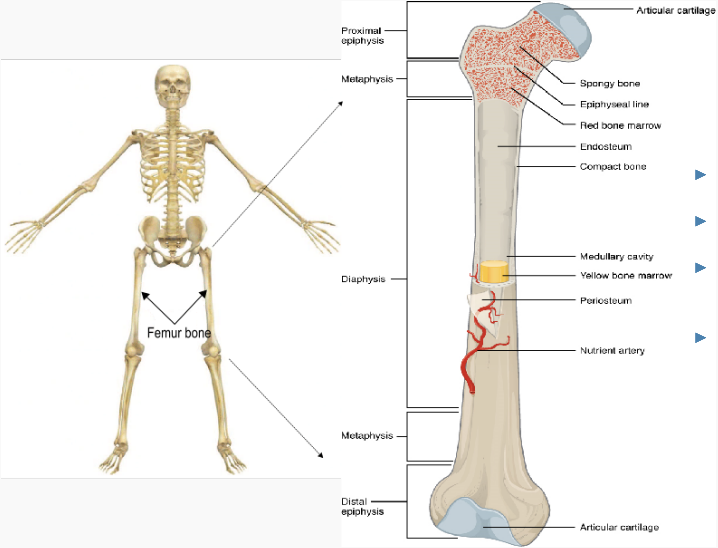
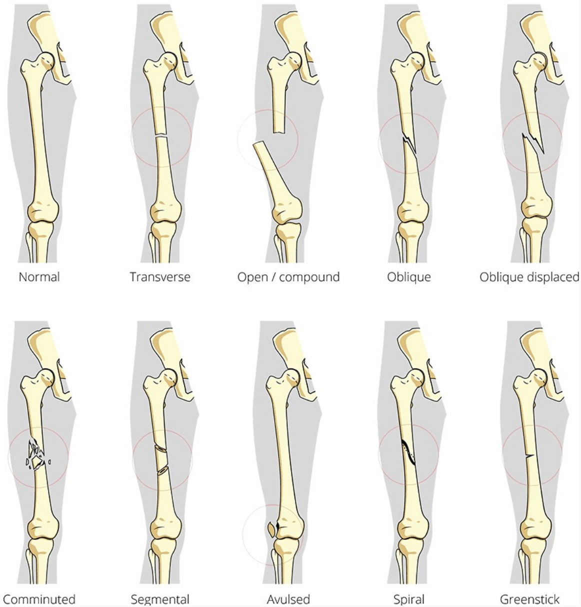
# Introduction




- the Femur is one of the long bones in the human skeletal structure
- there are two femur bones joining the hip to the knees.
- the femur anatomy includes: distal epiphysis, metaphysis, diapysis and proximal epipysis.
- there is also the medullary cavitym bone marrow and spongy bone in its internal section.

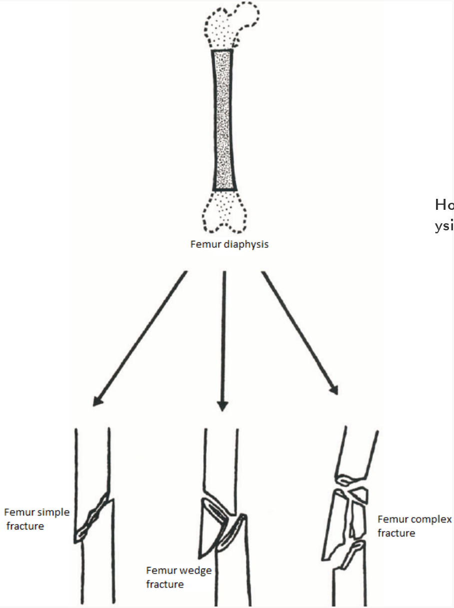
# General femur fractures




There are generally many fractures that occur on different sections of the femur incase of accidents or disease, some of them are illustrated by several authors[3] as:

- transverse
- open/compound
- oblique.
- oblique displaced
- comminuted
- segmental.
- avulsed
- spiral
- greenstick.

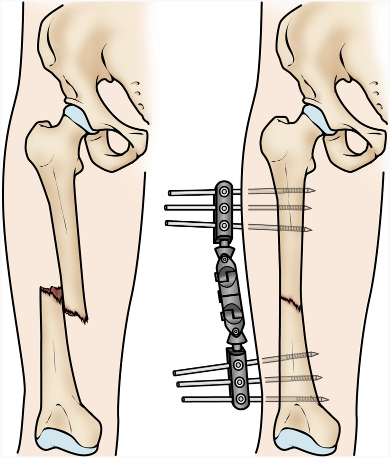
# Femur diapysis fractures




However, the common fractures on the femur diapysis (shaft) are[3]:

- Simple fracture: a single circumferential disruption of a diaphysis or metaphysis or a single disruption of an articular surface. Simple fractures of the diaphysis or metaphysis are spiral, oblique or transverse.
- Wedge fracture: A fracture with one or more intermediate fragment(s) in which after reduction there is some contact between the main fragments. The spiral or bending wedges may be intact or fragmented.
- Complex fracture: A fracture with one or more intermediate fragment(s) in which after reduction there is no contact between the main proximal and distal fragments. The complex fractures are spiral, segmented or irregular.

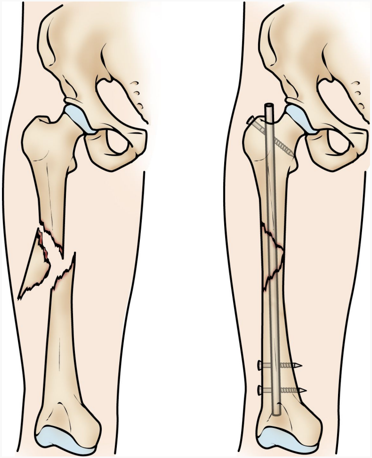
# Current practice



External fixation [2]:

- A typical external fixation system involves of wires or pins pieced through the bone and held under high tension by screws to external frame. The wires can be oriented at different angles across the bone and their tension is adjusted to provide necessary fixation rigidity.
- To ensure stability, the external fixators are designed with high rigidity and strength. Traditional designs are made from stainless steel, which is heavy and causes discomfort to the patients as they carry the system for several months. External fixators constructed from CF/epoxy composite material;s are gaining acceptance owing to their lightweight yet sufficient strength and stiffness.

# Current practice...



Internal fixation [1]:

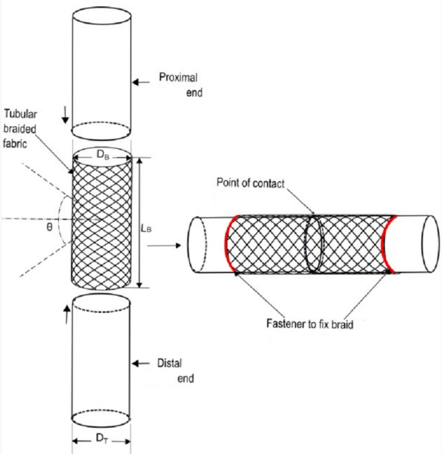
- In the internal fixation approach the bone fragments are held by different ways using implants using implants such as wires, pins, screws, plates, and intramedullary nails. The conventional implants are mode of stainless steel, Co-Cr, or Ti alloys. The surgeon based on his experience and the type of fracture judges the bone fracture treatement method. Surgical wires and pins are the simplest implants used to hold the small fragments of bone together.
- They are also used to provide additional stabilityin long oblique or spiral fractures of long bones (femur). Most widely used screws are 2 types: cortical bone screws (with small threads) and cancellous screws (with larger threads). They are used to either directly fasten bone fragments together or to attach a plate to the fractured bone.
- However proper implant design and surgical technique must be utilised to ensure the desired biomechanical outcome of the fixation and to avoid additional tissue trauma and devascularisation at the fracture site. Fracture healing also would depend on the patient activity as they determine the stable or unstable mechanical conditions at the fracture site.

# Rationale

This project is motivated by the fact that:

- The process of conventional femur repair especially at the diapysis regions involves a significant damage to the bone structure
- the implants, nails and wires have to be removed at some stage during the bone healing process.
- this depends on the experience of surgeon and the physical activity of the patients.
- this exposes the bone to re-fracture and deformations in case the timing of the implant removal is not done perfectly.
- there is therefore need to innovate ways of bone diapysis repair which would not destroy the bone structural components and could be easy to remove after healing!

# Theoretical approach




- The repair will performed on the femur bone shaft (dypysis) which will be assumed to have a uniform circular shape.
- A simple fracture will be considered to emulate a uniform break at the mid-section of the bone shaft
- A tubular diamond braied fabric will be deployed around the fractured site of the bone and pressure applied so that the two ends of the fractured bone are held together in position to emulate a realistic repair.
- Simualtion of the flexural rigidity of the repair site will be performed with both fastened and unfastened ends of the braided structure.
- 3D models: CAD model of the femur model will be developed using commercial software. In the next phase of the project the femur bone modeling will done using computed tomography (CT) scan.
- Finite Element Analysis (FEA): A three-dimensional (3D) FE model was developed using Abaqus/Explicit 6.17 (Simulia, Providence, RI, USA) to simulate the application of a braided structure in repair of fractured femur bone model and to simulate the different loading tests.

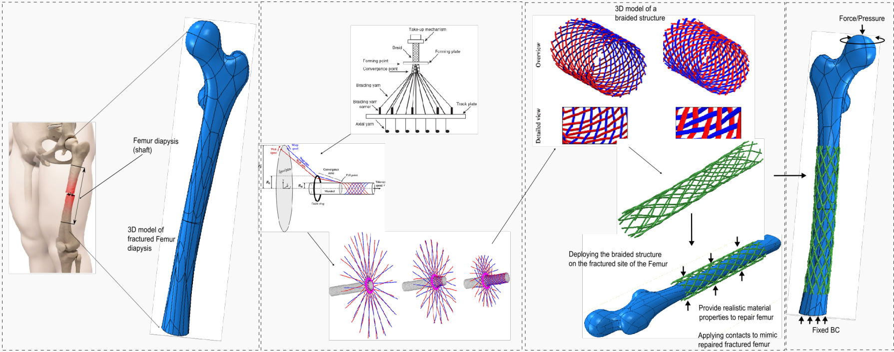
# Numerical modeling

**CAD 3D modeling of Femur Bone with fracture**

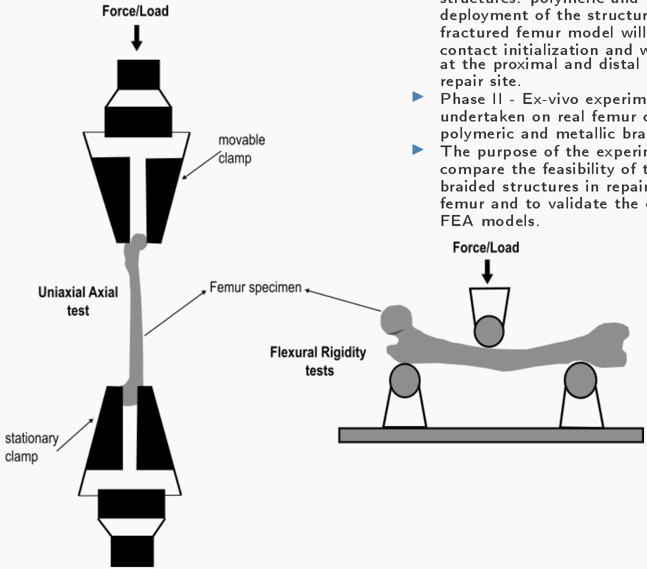
**the Braided structure geometry**

**Pre-processing in Python and Abaqus/Explicit**

**FE Analysis and Post-processing**

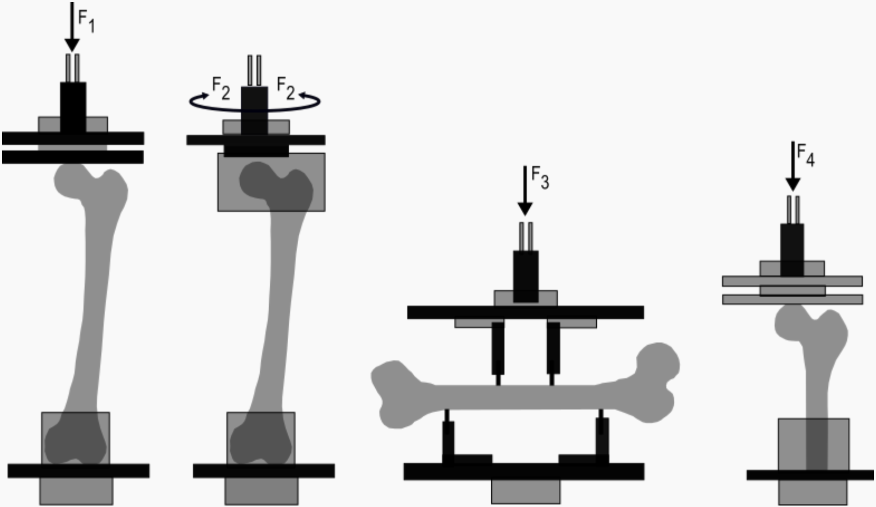


# Experimental Approach




- Phase I - Experimental tests will be performed on a synthetic femur bone repaired using two types of braided structures: polymeric and metallic: the deployment of the structures onto the fractured femur model will be done using contact initialization and without contacts at the proximal and distal ends of the repair site.
- Phase II - Ex-vivo experimentation will be undertaken on real femur cadavers using polymeric and metallic braided structures.
- The purpose of the experimental will be to compare the feasibility of the two types of braided structures in repair of fractured femur and to validate the corresponding FEA models.

# Experimental Approach...



# Project Status

Finished work:

- python programming: development of a three model of the braided fabric using numerical python in PyFormex.
- CAD: three dimensional set up of the femur bone model in a Finite Element Analysis interface in ABAQUS/Explicit.
- Pre-processing: input files for the braided structure and femur have been assembled in a FEA interface.
- FEA: preliminary analysis using tentative parameters and material properties.

Ongoing work:

- Optimisation of the Numerical models and simulation of the three dimensional models and trials.
- Designing of experiment and test set-up for phantom models of femur and braided fabric.
- Designing of experiment and test set-up for ex vivo experimentation and measurements to be done on femur cadaver.
- ....

# Acknowledgments

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- Department of Civil Engineering and Architecture (DICAr), University of Pavia.
- School of Engineering & School of Medicine, Moi University, Eldoret, Kenya.

# References


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[2] Baidya, K., Ramakrishna, S., Rahman, M., and A., R. Design and evaluation of composite external fracture fixation device. *Proc. ICCM-12*.

[3] Muller, M., Nazarian, S., Koch, P., and Schatzker, J. (1990). The comprehensive classification of fractures of long bones.

Thank you!