INTRODUCTION: The measurement of functional implant loading during daily activities is critical to the assessment of long-term implant longevity and morbidity. For total knee replacements (TKR) aberrant tibial component shear loads encountered during walking can significantly affect implant fixation, wear, and kinematics. In vitro studies of implant shear loading often fail to consider the effects of soft tissue structures on implant loading, which have been shown to be significant contributors to knee stability, and therefore could affect resulting implant loading. The current study uses a multi-axis force-controlled testing machine to evaluate and quantify the effect of implant design on TKR and soft tissue shear loading using eight TKR designs during a simulated walking cycle.

METHODS: The eight TKR designs tested were chosen to include a wide range of suspected anterior/posterior (AP) and internal/external (IE) geometrical constraint. They were as follows: Zimmer Mobile Bearing Knee, Mark III (MBK); Howmedica Duracon (HOWD), Johnson & Johnson PFC (JIPFC), Sulzer Protek Guespar (SPRO), Zimmer NexGen Cruciate Retaining (NGCR), Zimmer Insall/Burstein II (IB), Zimmer NexGen Legacy posterior stabilized (NGL), and Stanmore SMILES rotating hinged knee (SML). All TKRs were installed on the kinematic knee simulator, insuring that the relative alignment of the tibia with respect to the femur mimicked that of the recommended surgical implantation. The zero laxity or “home position” of the tibia with respect to the femur corresponded to the location of the tibia at 0º of femoral flexion with no AP load or torque and a 50N axial coupling load. For all studies, linear soft tissue constraints of 20N/mm for AP displacements and 0.27Nm/deg. for rotation were incorporated to approximate all studies, linear soft tissue constraints of 20N/mm for AP displacements and 0.27Nm/deg. for rotation were incorporated to approximate in vivo restraint conditions.

RESULTS: All implants translated and rotated within the commonly accepted ranges of in vivo walking cycle laxities (24 degrees and 13mm). In general, all implants moved predominantly posteriorly and internally during the walking cycle producing predominantly anterior and external reaction forces (figure 2 and 3). The data presented in figure 2 describes the dynamic shear reaction forces of the implant and soft tissues to the imposed loading cycle during gait, and the data presented in figure 3 summarizes the peaks and troughs of these reaction forces. The data collected was very reproducible, with standard deviations at any point in the gait cycle averaging less than 8.21N and 0.26Nm for the implant reaction loads, and less than 4.31N and 0.15Nm for the soft tissue reaction loads for any one implant. Imposed A/P shear forces were constrained more by the TKR than soft tissues for all implants tested (figure 3). The SML implant geometry was found to carry the highest peak A/P shear force (93%), and the SPRO was found to carry the lowest (56%). Conversely, the SPRO required the soft tissues to carry the highest peak shear force (44%), and the SML was least dependent on soft tissues (7%). For rotational constraint, both SML and IB absorbed a peak of nearly 80% of the input torque, with SPRO absorbing the lowest (41%).

DISCUSSION: The results presented here show that most TKR designs depend on soft tissues to distribute the imposed shear forces and torques seen during dynamic activity. If the contribution of these soft tissues (which has been shown to be greater than 40% in some designs) is neglected during simulation or testing, even basic measures of implant performance could be misinterpreted. As with any in vitro investigation, the results presented here are limited by the ability of the experiment to reproduce the in vivo condition. Future studies should concentrate on extrapolating these kinetic results to in vivo findings. The in vivo mechanics of every TKR design are dependent upon a number of experimental variables. These include implant alignment, external loading, soft tissue constraint and implant geometry. Too often, geometry is the sole factor investigated by experimentalists, with results having limited applicability to the in vivo condition. It is recommended therefore that future experimental studies of implant design consider more fully the effects of surgical/patient factors when assessing implant function.


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