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Assessment of Collateral Ligament Function following Total Knee Arthroplasty using Mobile Video Fluoroscopy

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INTRODUCTION

Intraoperative ligament balancing during TKA is generally performed based on subjective manual evaluation by the surgeon rather than quantitative metrics [1]. To define the optimal ligament tensioning and avoid postoperative complications, a thorough understanding of the elongation patterns experienced by the MCL and LCL throughout functional activities is crucial. Assessment of ligament elongation has been demonstrated via fluoroscopy-based tracking of the ligament attachment points, however, the studied activities have been limited to forward lunge and treadmill walking [2, 3] due to stationary imaging modalities. This study investigated the *in vivo* elongation patterns of the collateral ligaments throughout complete cycles of level walking and squatting and assessed the sensitivity of the estimated patterns to the positioning of the ligament attachment points in the subject-specific models.

METHODS

Tibiofemoral kinematics were captured using a moving fluoroscope [4] in 6 TKA patients (5m/1f, aged 68±5 years) with an ultra-congruent implant (INNEX, Zimmer, Switzerland) throughout complete cycles of level walking and squatting (Fig.1a). Ligament attachment footprints were identified based on pre- and post-operative CT scans. Multibody models were developed with ligaments represented by fibre elements distributed over their origin and insertion footprints (Fig.1b). The fluoroscopic knee kinematics were prescribed to the subject-specific models to assess the elongation of the ligament fibres throughout five cycles of each activity. Elongations were reported relative to the reference length at heel strike during walking.

A Monte Carlo analysis was performed by generating 500 new models for a single subject with the ligament attachments perturbed from their nominal location according to Gaussian distributions (standard deviations: 5mm in the anteroposterior and proximodistal directions, and 2mm mediolaterally). Tibiofemoral kinematics were fed into the perturbed models and the Pearson correlation coefficient (r) was computed between the maximum length-change of the ligaments and variation in the position of their attachments.

RESULTS AND DISCUSSION

The collateral ligament bundles remained nearly isometric during the first 50% of the level walking cycle (Fig.1c). From 50% to 70% gait cycle, the aMCL experienced lengthening with a maximum elongation of 5.4±1.8%, whereas the LCL slackened by 4.8±1.6%. With increasing the knee flexion angle during squat, the intermediate bundle of MCL (iMCL) showed an isometric behaviour while the aMCL lengthened (max: 4.6±1.5%) and the LCL and posterior bundle of MCL (pMCL) shortened (Fig.1d).

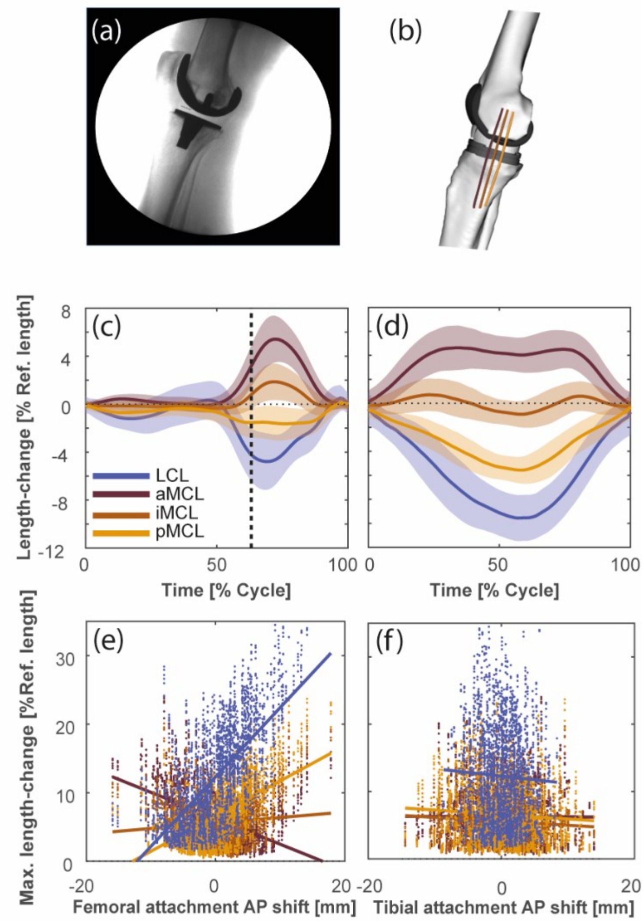

Fig 1: Fluoroscopic image during level walking (a). 3D model of the knee (b). Length-change patterns of LCL and MCL during level walking (c) and squatting (d). Sensitivity of the length-change patterns to the location of femoral and tibial attachments (e and f).

The sensitivity analysis revealed that the strongest correlations in the max length-change of the ligaments were in the location of the femoral attachments (Fig.1e). The LCL showed the greatest sensitivity with a 1mm shift in the AP direction inducing a 1.1% change in the max length-change (r=0.68). However, the tibial attachment locations did not substantially influence the collateral ligament elongations (Fig.1f).

CONCLUSIONS

We coupled dynamic imaging and subject-specific modelling to quantify post TKA collateral ligament function. This investigation revealed that MCL and LCL elongation patterns are substantially more sensitive to the location of the femoral attachment sites relative to the femoral component than the tibial attachments relative to the tibial component. Thus, in TKA where inlay designs dictate the relative tibiofemoral kinematics, the implantation of the femoral component will critically govern the post-operative ligament elongations.

REFERENCES

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