Computational Modeling of MPFL with Anatomical Attachment Sites

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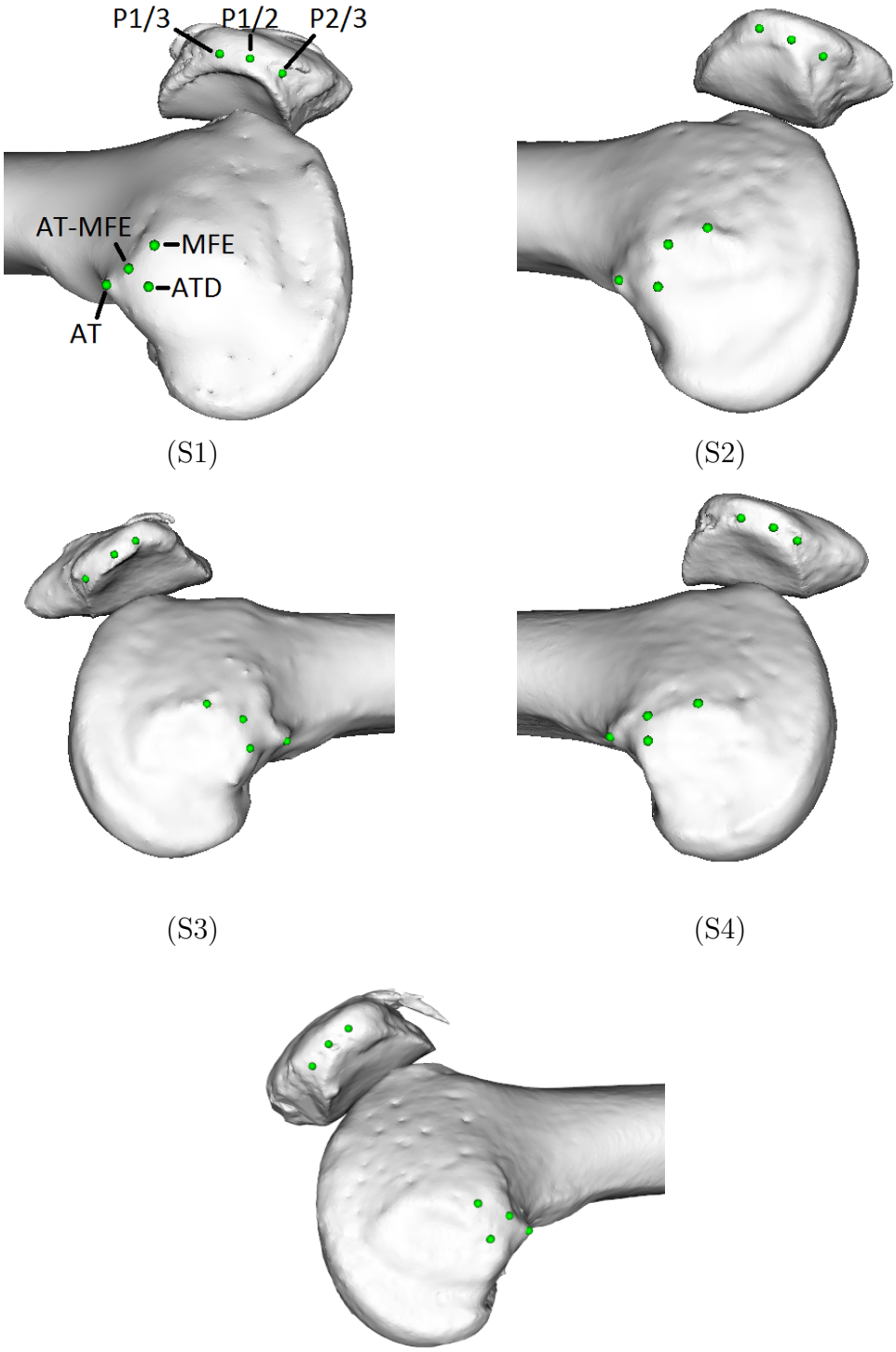
Purpose: There are many proposals of optimal attachment sites for medial patellofemoral ligament (MPFL) reconstruction [1, 2, 3, 4, 5, 6, 7]. However, the results in these proposals are inconsistent. This study aims to examine the issue of optimal MPFL attachment sites by means of computational modeling. In particular, we want to examine whether there is subject-specific variations of optimal MPFL attachment sites, which complicates the planning of MPFL reconstruction.

Method: CT scans of four males and one female unloaded cadavers' knees aged between 57 and 78 years old were captured from 0° to 120° flexion angle at 30° interval. The CT scans were segmented to obtain 3D models of patellofemoral joint poses (Fig. 1). Next, the patellar and femoral attachment sites of each patient were identified according to the previous studies [1, 2, 3, 4, 5, 6, 7]. The patellar attachment sites were (Fig. 1) proximal one third, proximal half and proximal two thirds of the medial side of the patella. The femoral attachment sites were (Fig. 1) adductor tubercle (AT), medial femoral epicondyle (MFE), 10 mm distal to AT and the concave area (saddle) between AT and MFE. The shortest straight-line distance between a pair of attachment sites was computed over the surfaces of the bone models (Fig. 2). We call this distance the *virtual MPFL length*, as it is a good approximation of the length of the actual MPFL when it is taut. The virtual MPFL length was computed for each pair of attachment sites at each flexion angle. Finally, we examined the length change pattern of the virtual MPFL to determine whether it satisfies the desired pattern. For a desired length change pattern [3, 4, 5, 6, 7], the virtual MPFL length should be longest at 30° flexion angle, and its longest length should be no more than 5% of its length at 0° flexion angle. Above 30° flexion angle, the virtual MPFL length should decrease, and above 60° flexion angle, it should be shorter than its length at 0°, which corresponds to the actual MPFL being relaxed.

Results: The test results are as follows: (1) Varying patellar attachment sites does not significantly affect the length change pattern of the virtual MPFL. On the



(S1) (S2)

(S3) (S4)

(S5)

Figure 1: Locations of anatomical MPFL attachment sites. Patellar attachment sites are placed at proximal one third (P1/3), proximal half (P1/2), proximal two thirds (P2/3) for all patients. Femoral attachment sites are placed at medial femoral epicondyle (MFE), adductor tubercle (AT), 10 mm distal to AT (ATD) and saddle between AT and MFE (AT-MFE) for all patients.

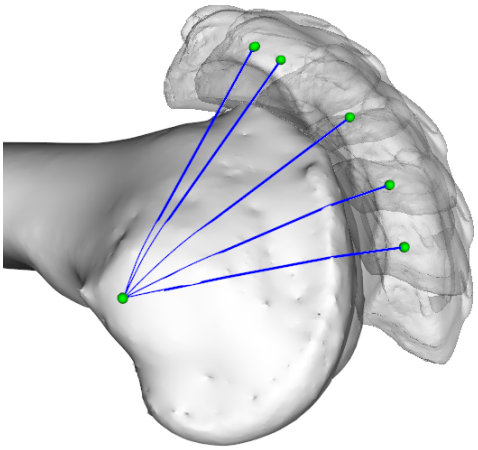


Figure 2: An illustrative example of the virtual MPFL of subject S1 at different flexion angles with a pair of attachment site fixed at ATD and P1/2.

other hand, varying femoral attachment sites significantly affects virtual MPFL's length change pattern. This result is consistent with those of [3, 5, 9]. Figure 3 shows the percentage change of virtual MPFL length with varying femoral attachment sites and patellar attachment site fixed at P1/2. (2) No single pair of attachment sites yields desired virtual MPFL length change pattern for all subjects under study. Specifically, the femoral attachment site located at ATD results in desired length change pattern for subject S1, S2 and S3, whereas there is none for subject S4 and S5.

Conclusion: Our study confirms the results of [3, 5, 9] that femoral attachment sites have more significant impact than patellar attachment sites in MPFL reconstruction. Unfortunately, the optimal pair of attachment sites that yields desired MFPL length change pattern is subject specific. This poses great challenges in MPFL reconstruction. Our continuing work is to develop a subject-specific computational model that predicts optimal MPFL attachment sites.

References

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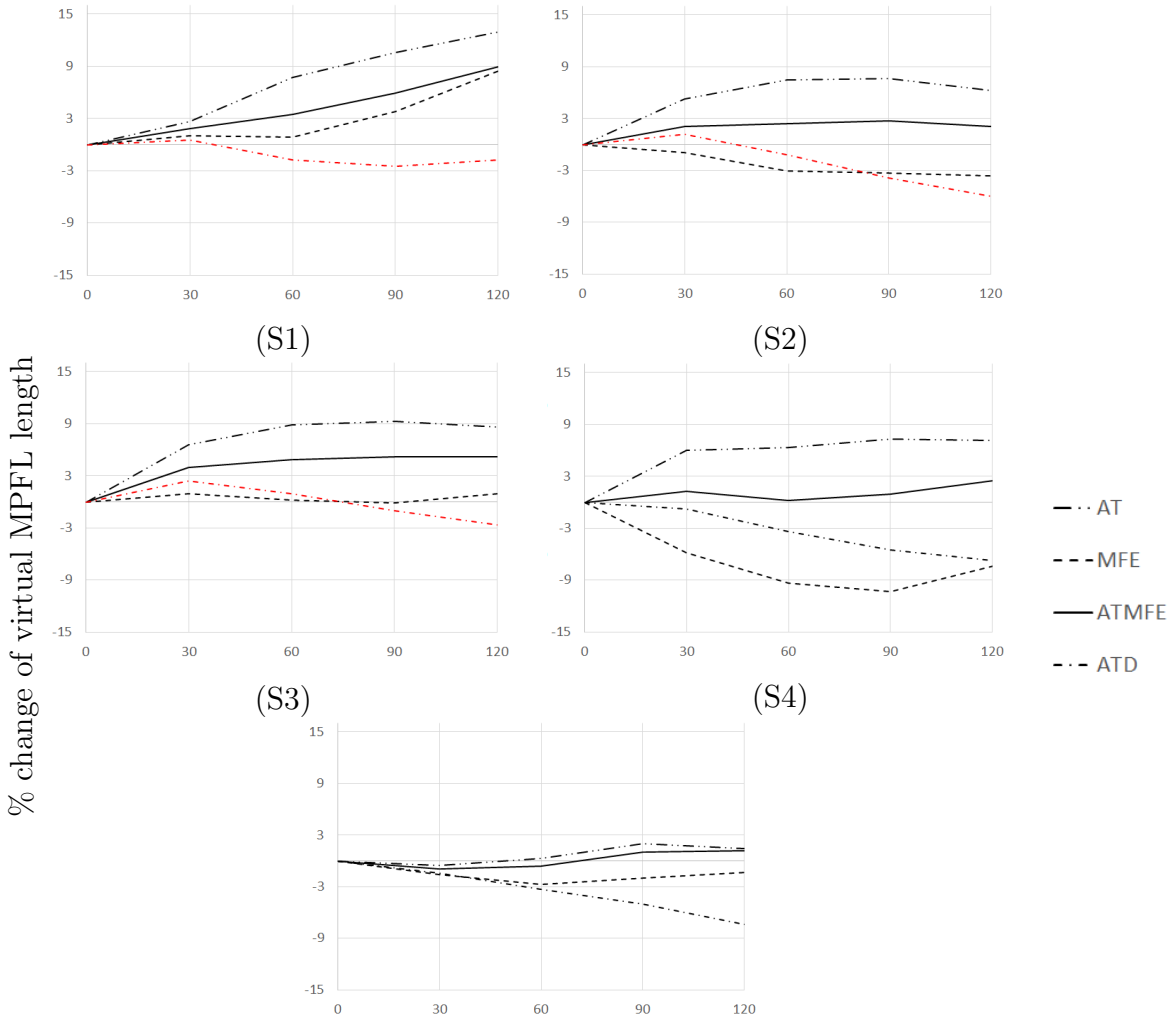

Figure 3: Percentage change of virtual MPFL length with varying femoral attachment site and fix patellar attachment site at P1/2. The red curve denotes the pair of attachment sites with desired length change pattern.

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