3D PRINTED KNEE FOR EXPERIMENTAL VALIDATION OF PATELLAR TRACKING AND CONTACT SIMULATION OF DIGITAL TWINS ATFER TKR

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Introduction

As postoperative patellar complications are common, total knee arthroplasty aims to ensure proper patellar tracking. It depends on numerous parameters, as the size, the position and the orientation of the implants, and the balancing of ligaments. Computational simulations to estimate the kinematics and the knee contact forces after total knee replacement (TKR) have been extensively treated and numerous approaches can be found in the literature. However, experimental validations are often limited by the technological means available to the researchers and the need of compliance with ethical rules. For this reason, a knee testing rig offers an alternative solution for model validation. In this study, a leg workstation composed by 3D printed bones and real implants, and equipped with motion and force sensors, was adapted for experimental validation of the simulated patellar tracking with an in-house developed library.

Methods

A leg workstation for surgeon training (Mita®) with 3D printed tibia and femur was used in this work (Figure 1a). Bone geometries were reconstructed from preoperative CT scans, which allowed the virtual application of TKR implant geometries, so that the resulting cut bones were printed. Microport® tibia and femur implants were placed on the respective bones. A patellar prosthetic button was attached to a pressure sensor, linked to the tibia by a rope and to the femur by a spring in series with a strain gauge, so as to model the quadriceps tendon and to measure its tension. The movements of femur, tibia and patella were recorded by an optical motion capture system. The recorded motion of femur and tibia were used as inputs to the simulation. The recorded motion of the patella was used, on the one hand, to define its initial position in the simulation, and, on the other hand, and in combination with the forces recorded by the pressure sensor and the strain gauge, to validate the results obtained from the simulation.

Because this work was a preliminary study, cruciate ligaments were released and lateral ligaments were considered as rigid bodies (to avoid contact between femur and tibia implants), thus allowing a single degree of freedom at the knee, in addition to the three rotations at the hip. The sizes of these lateral rigid bodies and the initial spring (quadriceps tendon) tension were modified to simulate different gap and tension configurations. The multibody system and the rigid body contacts were simulated by an in-house developed library [1-2] (Figure 1b).

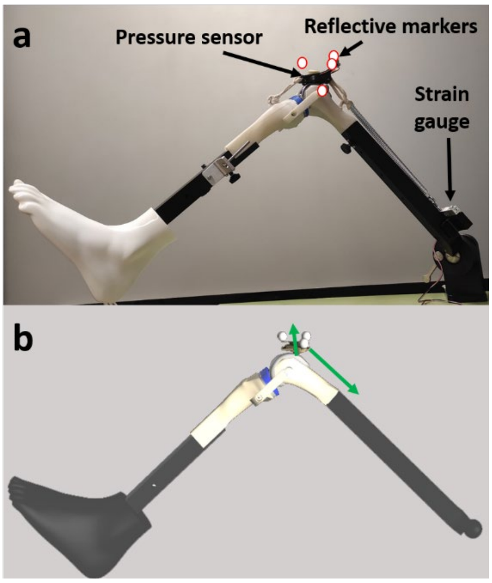

Figure 1: a) experiment; b) simulation.

Results

The simulated motion consisted in manually flexing and extending the knee (motion typically exerted by the surgeon to ensure that the patella tracking is correct after TKR surgery). Histories of position, orientation and pressure of the patella during the motion were compared with experimental measurements, offering good correlations for all the configurations tested.

Discussion

This preliminary study yielded promising results and allowed to validate the simulation of patellar tracking made with the in-house library. The use of 3D printed models and sensors enabled to work with digital twins for low cost experimental validation. They can also offer physical realistic representation of bone pathologies and planed treatment for surgeon training. Future work will aim to increase the detail of the system, so that it reflects the anatomy with higher fidelity.

References

1. D. Dopico, "MBSLIM: Multibody Systems en Laboratorio de Ingeniería Mecánica, lim.ii.udc.es/MBSLIM." 2016.
2. Dopico D., et al., 10.1007/s11044-019-09670-8

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