Real-time imaging of the temporomanibular joint motion based on golden ratio radial MRI

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Introduction: The motion and the anatomy of the temporomandibular joint (TMJ) is very complex. Static or pseudo-dynamic MRI of the TMJ does not allow for full analysis of the disc deformation and displacement during the mandibular motion. The purpose of this study was to develop and evaluate a fast dynamic MRI technique for measurement of the TMJ with an arbitrary reconstruction window time point and width.

Subjects and Methods: For the study, seven healthy volunteers (mean age 28, age span 25-37) and eight patients (mean age 31.3, age span 18-67) with different TMJ disorders were scanned on a 1.5T MRI system using two 4-channel multifunctional coil arrays. A radial FLASH sequence (with parameters TE 5/12ms, TR 30ms, flip angle 11°, in-plane resolution 0.59x0.59mm², slice thickness 3mm, two non-parallel alternatingly measured slices for the right and left TMJ) was employed for examination of the intra-articular space. Because of the short T2 of the fibrocartilagenous tissue, the disc gives less signal at long TEs and becomes well-delineated due to the contrast to the surrounding tissues. On the other side, the shorter TE of 5ms results in a better contrast between the cortical bone and soft tissue of the intra-articular space. The sequence uses a trajectory with a constant azimuthal profile spacing of 111.246°, based on the golden ratio [1], was implemented. The golden ratio based profile spacing guarantees a flexible reconstruction window and a low artifact level if the number of used projections equals a Fibonacci number. The measurement data was gridded and reconstructed with the NUFFT algorithm [2]. Two different kinds of TMJ measurements were performed: opening and closing of the mouth in a 15s timeframe and biting into a cooled chocolate-covered caramel placed on one side between the posterior teeth (unilateral asymmetric loading). To reconstruct the dynamic dataset, a sliding window reconstruction was used [3]. Additionally, in order to obtain the optimal trade-off between spatial and temporal resolution, a KWIC filter was applied [4].

Results: For the sliding window method 34 projections (Fibonacci number; window width of about 1s) were sufficient to reconstruct an image that sharply depicts the mandibular condyle and suppresses temporal blurring in the images. In the case of a KWIC filter, a constant Nyquist sampled k-space dataset gave a sufficient result. Fig. 1 shows three images from a dynamic sequence acquired for one volunteer. TMJ of a patient under asymmetric loading is shown in Fig.2. High in-plane resolution allowed for assessment of the distance between the condyle and fossa in all cases. This information served as an indicator of disc deformation or displacement.

Figure 1: Three images at different mouth opening states of the left TMJ during slow mouth opening taken from one measurement. The mouth is (left) closed at the beginning of the measurement, (middle) slightly opened and (right) wide open. The harmonious movement of the disc in the intra-articular space is clearly visible. The series is reconstructed with the KWIC filter at constant Nyquist sampling.

Conclusion: The proposed method for dynamic MRI of the TMJ is suitable for diagnosis as well as therapy planning and monitoring. Mandibular motion with or without loading can be acquired within a total acquisition time of about 20s and analyzed with an arbitrarily chosen reconstruction window.

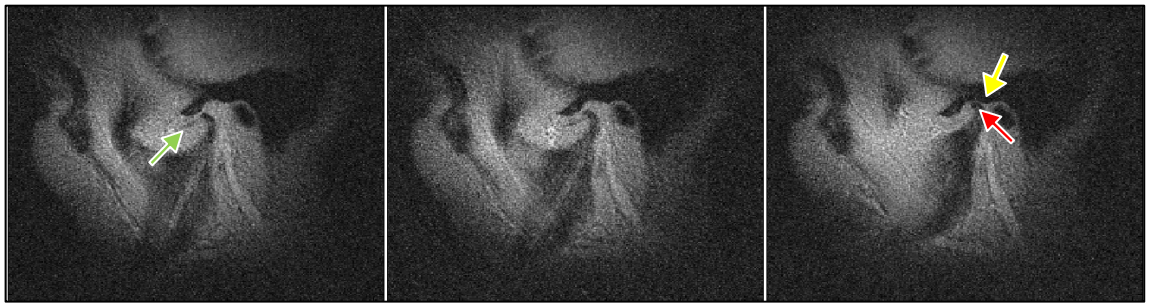

Figure 2: Three images of an image series while the patient bites on a caramel. The right (loaded) TMJ is shown. (left) The patient has not yet started biting, (middle) during biting, (right) mouth closed. In the last image almost no space is left between the condyle (red arrow) and fossa (yellow arrow). The disc turned out to be displaced in anterior position (green arrow). The series is reconstructed with a sliding window technique with a window size of 64 projections.

References:

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