In-vitro Validation of a Device Measuring the Tibio-Femoral Contact Forces and Moments for Efficient Assistance during Ligament Balancing in Total Knee Arthroplasty

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Introduction
Ligament balancing in total knee arthroplasty is believed to have an important influence on the joint stability and prosthesis lifetime. In order to provide quantitative information and assistance during the ligament balancing phase, a device that intraoperatively measures knee joint forces and moments has been developed.

Methods
Thanks to its small thickness (6mm), the developed device fits after a tibial precut entirely in the tibio-femoral gap with the patella in its anatomical place. The device measures the tibio-femoral contact force amplitude and location, thus allowing the computation of the net varus-valgus moment, which characterizes the ligamentous balance. Following an accuracy study, the device was validated with a plastic knee joint model equipped with spring-ligaments, which allowed the application of various degrees of ligamentous imbalance. Finally, the device was tested in a cadaver experiment by an experienced surgeon.

Results
During the accuracy study, the absolute force amplitude and location error were respectively 1.4 N and 0.6 mm, which corresponds to a 3% relative error on the active measurement range. The expected linear relationship between the varus-valgus moments and the spring forces in the plastic bone experiment was experimentally verified and the slope corresponded effectively to the lever arm within 12%, which attests the device's suitability for the purpose of ligament balancing. The cadaver experiment demonstrated the adequacy of the measurement scale (0-500N) as well as the consistency between the acquired data and the surgeon's perception.

Discussion & Conclusions
The design and first prototype of the proposed device has been experimentally validated. In a near future, the benefit of using such a device will be examined by a series of cadaver experiments.

Clinical Relevance
Quantitative measurements of knee joint forces and moments during total knee arthroplasty could improve the ligament balancing procedure, thus ensuring a good joint stability and an increased prosthesis lifetime.