MR imaging of the temporomandibular joint at 7.0 Tesla: a feasibility study using novel high permittivity dielectric pads

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Introduction: Temporomandibular disorder (TMD) is a collective term for various pathologies of the temporomandibular joint (TMJ), has a great impact on the quality of life of patients and causes great socioeconomic costs (1). Magnetic resonance imaging (MRI) at 1.5T and 3.0T arose as the leading imaging method to assess the TMJ (2) but does still not provide the required spatial resolution to accurately evaluate the clinically relevant structures of the TMJ. Imaging the TMJ at higher field strengths, such as 7T is assumed to enhance visibility of the TMJ by enabling a superior spatial resolution by taking advantage of the higher SNR. However, imaging the TMJ at 7T has not yet been demonstrated due to significant challenges, such as strong inhomogeneities of the transmit radiofrequency field (RF; B1+) which are caused by the elliptical head shape and the susceptibility differences between different types of tissue composing the TMJ. Recently, dielectric pads consisting of suspended metal titanates have been used to homogenize the B1+ field within the brain at 7T as well as the inner ear without increasing the specific absorption rate (SAR) (3-5). The aim of the current study was to quantitatively and qualitatively evaluate the use of high-permittivity dielectric pads for enabling clinical MR imaging of the TMJ at 7T.

Methods: 12 asymptomatic volunteers without history of TMD were imaged with and without high-permittivity dielectric pads on a 7.0 T Philips Achieva system (Philips Healthcare, Best, The Netherlands) equipped with a 32-channel head receiver array. Written informed consent according to institutional guidelines was obtained from the participants prior to imaging. Dielectric pads were manufactured using a suspension of barium titanate (-325 mesh powder, Alfa Aesar GmbH & Co KG, Karlsruhe, Germany) and deuterated water (9.99%, Sigma Aldrich, Zwinjndrecht, the Netherlands) and individually tailored for female and male volunteers (5). Imaging protocol consisted of proton density weighted (PDw) turbo-spin echo (TSE) sequence in oblique sagittal orientation. Both TMJs were covered with 12 slices respectively, resulting in a total of 24 slices with the following imaging parameters: field-of-view (FOV): 150x150mm^2, in-plane resolution: 0.2x0.2mm^2, slice thickness: 2mm, TE: 22 ms, TR: 3300 ms. For 6 volunteers, image acquisition was accompanied by an identical scan without RF excitation to assess the noise statistics of the data. In addition, maps of the B1+ distribution were assessed using the dual refocused acquisition mode sequence. For SNR analysis, participants´ image data were post-processed together with corresponding noise data of every coil channel using dedicated software routines (Matlab, Natick USA), resulting in voxel-based SNR maps for the whole FoV. Manual segmentation was performed to extract the corresponding values according to the anatomical location of the TMJ (6). For qualitative analysis, images were independently assessed by two fellowship-trained radiologists and rated with respect to the overall image quality as well as the visibility of clinically relevant structures on a 5-point Likert scale. Assessments performed with and without pads were compared using t-tests.

Results: Applying high-permittivity dielectric pads, SNR was significantly higher within the region covered by the TMJ and its surrounding structures (mean±SD with pads: 18.34±8.54; without pads: 7.79±1.75, p<0.001; see Figure 1). Assessed effects of the dielectric pads on transmit efficiency are shown in Figure 2. The qualitative analysis is presented in Figure 3 and showed significantly better image quality and better visibility of all subregions of the articular disc as well as surrounding anatomic structures when using the high-permittivity dielectric pads (p<0.05, corrected for multiple comparisons). In particular, the TMJ was not visible without the application of high-permittivity dielectric pads.

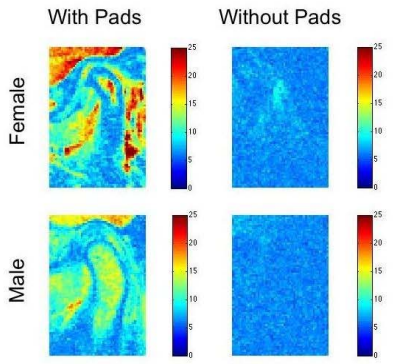

Fig. 1: SNR-maps of the TMJ of a female and a male volunteer with and without dielectric pads. SNR is color-coded and ranges from 0 (blue) to 25 (red).

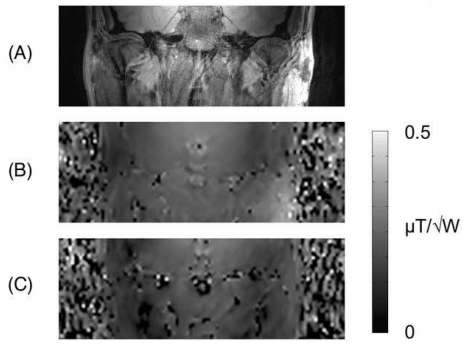

Fig. 2: Coronal anatomical reference image (A) and measured transmit efficiency with (B) and without (C) dielectric pads. Assessed data were normalized to the transmit power of 1W.

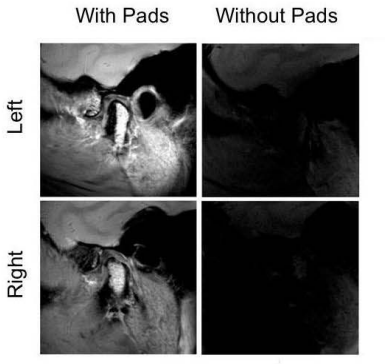

Fig. 3: PDw-TSE images of a healthy female volunteer with and without dielectric pads.

Conclusion: The current study provides first evidence that clinical imaging of the TMJ is feasable at 7T. The application of high-permittivity dielectric pads improves SNR as well as local B1+ fields, which permits the evaluation of all clinically relevant structures of the TMJ at a very high spatial resolution for the first time.

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