3D KINEMATICS OF ANKLE ARTHROPLASTIES USING VIDEOFLUOROSCOPY

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INTRODUCTION

One important design criterion of total ankle arthroplasty (TAA) is to recover some of the normal anatomical function to master motion tasks of daily activities, which could be tested with kinematic analyses. Recent technological developments, such as videofluoroscopy, enable the in vivo measurement of the 3D kinematics of implant components more accurately than by means of skin marker tracking [1-3]. Since the kinematics and therefore the in vivo perfomance of TAA components are not yet fully understood, it is the goal of the present study to analyze the 3D kinematics of TAA during the stance phase of gait using videofluoroscopy.

METHODS

The kinematics of 4 good outcome patients (> 1year postop) having an unconstrained TAA (Mobility^{TM} Total Ankle, DePuy) was analyzed during the stance phase of daily motion tasks (level gait, walking over a side inclined slope (10°) and walking up- or down a slope (10°)) using a videofluoroscopy system (BV Pulsera, Philips Medical Systems, 25Hz, 1ms shutter time) integrated in a walkway [1]. 3D reconstruction was performed using the CAD models of the TAA and an intensity based registration algorithm [4]. The respective output was the 3D pose of the TAA components with an accuracy of 0.4mm and 0.2° in plane and 2.1mm and 1.3° out of plane. The motion of the talar relative to the tibial component was described with respect to the implant coordinate system (Fig.1). Furthermore, the motion of the construction axis (defined by the cylinder axis of the talar component) relative to the tibial component was analyzed (Fig.1).

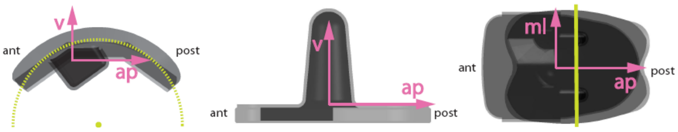

Figure 1: Implant coordinate system (mediolateral (ml) axis, anteroposterior (ap) axis, vertical (v) axis) and construction axis.

RESULTS AND DISCUSSION

The 4 subjects showed a mean maximal static range of motion (ROM) around the ml axis under weightbearing of 27.0±11.9° (Table 1).

ROM [°]	level gait		uphill		downhill		side slope bottom		side slope top		static maximal	
	PF	DF	PF	DF	PF	DF	PF	DF	PF	DF	pfdf	evinv
sub1	3.9 ± 2.8	10.3 ± 1.4	2.5 ± 1.3	5.0 ± 0.8	8.7 ± 2.3	13.3 ± 1.7	7.8 ± 3.8	11.0 ± 3.1	2.4 ± 1.9	11.4 ± 1.6	21.2	0.8
sub2	7.5 ± 1.7	17.1 ± 1.7	3.9 ± 1.6	14.3 ± 2.4	6.3 ± 1.4	16.7 ± 1.7	3.7 ± 2.6	15.6 ± 1.2	2.5 ± 2.6	16.8 ± 2.8	41.7	3.5
sub3	5.6 ± 2.4	6.5 ± 1.4	0.9 ± 1.2	2.8 ± 0.9	10.4 ± 2.3	6.0 ± 1.1	6.7 ± 2.6	3.9 ± 0.6	4.0 ± 1.5	6.5 ± 2.7	30.6	2.1
sub4	0.9 ± 1.4	7.7 ± 1.1	0.3 ± 0.4	3.3 ± 0.8	3.5 ± 0.9	8.7 ± 1.1	1.8 ± 0.9	6.9 ± 0.8	0.4 ± 0.3	2.8 ± 0.9	14.3	4.3
mean	4.5 ± 2.8	10.4 ± 4.7	1.9 ± 1.6	6.3 ± 5.4	7.2 ± 3.0	11.2 ± 4.8	5.0 ± 2.8	9.3 ± 5.1	2.3 ± 1.5	9.4 ± 6.1	27.0 ± 11.9	2.7 ± 1.5

Table 1: Mean and standard deviation (SD) of 5 trials of each subject of the ROM around the ml axis and mean and SD over all 4 subjects. Last column: static maximal ROM under weightbearing around the ml axis (pfdf) and around the ap axis (evinv).

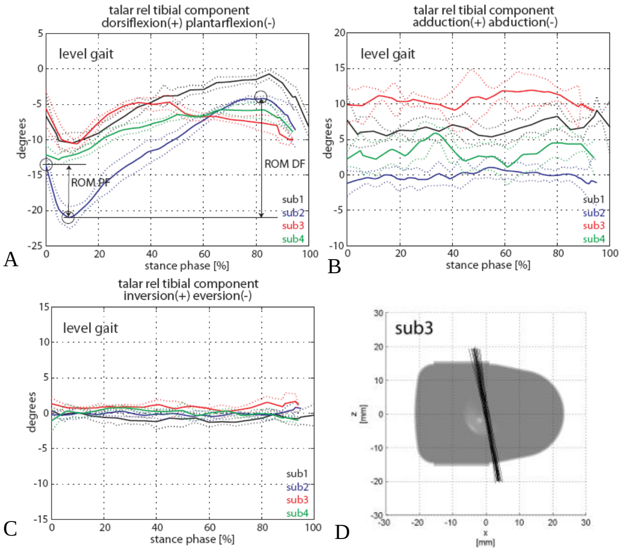

Figure 2: Mean and SD over 5 trials of each subject during the stance phase of level gait – Rotation around ml (A), v (B) and ap (C). D: motion of the talar construction axis during one level gait trial of subject 3.

During the stance phase the relative rotations between the talar and the tibial component showed large interindividual differences. A meaningful ROM could only be defined for the rotation around the ml-axis (Fig. 2A). Rotations around the ap and the v axes were marginal and in the range of the detection limit (Fig. 2B-C). The translation of the talar construction axis showed for all subjects and all conditions less than 4.6mm of translation along the ap axis (Fig. 2D). Except for subject 2, all subjects showed a minor reduced ROM during level gait compared to gait data of healthy ankles that showed a mean ROM of around 13° [5]. However, none of the subjects exploited the actual available static ROM during the stance phase of all gait tasks (Table 1). Thus it can be assumed, that the TAA did not limit gait.

CONCLUSIONS

The kinematic data presented shows TAA motion without being limited by skin movement artefacts. Hereby separating motion at the TAA from motion at adjacent joints, which is not possible with skin marker analysis. The four subjects show large interindividual differences, but overall compared to healthy ankles the TAA patients showed only minor reduction in their ROM around the ml axis.

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