Reliability of Digitizing Anatomical Points from Knee MR Images for Establishing Reference Frames

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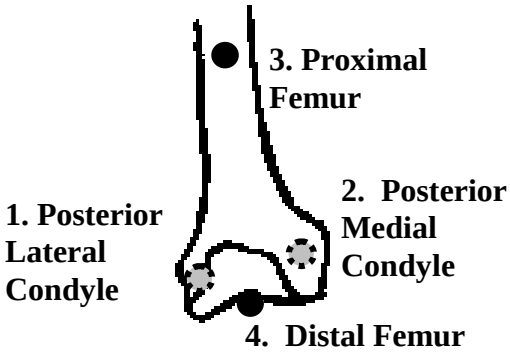
INTRODUCTION

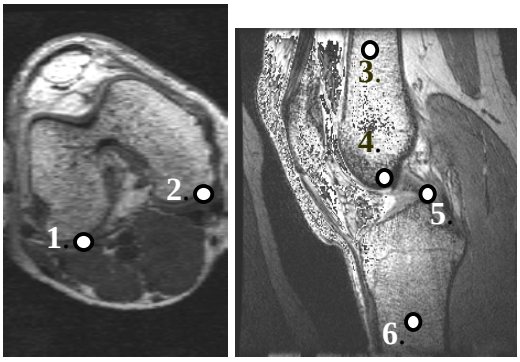
Recent studies suggest the determination of anatomic axi of the femur and tibia from palpated surface landmarks are prone to errors (≈ 13 °) (Piazza, 2000). The result of incorrectly locating the flex/ext axis is cross talk or the expression of sagittal plane movement in the frontal and transverse planes. Recent advances in tracking skeletal motion in vivo propose merging anatomic points defined with magnetic resonance (MR) images and data obtained in a movement analysis laboratory(Andriacchi, 2000). Although improved consistency and accuracy are expected few studies have evaluated the consistency in determining points from MR images. The purpose of this study was to evaluate the reliability of determining points (x, y, z) from MR images used to establish anatomic reference frames and the effect of these inconsistencies on establishing tibiofemoral orientation.

METHODS

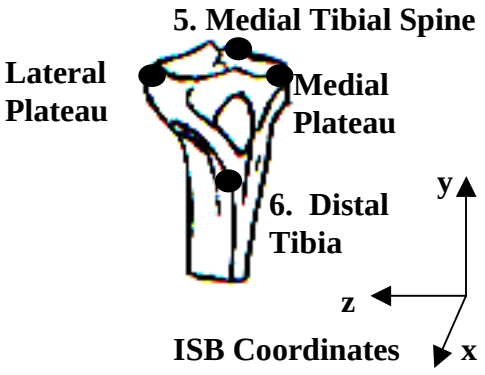
Four subjects were recruited for this study. The left knees of two subjects and both knees of two subjects were imaged, generating 6 sets of knee images. Each knee was imaged using a gradient recalled echo (GRE) sagittal, 3 minute sequence. The slice thickness was 1.5 to 1.7 mm. The in plane resolutions were either 0.5 x 0.5 mm or 0.7 x 0.7 mm. Sagittal and axial images were analyzed using NIH image software.

Figure 1. Anatomic Points





1. Post. Lat. Cond 2.Post. Med. Cond., 3. Prox. Fem., 4. Dist. Fem., 5. Med Tib Spine, 6. Dist. Tib.



Using operational definitions for each point (Figure 1) 2 testers recorded the (x, y, z using the ISB standard) location 8 points two times, blinded to which image they were digitizing. For a right femur the M/L axis was the vector from the Post. Med. Cond. to the Post. Lat. Cond. The A/P axis was the cross between the vector from the dist. Fem. to the Prox. Fem. point and the M/L axis. The vertical axis was the cross between the M/L axis and A/P axis (Sheehan, 1998). The origin was the Dist. Fem. point. An analogous reference frame was established for the tibia.

RESULTS AND DISUCSSION

Pearson correlations for intra and inter rater reliability were above 0.9 except for the medial tibial spine. The root mean square (rms) differences between test 1 and test 2 were < 3 mm (≈ 4 pixels or 2 slices) (Table 1).

Table 1. RMS difference of the x, y, z coordinates between Test 1 and Test 2.

Anatomic Point	**Intra-rater Reliability**	
	Tester 1	**Tester 2**
Tibia Points	**x,y,z(±mm)**	**x,y,z(±mm)**
Tibial Spine	0.9, 1.3, 0.7	2.6, 0.5, 0.9*
Dist Tibia	2.1, 1.3**, 5.0**	0.7, 1.3, 0.9
Med Tibial Plateau	**3.7**, 0.2, **5.4**	1.4, 0.7, 0.7
Lat Tibial Plateau	2.0, 0.4, 0.3	1.4, 0.3, 1.5
Femur Points		
Dist Fem	1.1, 0.4, 1.5	0.5, 1.5, 3.0
Prox Fem	0.4, 1.4, 1.5	0.5, 1.2, 3.0
Med Cond	0.5, 0.2, 1.1	0.3, 0.3, 1.1
Lat Cond	0.7, 0.2, **5.3**	0.5, 0.3, 0.5

***One subject with a difference of 1 cm in the y and z coordinate is excluded.**

However, there were some exceptions. Tester 2 was inconsistent in identifying the medial tibial spine in one subject, in contrast to tester one, suggesting additional training is necessary to accurately identify this point. The errors correlated with identifying the lateral rather than the medial tibial spine.

The RMS differences led to between tester and within tester changes in axi alignment of < 3 °. However, a 10 mm difference in locating the A/P coordinate of the Med. Tib. Plat. in one subject resulted in a 7° transverse plane rotation of the tibia M/L axis. In contrast a 9 mm difference in locating the M/L coordinate of the Post. Lat. Fem. Cond. resulted in little change in the M/L axis (< 1°). The definition of the reference frames explains this result.

SUMMARY

The consistency of locating the axi of the tibia and femur appears with in a few (< 3°) degrees for most subjects (5 of 6). It's plausible that training and refinement of operational definitions may reduce peak differences (< 7 °), thereby improving the consistency of identifying anatomic points for establishing reference frames.

REFERENCES

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