A SIMPLIFIED TOPOLOGY FOR THE TIBIAL PLATEAU AND MENISCAL SURFACES AND THE ROLE EACH OF ITS GEOMETRIC FEATURES PLAY IN GUIDING THE PASSIVE MOTION

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INTRODUCTION

The goal of this study was to see if the geometry of the tibial plateau and meniscal surfaces in the passive computer knee models can be considered as a combination of simple rigid geometries. It was also desirable to assess the role of each part of the proposed geometry in guiding the passive pattern of motion. The latter was done by eliminating different parts of the geometry from the complete model and comparing the simulation results before and after each elimination. It has been found that the resulting pattern of motion of the proposed geometry matches the experimental data and the constrained-based knee model. The comparisons between the results of different geometrical configurations led to the understanding of the roles of each part of the geometry in guiding the passive motion.

METHODS

The data reported in the literature regarding the profile of the tibial plateau in different planes were used to construct the simplified tibial geometry. The geometry of the tibial plateau surfaces in the sagittal plane has been reported to be flat in the lateral part, and a combination of a flat surface and a 11° slope in the medial portion [1]. The medial side of the tibial eminence in the frontal plane has a radius matching the femoral condyle [2], and it was modeled as a wedge with the profile in the frontal plane and extruded antero-posteriorly [3]. The lateral side of the tibial eminence was simplified as an incomplete cone [3]. The geometry of the medial meniscal surface was considered rigid and located at the extreme end points it can reach in its range of motion [4,5]. The profile of the meniscal geometry was generated considering the fact that the meniscal geometry follows the femoral surface shape. The lateral meniscus was considered as an extension to the flat lateral tibial surface [6].

Ligaments were modeled as non-linear springs and their stiffness, initial strains, and insertions points were extracted as average values reported in the literature [7,8]. A scanned femoral surface was used and all the elements were put together in ADAMS (dynamic simulation software package). A gradual flexion imposed to the model, and the kinematics response of the model was measured. Subsequently, different parts of the tibial geometry were eliminated separately and simulation was performed for each case.

RESULTS AND DISCUSSION

The internal-external rotation of the tibia and its anterior-posterior movement were determined for the complete configuration. Figure 1 compares the internal external rotation of the tibia with the results of the experimental data reported by Wilson et al. [9] and the prediction of the constrained-based model proposed by Feikes et al. [10]. Table 1 shows the internal tibial rotation for different configurations.

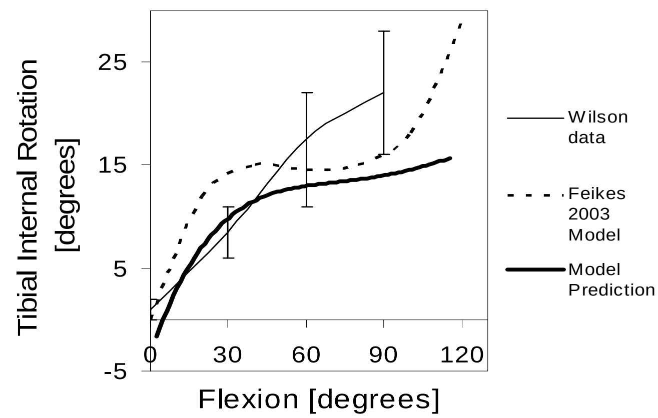

Figure 1: Comparison of the model prediction with the published experimental data and the constrained-based model

Geometric Configuration	Tibial Rotation			
Flexion	30º	60º	90º	120º
All Elements present	9.7	13.4	13.8	17.3
Excluding Lateral Meniscal	9.3	15.7	48.1	48.2
Excluding Medial Meniscal	6.2	8.2	10.1	8.7
Excluding Lateral Cone	8.2	13.3	14.1	16.6
Excluding Medial Eminence	8.9	12.9	14.5	28.7

Table 1: Tibial internal rotation for different geometric configurations at different flexion angles.

CONCLUSIONS

Based on the fact that the proposed simplified geometrical configuration replicates the natural passive kinematic patterns, it can be concluded that the recommended geometry includes the important shapes that have influence in guiding the passive motion. The medial meniscus has shown important roles in forcing the joint to undergo higher internal rotation during flexion, while the lateral meniscal extension and medial eminence seem to have a role in preventing the joint from going to excessive internal rotations.

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