Analysis of a surgical error in position of a bilateral unicompartmental knee prosthesis

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Context of the project:

Unicompartmental Knee Arthroplasty (UKA) is, nowadays, a valid alternative to total knee prosthesis when a patient present issues only on the medial or on the lateral side of his knee joint.

To keep the cruciate ligaments in the patients, some surgeons prefer to implant simultaneously two UKAs, one on the medial side and one on the lateral side. Such approach, with respect to a full knee prosthesis has some advantage with respect to the preservation of the soft tissues and in terms of patient perception.

However, such procedure is really technical demanding and several mistake could influence the final performance of the knee joint.

Therefore, the aim of this project is to compare the stress in the bone and the strain in the ligaments in a knee, when two UKAs are inserted in the theoretical position and the changes induced by a possible surgical mistake in the UKA position.

The project will be performed numerically with the use of Finite Element Analysis.
Biomechanical analysis of Lateral Unicompartmental Knee Prosthesis

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Context of the project:

Unicompartmental Knee Arthroplasty (UKA) is, nowadays, a valid alternative to total knee prosthesis when a patient present issues only on the medial or on the lateral side of his knee joint.

Usually UKA are used for replace tibio-femoral joint only on the medial side, however, sometimes, UKA is also used as replacement for the lateral side.

Such procedure is more complicate than the conventional medial replacement and several error could be performed during surgery influencing the final results of the procedure.

Therefore, the aim of this project is to compare the stress in the bone and the strain in the ligaments in a knee, when a lateral UKA is inserted in the theoretical position and the changes induced by a possible surgical mistake in the UKA position.

The project will be performed numerically with the use of Finite Element Analysis.
Dynamic Biomechanical analysis of Unicompartmental Knee Prosthesis

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Context of the project:

Unicompartmental Knee Arthroplasty (UKA) is, nowadays, a valid alternative to total knee prosthesis when a patient presents issues only on the medial or on the lateral side of his knee joint.

With respect of conventional prosthesis, UKA is a more demanding surgical procedure and some mistake in positioning could be performed.

Several numerical models are in use nowadays to predict the biomechanical behaviour of a UKA implanted in the knee. One the last models, developed at ULB, demonstrated the importance of including ligaments in knee model and performed a static analysis.

The aim of this project is to analyse dynamically the biomechanics of a medial UKA. The project will be performed numerically with the use of Finite Element Analysis. The analysis will be performed investigating different motor tasks (as gait, squat,...).
EFFECT OF BONE SUBSTITUTES FOR TKAs (Femoral Bone)

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Context of the project:

Femoral and tibial augment are commonly used in surgery coupled with stem or stem-less implant however a clear algorithm able to define the best augment size and implant stem size according to bone quality and bone defect geometries/size is not well defined.

Therefore the purpose of the project is to analyze the effect that different combination of femoral augment size and implant stem size on bone stress and implant micromotions during several daily activities.

A finite element model of a Femoral bone will be developed based on a CT scan of a mechanical equivalent sawbones. We will use this kind of geometrical model to be able to further validate the numerical model with experimental setup.

A revision-TKA will be inserted according to the manufacturer’s surgical technique.

Several configurations of distal augment depths and stem size will be modeled:
- Distal augment size: 5mm – 15mm – 25mm (the augment sizes of 10 mm and 20 mm could be also considered but I will not consider them initially for reducing computational time).
- Stem length: 80 mm cemented (short stem) - 120 mm cemented (middle stem) - 160 mm cemented (long stem). A no stem configuration will be also modeled and compared with the other configurations with a 5 mm augment and without.

A validated musculoskeletal model (Innocenti et al, J Biomech 2011) will be used to reproduce numerically several daily activities to determine the load condition for the model.

Two material properties configurations (physiological bone and osteoporotic bone) will be simulated to check the effect of a weak bone quality on the results.

Average and maximal Stress and strain in several region of Interest will be extracted and compared between different configurations. Implant micromotions will be also calculated.

A further validation on our loading frame using sawbones and physical implants could be executed to prove the predicted values from the models.
EFFECT OF BONE SUBSTITUTES FOR TKAs (Tibial Bone)

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Context of the project:
Femoral and tibial augment are commonly used in surgery coupled with stem or stem-less implant however a clear algorithm able to define the best augment size and implant stem size according to bone quality and bone defect geometries/size is not well defined.

Therefore the purpose of the project is to analyze the effect that different combination of tibial augment size and implant stem size on bone stress and implant micromotions during several daily activities.

A finite element model of a Tibial bone will be developed based on a CT scan of a mechanical equivalent sawbones. We will use this kind of geometrical model to be able to further validate the numerical model with experimental setup.

A revision-TKA will be inserted according to the manufacturer’s surgical technique.

Several configurations of distal augment depths and stem size will be modeled:
- Distal augment size: 5mm –15mm – 25mm (the augment sizes of 10 mm and 20 mm could be also considered but I will not consider them initially for reducing computational time).
- Stem length: 80 mm cemented (short stem) - 120 mm cemented (middle stem) - 160 mm cemented (long stem). A no stem configuration will be also modeled and compared with the other configurations with a 5 mm augment and without.

A validated musculoskeletal model (Innocenti et al, J Biomech 2011) will be used to reproduce numerically several daily activities to determine the load condition for the model.

Two material properties configurations (physiological bone and osteoporotic bone) will be simulated to check the effect of a weak bone quality on the results.

Average and maximal Stress and strain in several region of Interest will be extracted and compared between different configurations. Implant micromotions will be also calculated.

A further validation on our loading frame using sawbones and physical implants could be executed to prove the predicted values from the models.
Development of a Knee Gait Kinematic simulator for experimental test

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**Context of the project:**

Analyse the kinematics during a gait cycle is fundamental to understand the performance and to check the design of different knee prosthesis.

Such tests need to be performed in a more stable and reproducible way as possible, so the aim of the study is to mechanically design, realize and test, a device that, coupled to a loading frame machine, is able to replicate a knee gait task.

The device will be used to simulate gait task for a physiological knee or for knee with a prosthesis.
Analysis of the effect of Femoral Intramedullary Nail

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Context of the project:
Intramedullary nails are used when it is needed to create or reconstruct stability in the femur bone after a bone fracture.

The real effects in the bone and bone interface after implantation of the nail are not completely known. Moreover, the effect of different insertion point are still unknown.

For that reason, the aim of this project is to develop a numerical model of a femur with a nail implanted simulating different internal condition and analysing final mechanical outputs (stress in the bone and at the nail) during several daily activities (gait, squat, chair rise, ...).
Analysis of the effect of foot-floor interaction in soccer player during jump

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**Context of the project:**

During several sport activities, especially in soccer, player report pathologies to their articular cartilage.

The reason of such injuries could be explained in the increase in the stiffness induced by a wrong coupling shoe-field during the sport practice.

To be able to investigate the shoes-field interaction during a jump, a specific mechanical device need to be developed and tested.

For that reason, the aim of this project is to design such device and to use it to simulate the jump of a soccer player in different condition (changing load, humidity, shoes, floor,..) and to measure the energy of the impact and other useful outputs to be able to characterize such interaction.
Dynamic Analysis of All-Polyethylene Vs Metal-Backed Implant Design

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Context of the project:
Total Knee Arthroplasty is a successful well-established procedure.

The most common design of the tibial component is Metal-Backed, but an alternative to this solution, with a tibial component fully made of polyethylene, exists (All-Polyethylene design).

However, to date, no biomechanical data confirming the equivalence of both the designs are available.

Therefore, the aim of this study is to investigate the mechanical performances of the two implant designs dynamically during gait and during a squat motor task, using finite element analyses.

In particular stresses in the tibial bone, strain in the ligaments and micromotions at the bone-implant interface will be determined.
Analysis of CR All-Polyethylene Vs Metal-Backed Implant Design

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Context of the project:
Total Knee Arthroplasty is a successful well-established procedure.

The most common design of the tibial component is Metal-Backed, but an alternative to this solution, with a tibial component fully made of polyethylene, exists (All-Polyethylene design).

However, to date, no biomechanical data confirming the equivalence of both the designs are available.

Therefore, the aim of this study is to investigate the mechanical performances of the two CR implant designs dynamically during gait and during a squat motor task, using finite element analyses and compared with PS implant.

In particular stresses in the tibial bone, strain in the ligaments and micromotions at the bone-implant interface will be determined.
Analysis of Fixed and Mobile ULA

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Context of the project:

Unicompartmental Knee Arthroplasty (UKA) is, nowadays, a valid alternative to total knee prosthesis when a patient present issues only on the medial or on the lateral side of his knee joint.

With respect of conventional prosthesis, UKA is a more demanding surgical procedure and some mistake in positioning could be performed.

Both fixed and mobile designs are available, but very few data in the literature observe differences between the two solutions.

The aim of this project is to compare the outputs of a fixed UKA and mobile UKA for several motor tasks. The project will be performed numerically with the use of Finite Element Analysis.