In vivo joint loading, biomechanical analysis and arthroplasty outcome

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INTRODUCTION:

Osteoarthritis (OA) is a progressive degenerative disease of tissues within and around synovial joints that leads to joint pain, restricted mobility and ultimately, functional disability [1]. The implantation of an artificial joint is one of the most successful orthopedic surgeries to treat structural joint degeneration. However, in the last two decades, patients have become younger and their expectations after surgery regarding return to sport and normal activity levels have increased. This fact greatly challenges the durability of joint replacements due to increased use and risk of implant loosening. Physiological data on the variation of in vivo joint loads and the specific influence of implant design on surgical and patient outcomes are required to increase the lifetime success and to design implants that can handle these higher demands.

METHODS:

Our research group has developed several instrumented implant that enable direct in vivo load measurements [2]–[6], which have been implanted in more than 40 patients. Using this very specific technology, we have performed a substantial number of measurements over a postoperative period of more than 10 years to determine joint loads in vivo and biomechanical parameters with which these loads interplay. These in vivo data were supplemented by capturing external 3D kinematics and kinetics synchronously, and employing musculoskeletal modeling to assess the mechanics of related structures and their impact on joint loading. In addition to these telemetric in vivo measurements, X-ray fluoroscopy measurements were conducted to analyze the interplay between joint loading and motion and implant design.

RESULTS:

Based on these valuable in vivo load datasets, key basic research and clinical questions have been answered. For instance, we have shown that internal joint contact forces were related to internal joint kinematics and external measures of loading. Furthermore, we demonstrated that in vivo loads were influenced by antagonistic muscle co-contraction as well as muscle-to-fat ratio, which was compromised postoperatively as a result of muscle damage from the surgery. We have translated our findings to support clinical decision making, patient therapies and product engineering and design, and have published our data in a free, publicly available online database (OrthoLoad.com). Moreover, based on our clinical and scientific background, our team has established Berlin Movement Diagnostics (“BeMoveD”), a distinct diagnostic unit that provides objective, biomechanical assessments of athletes and patients with musculoskeletal conditions using gait and running analyses. Using cutting-edge motion analysis techniques and implementing evidence-based science, we provide objective, biomechanical evaluations about how patients/athletes move and load their joints. This way, we can better identify causes of musculoskeletal pain and injuries, and can implement targeted therapies to prevent the onset or worsening of OA.

DISCUSSION AND CONCLUSION:

Our public database OrthoLoad.comis already used internationally as an established basis for further developments in scientific, clinical and technical environments. For example, the in vivo measured load data in combination with the synchronously measured kinematic data can be used to validate musculoskeletal models for the investigation and analysis of different clinical and scientific questions such what are the main key parameter in vivo and how are they modulating the acting joint loads, but also to acquire detailed insight about the loads acting in vivo during several typical activities and postoperative time points. Moreover, these data are also a useful basis for designing new test standards and implant developments, and can be used to establish new guidelines for orthopedic rehabilitation. In combination with the biomechanical database from our translational hub, we aim to identify key biomechanical parameters of early onset OA that can be targeted via tailored physical interventions to alleviate symptoms, restore physical function and prevent or manage OA.

Figure1: Instrumented implants for the hip, spine, shoulder and knee joints.