INTRODUCTION
Patellar maltracking results in many patello-femoral joint (PFJ) disorders, usually source of anterior knee pain. In the intact knee, this maltracking is generally due to abnormalities in the PFJ interface, soft tissue tightening and lower limb rotations. In the replaced knee, PFJ maltracking is generally due to prostheses component misalignments in both PFJ and tibio-femoral joint (TFJ), inaccurate soft tissue balancing, and inappropriate patellar component positioning, in case of patellar resurfacing. These can lead to anterior knee pain and failure of the total knee replacement [1].

A number of studies, both in-vitro and in-vivo, have dealt with the tracking of PFJ kinematics, but the literature providing quantitative reference for normal PFJ kinematics according to which patellar maltracking could be identified is still limited.

It is still debated how to study patellar motion, i.e. by X-ray graphical approach or by tracking all PFJ six-degree of freedom. No standard anatomical and articular conventions are available. Some techniques resulted to be unreliable. All these hinder the comparison of the results and their interpretation.

Computer-aided surgery has recently introduced knee surgical navigation systems in total knee replacement. These are able to monitor accurately all six degree of freedom of TFJ kinematics during all phases of the surgery and improve femoral and tibial prostheses component positioning [2].

The aim of this study was to measure in-vitro accurately all six-degrees-of-freedom of patellar motion with respect to the femur and tibia on twenty normal specimens by a knee navigation system suitably adapted to this study aim.

MATERIALS AND METHODS
Twenty below-hip amputated legs from cadavers with the knee free from anatomical defects, with intact joint capsule and quadriceps tendon were analyzed using a surgical knee navigation system (Stryker-Leibinger, Freiburg im Breisgau, Germany).

Clusters with active markers were pinned onto the femur, tibia and patella for relevant bone tracking. Particularly, the patellar cluster is lighter and smaller than the others in order to avoid inertial effect during movement registration. The standard pointer was used for system control and relevant landmark digitations used for anatomical reference frame definitions.

Movement registrations, consisting of acquisitions of five manually driven knee flexions in a 0°-140° arc, were performed under condition of 100 N vertically applied at the quadriceps tendon.

Both TFJ and PFJ kinematics were analyzed using recommended [3,4] and recently proposed [5,6] anatomical and articular conventions. For the PFJ, this includes flexion, tilt, rotation and translations [6]. Standard deviation (SD) and mean values for all kinematic variables were calculated at each degree of TFJ flexion.

RESULTS
As for the general data quality, intra-specimen repeatable paths of motion over repetitions and coupled path of motion throughout the TFJ flex-extension cycle were observed in intact and replaced knees (average SD < 0.7° and 0.5 mm, respectively for all rotations and TFJ translations). A continuous internal rotation during TFJ flexion was observed, whereas TFJ adduction was in a range of +/- 4° (Fig A).

An increase in PFJ flexion over specimens was observed over 0°-140° TFJ flexion. Particularly, the overall PFJ flexion range was 87° on average. The analysis of PFJ rotation versus TFJ flexion did not reveal a clear trend; the total amount for this variable averaged over specimens was 6.5°. The amount of the PFJ tilt on average was 7.7° medial from 0° up to 30°; remained nearly steady up to 100° TFJ flexion and a 4.8° medial tilt occurred again up to near full TFJ flexion.

A continues decrease in pattern for PFJ translations of 50, 40, 5, 38, 24 mm on average was observed along femoral antero-posterior, proximodistal and medio-lateral axes (Fig. B), and along tibial antero-posterior and medio-lateral axes respectively. The patellar translation along tibial proximo-distal axis was on average steady up to 60° of TFJ flexion, followed by a decrease in pattern of about 9 mm.

DISCUSSION
The technique used allowed the collection of a large range of knee motion by adapting a standard knee navigation system to this study aim. The results here reported seems to be very robust. Particularly, this robustness is enforced by several aspects. TFJ rotations were in physiological ranges. The total number of collected specimens allows reliable statistical assessments to be performed. The availability of whole lower limbs allowed the definitions of more realistic anatomical-based reference frames and according to general recommendations.

This study focused at contributing to the much controversial knowledge on normal PFJ kinematics and, generally, on the normal knee kinematics. The consistence of these results provides fundamental information for the comprehension of knee orthopedic treatments.

REFERENCES