**Development of an experimental set-up for material characterization of articular cartilage**

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**Context of the project:**

Articular cartilage is a very complex composite material, overlaying diarthrodial joints surfaces (e.g. knee, shoulder, temporomandibular, etc.), holding load bearing, lubrication and shock absorbing capabilities [1]. Characterization of articular cartilage material properties is necessary to study its mechanical response and consequently its impact on joints biomechanics [2]. Furthermore, the determination of articular cartilage material properties will contribute to advancements in tissue engineering applications, aiming to restore the tissue functionality after damage.  

In order to be able to characterize articular cartilage material and mechanical properties, a proper technique, taking into account the unique ultrastructure of the tissue, needs to be developed and validated.  

Therefore, the aim of this project is to design an experimental set-up enabling an accurate, reproducible, and reliable material characterization of articular cartilage (Fig. 1). An indentation system will be developed and finally validated testing rubber-like materials characterized by an elastic and/or visco-elastic mechanical behaviour.

![Indentation system design](image)

**Figure 1** Indentation system design (A) to be developed and validated for future material characterization of articular cartilage (B) [2].

**References**

Design of a fixator for scaphoid fracture osteosynthesis

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Context of the project:
The scaphoid is a carpal bone of the wrist, located between the hand and forearm (Fig. 1A). The palmar, proximal, lateral, medial, and dorsal surfaces of the scaphoid are strongly irregular, characterized by peculiar geometrical features that make it difficult to fix after fracture.

Currently, implants used for the scaphoid bone osteosynthesis consist in fixators with a straight design. They are basically screws that mainly differ in the threading shape [1]. In spite of the numerous designs available on the market (Fig. 1B), fracture fixation of the scaphoid presents drawbacks for which current technologies did not address a proper effective solution yet.

Therefore, the aim of this project is twofold: (1) to analyse different existing implant designs used for the osteosynthesis of the scaphoid bone that are utilized to improve the treatment of fractures; and (2) finalize a new design (prototype) capable of overtaking current limitations.

**Figure 1** The scaphoid (A) is frequently subjected to fracture and osteosynthesis is currently achieved by implanting fixators (B), all characterized by different threading designs [1].

References
Development of a device for intra-operative measurement of the flexion and extension gap during knee prosthesis surgery

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Context of the project:

During knee arthroplasty, a surgical procedure performed to restore the integrity and function of the knee joint, a prosthesis is often implanted (Fig. 1A). During prosthesis implantation, the surgeon must define the alignment between femoral and tibial anatomical axes; thus ensuring stability of the knee joint. The alignment is often determined by evaluating the gap between the femoral condyles and the tibial plateau at 0° (i.e. extension gap) and 90° flexion (flexion gap) (Fig. 1B).

However, the alignment procedure is technically demanding and current techniques are strongly operator dependent. Consequently, the surgical outcome during knee prosthesis implantation is still highly influenced by errors in fixing the final flexion and extension gap.

Therefore, the aim of this project is to design a device for a “smart” and reliable intraoperative measurement, aiding the surgeon in performing a fast and accurate flexion and extension gap procedure during knee prosthesis implantation surgery.

Figure 1 Computer tomography imaging of a knee characterized by a total knee prosthesis implant [1] (A) and frontal view of the flexion and extension gaps used for joint alignment [2] (B).

References
Development of a parameterized total knee prosthesis

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Context of the project:

Several total knee prosthesis implant designs are currently available on the market (Fig. 1), each of them with its own characteristics and design features (i.e. condyles radii, condyles symmetry, posterior stabilization, etc.).

The identification of an optimal prosthesis that might incorporate “ad hoc” design features is a challenging task. Currently, there is no existing tool capable of estimating the impact of each design feature on the prosthesized knee biomechanics. Consequently, during the surgery pre-planning phase, the surgeon decision-making process is based on pure empirical considerations, experience related.

Therefore, the aim of this project is to develop a parametric model of a total knee arthroplasty prosthesis, allowing the study of the influence of each prosthesis component features (i.e. femoral and tibial components and tibial insert features) on the prosthesized knee biomechanics.

Figure 1 The knee prostheses designs available on the market are different. However, no existing tool is able to estimate an optimal prosthesis design considering all the possible available components features.
Analysis of prosthetic stem inclusion in the tibial bone

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Context of the project:

The knee prosthesis (Fig. 1A) is an implantable device; it allows the restoration of the knee biomechanics in subjects with compromised mobility, caused by degenerative pathologies such as osteoarthritis [1]. The prosthesis components, replacing the femur and tibia functional integrity, are fixed to the bone (i.e. typically the tibial bone) by a stem (Fig. 1B).

Stems differ in their design according to length, thickness, and shape (Fig. 1C). They can be cemented or characterized by porous surfaces increasing osteosynthesis and consequently the implant stability. However, designing choices are arbitrary and there is no agreement on the proper designing strategy to adopt for optimizing the prosthesis stability, in function of the subject daily activity.

Therefore, the aim of this project is to employ finite element analyses techniques to evaluate the impact of the most adopted stem designs onto the stress generated in the tibial bone. The comparative study will be performed taking into account motor tasks such as gait or squat (Fig. 1C).

Figure 1 The standard knee prosthesis (A) can be equipped with femoral and tibial component stems (B) that can enormously differ in their design (C).

References
Analysis of the kinematics and kinetics of a prosthized knee during daily activity: single-radius v.s. J-curved designs

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Context of the project:
The knee prosthesis is an implantable device; it allows the restoration of the knee biomechanics in subjects with compromised mobility, caused by degenerative pathologies such as osteoarthritis [1]. The femoral component of a total knee prosthesis may be single-radius (SR) or J-Curved (JC) if the radius of curvature is constant or progressively changes during flexion, respectively (Fig. 1).

Differences in the radius of curvature of a knee prosthesis femoral component can induce severe changes in both (1) polyethylene tibial insert stresses and (2) ligaments strain.

Therefore, the aim of this study is to compare the effects of SR and JC femoral component designs on the tibial insert stresses and ligaments strains induced during walking and squatting. The comparative study will be performed using finite elements analyses techniques.

Figure 1 SR femoral components (A) are designed according to one radius of curvature; JC femoral components (B) are designed according to multiple radii of curvature.

References