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Knee Replacement Implant of Joint Contact Forces

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Abstract

Prediction of lower extremity muscle and force of contact can provide useful insights to assist clinicians in the diagnosis as well as in the development of appropriate treatments for musculoskeletal disorders. Studies often estimate joint contact forces using model-based muscle force estimates due to the lack of reliable contact models and material properties. The objective of this study was to develop an integrated Hertzian contact model. Next, the in vivo elastic properties of the total knee replacement (TKR) implant were determined using in vivo contact force, providing reliable material properties for modeling purposes. image. First, a rigid patient-specific musculoskeletal model was constructed. Second, an STL-based implant model was designed to account for changes in contact area during gait movements. Finally, an integrated hertzian contact pattern was determined for in vivo identification of the elastic properties of Young's modulus and Poisson ratio of instrument-equipped TKR implants. Our study shows the possibility of using a new method to predict contact force without knowing the mechanical force. The outcomes can therefore lead to an accurate and reliable prediction of the general human contact forces for a new case study.

Keywords: Knee replacement; Implants

Introduction

Total knee replacement implants are often indicated for patients with severe knee damage, such as osteoarthritis associated with progressive pain and functional impairment. Implants with distal and proximal tibial compartments are usually made with biocompatible materials. Alternatively, a TKR implant may include an interaction between the kneecap and the femur that provides functional stability to the knee joint. It is important to emphasize that knee contact force behaviors are activity specific and that optimal design of TKA can lead to maximum clinical outcomes. However, implant design can be optimized when its effects on musculoskeletal tissues and structures can be elucidated. Joint contact force plays an important role in understanding the influence of implants on joint performance and musculoskeletal load. Finite element modeling can provide reliable information about the behavior of the general contact force. However, the lack of an accurate mechanical model and reliable definition of the load and boundary conditions can affect the contact force calculation. Studies have demonstrated a deeper understanding of hip implantation effects through rigid body computer models and available in vivo experimental data measured directly in device hip implants. Recently, in vivo knee contact force can be measured from a new knee device. Therefore, for the first time, computerized musculoskeletal models, used to aid in surgical treatment and rehabilitation of musculoskeletal disorders, can be evaluated for their predictive power. they relate to estimates of muscle strength and knee contact loads using these available experimental data. Therefore, these models could potentially be accepted into routine clinical procedures in the future [1-5]. In addition, a free and open access database on orthopedic implant fillers has also been made available, which has spurred extensive research activities in this research area. Predicting muscle force and contact force in vivo, especially in the context of total knee replacement, is a challenging task for biomechanical engineering researchers. Model-based estimates of these forces have been commonly made. Therefore, the phenomenon of redundancy in human neural control, i.e. the number of muscles is greater than the number of degrees of freedom, can be solved by computers using optimization techniques even when the best d optimization is unknown. However, the accuracy of predicting these forces depends on the exact model of the musculoskeletal tissues, e.g. muscles, bones, tendons, ligaments and cartilages, and structures e.g. joints, as well as the appropriate formulation of physical behaviors, for example, general contact or multi-person dynamics.[6] . Model validation is a difficult problem. Qualitative muscle strength models are commonly validated for EMG-based muscular activities. In vivo knee contact force can be estimated by computer with or without contact model. On the one hand, modeling efforts involve the use of an inverse dynamic approach combined with elastic contact modeling. As part of this view, Kim et al. developed two-step simulations to calculate muscle forces, and then combined them with ground response forces and fluorescence data in a radio contact model to predict knee contact forces. In addition, Hast and Piazza used a combination of inverse dynamics, forward dynamics, and mechanical control algorithms calculated in a spring-based contact model to calculate the knee node surface contact force. . On the other hand, knee contact force was predicted without contact model. Based on the mechanical forces estimated from the pseudo-inverse method and limited static optimization with the Lagrange multiplier formula and the parameter reduction strategy, the contact forces were calculated. In addition, an electromechanical-based muscle strength estimation method combined with a moment equilibrium algorithm was used to predict the intermediate contact strength. In addition, a parametric numerical model consisting of 9 balanced equations reflecting the highest degree of muscle activation, passive structural activation, joint moment, joint external force, torque and maximum physiological muscle force was also obtained. Developed to predict knee contact force. In fact, if there is no relational model, the construction of the problem and the computational cost can be more favorable than using the relational model. A recent comparison of contact forces predicted in the Knee Challenge suggests that using a contact model does not guarantee their accuracy [7-9]. However, a deformable contact pattern

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can provide useful information on interactions between implant components and also on the bone-implant surface. It is important to note that the Knee Challenge was created to open up a new dimension in muscle and contact force prediction in the body. Almost all available measurements ranging from medical imaging data to gait analysis and experimental contact forces have been made available to enhance research activities related to prediction of these forces.

Previous studies used only a simplified representation (e.g. point contact or button surface contact) of the contact surface between implants. In addition, the material properties of the implant are usually provided by the manufacturer. However, assumptions are often made for the musculoskeletal model. Therefore, these properties must be calibrated and adjusted according to modeling assumptions to accurately predict the knee contact force. In practice, the predictive bias of numerical models is limited to clinical applications [10]. Therefore, the objective of this study is twofold: the development of an integrated Hertzian contact model based on global surface-surface interactions and using in vivo contact forces and developed contact modeling to reliably determine elastic properties and modified implant for modeling purposes.

Conclusion

Reliable elastic properties of TKR implants were determined using an integrated hertzian contact model and in vivo contact force. The availability of contact zone information allows in vivo prediction of contact force without knowledge of muscle force. Therefore, our present study demonstrated the possibility of using such method in accurate and reliable prediction of human joint contact force leading to better diagnosis and prescribing appropriate treatment.

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