Berichte aus der Biomechanik

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Étude biomécanique comparative de cinq différents systèmes de fixation utilisés dans les cas d'ostéotomies tibiales valgisantes: Essais expérimentaux et simulations numériques incluant les forces musculaires

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Performing tests or measurements in order to investigate the biomechanical behavior of the knee joint is very difficult and, when possible, mostly invasive. On the other hand when the tests are performed on physical prototypes (such as artificial bones often used to perform osteotomy tests for example), the difficulty resides on the experimental reproduction of the realistic mechanical environments in which the body evolves daily. Beside this difficulty, if one considers the boundary and the loading conditions which should be apply while performing the tests, one comes up additionally against the lack of accurate knowledge about the real conditions which exist.

Assessment of individual muscle forces during human movement can push forward the consideration of realistic loading of the joints while performing the experimental tests or numerical simulations. But until today direct measurement of muscle forces is not feasible. Contact forces between the bones that build articulation are measurable by means of telemetric instrumentation incorporated in prosthesis.

The musculoskeletal modeling offered a solution to that issue by providing models that enable the calculation of muscle forces. In the present work, muscles forces during a normal walk calculated by such a validated model have been applied to a finite element model of the lower limb in order to build a numerical model which can push forward the analysis of knee biomechanics. A comparison of five different currently used implants for open-wedge high tibial osteotomy has been performed by experimental study, and also by numerical analysis. The experimental study consisted in static compression loading to failure and dynamic loading to failure tests on artificial composite tibias. The numerical analysis simulated a simple loading, consisting in applying a vertical compressive load on the tibia plateau, and a realistic loading that take into account the muscle forces.

Comparing the simple loading to the realistic loading considering the muscle forces showed that the simple loading, used during the mechanical tests, is compatible with a realistic loading of the tibia with the leg at 15 % of the gait cycle during slow walking. Observations from numerical simulations considering the realistic loading emphasized the necessity to take into account the muscle forces in the testing protocols and implant design process. The results of the numerical simulations considering the simple loading were in line with the findings of the experimental study. All the implants tested showed sufficient stability during static loading. All the specimens failed due to fracture of the opposite cortical bone.

Simplifications were made to reduce the complexity of the different physical and numerical models; hence the transposition of the obtained results to clinical settings should be done with precaution.