Investigation of tibiotalar impingement using retrospective 3D volume reconstruction and a flexible tracking device

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Introduction Recent work in dynamic imaging of the knee has revolved around using an external mechanical device which restricts knee motion and additionally induces loading of the joint [1-3]. In this work we describe a method to construct 4D datasets of unconstrained and unloaded movement of the ankle using a special tracking device [4]. One use of these datasets is in the diagnosis of tibiotalar impingment, a condition defined as painful mechanical limitation of full ankle movement. It is caused by osseous, soft tissue abnormalities, or a combination of both. According to the anatomical site the condition is categorized as anterolateral, anterior, or posterior ankle impingement [5]. MRI provides crucial information for diagnosing soft tissue abnormalities causing ankle impingement. However, with static MRI, in a relevant number of patients impingement due to soft tissue abnormalities can at best only be suspected [6].

The technique presented enables a kinematic evaluation of the whole ankle joint. We also demonstrate that tibiotalar soft-tissue impingement can be recognized using this method in a volunteer with known ankle dysfunction.

Method ShapeTape (Measurand Inc., NB, Canada) is a tracking system comprising bend-sensitive optical fibers encased in a plastic sheath. Our custom-built MR-compatible ShapeTape consists of four such tapes. Each tape reports pose in four sensitive regions along its length at a rate of approximately 90 Hz. In our experimental setup two tapes are used. The first tape is fixed to the fore-foot above the metatarsals and the second tape is fixed to the leg above the tibia (Fig. 1). The base of each tape is mounted to a 12-channel head coil. By subtracting the position of the tape attached to the tibia from the tape attached to the fore-foot we produce a signal that describes the motion of the foot inside the coil.

Two healthy volunteers and one with tibiotalar impingement were scanned using a 3T Trio (Siemens Healthcare, Germany). All volunteers were instructed to slowly move the fore-foot backwards and forwards over a period of approximately 2 minutes. A CINE sequence was used (TR/TE = 274/1.5 ms, matrix size 256×256, voxel size ~1×1×3.8 mm, acceleration factor 2, flip angle 15˚) to collect 2D images of the ankle in the sagittal orientation. A total of 500 slices were acquired, spread evenly across 25 positions in the through-plane direction, covering a range of 95 mm. Following acquisition, the tracking data were synchronized with the images using their timestamp information.

Ten position bins were defined, which map to regions along the foot trajectory (Fig. 2). All 500 images were assigned a bin and then each bin was ordered by slice depth to produce 10 3D image stacks. These image stacks represent consistent 3D volumes at given foot positions. By selecting a common slice in each of the 10 bins a sequence showing foot motion can be generated. Additionally, slices of varying depths can be selected. This allows a clinician to investigate foot motion in both medial and lateral slices. The choice of 10 bins leads to redundant data in some central bins but produces a better bin-filling in the outer bins.

Results Fig. 3 shows 4 frames from the volunteer diagnosed with tibiotalar impingement and for comparison Fig. 4 shows 4 frames from a normal volunteer. A clinician was able to identify the impingement using the full motion-sequence partially shown in Fig. 3.

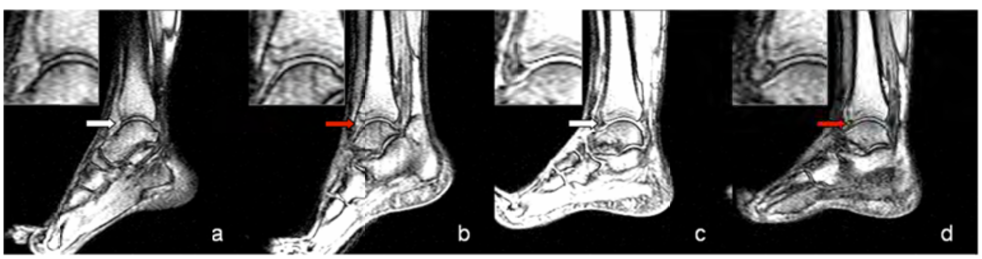

Fig. 3 - Volunteer with tibiotalar impingement - (a) In a central slice of the 29 year old patient no pathologic findings could be observed, whereas (b) the medial articular compartment showed a thickened synovial plica (red arrow). During dorsal extension of the foot in (c) the central compartment no soft-tissue impingement was observed. At (d) the medial compartment a bulging of the synovial plica with resulting soft-tissue impingement developed (red arrow). The top left-hand corners show the regions near the arrows magnified two times for clarity.

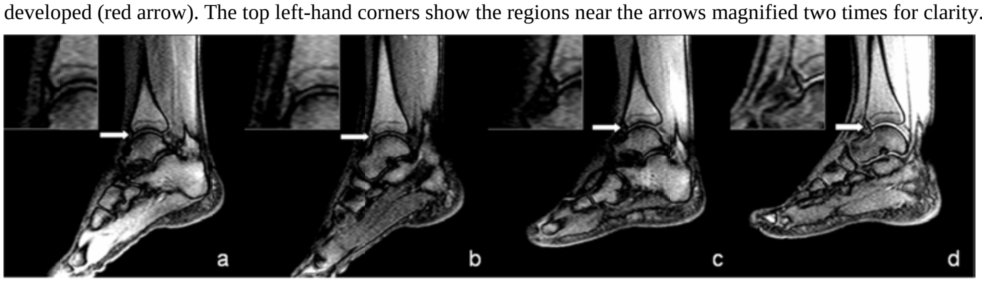

Fig. 4 – A healthy volunteer – In comparison with Fig. 3 tibiotalar impingement is not seen in the motion-sequence from a healthy volunteer. The labels a, b, c, d are defined in Fig. 3.

Fig. 1 – Tracking tapes (blue) are attached to the fore-foot and leg to track the motion of the ankle.

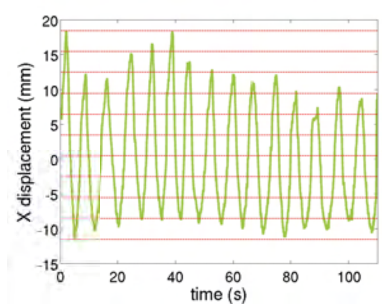

Fig. 2 - Tracking data (green) representing the ankle position are sorted into 10 discrete position bins (red horizontal lines) and used to produce motion sequences as shown in Fig. 3, and Fig. 4.

Discussion and Conclusion The presented method enables 4D datasets of free unloaded movement of the ankle to be constructed. This method could become a useful tool for clinicians once imaging has been completed on a greater number of subjects. The use of the tracking system allows unconstrained and unloaded motion to be followed, which is an advantage over existing diagnostic options.

References [1] Weber et al., Proc. ISMRM 2011, #3180 [2] d'Entremont et al., Proc ISMRM 2011, #3177 [3] Bradford et al., Proc ISMRM 2011, #3178 [4] Herbst et al., Proc. ISMRM 2011, #2683, [5] Bassett FH 3rd et al., J Bone Joint Surg Am 72:55–59, [6] Philip Robinson Eur Radiol. 2007 Dec; 17(12):3056-65.