Simulation study on safety of dental implants at 7T

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Introduction. One of the potential disadvantages of higher magnetic field strengths is the increased heating of medical and dental implants as the half-wavelength "resonant" dimensions become much shorter and similar to those of such implants. In Europe a very common implant is a retainer wire behind the teeth. In the Netherlands 40% of younger patients and healthy controls have such dental work [1]: given current guidelines which prohibits neurological scanning in high field magnets, this precludes a large proportion of the population. The aim of this study is to determine whether in fact scanning a person with this wire in place can be performed within safe SAR levels.

Method Simulations were performed at 298 MHz using a finite-difference time-domain model (xFDTD, Remcom). A 16-leg low pass birdcage head coil with length 220 mm, diameter 270 mm, driven by ideal current sources was used. Values were scaled to the measured B_1^+ produced by the actual 7T quadrature head coil. Electric fields, voxel-based SAR and 1g tissue averaged SAR values were simulated. Time-averaged SAR values used a duty cycle of 1%. A curved 35 mm long, 0.55 mm diameter titanium wire with conductivity at 298 MHz of $5x10^5$ S/m was based on actual dental implants. Simulations of the wire directly surrounded by homogeneous tissue, and with a 5 mm air gap between the wire and tissue were first performed. For "in vivo" simulations a 0.5 mm resolution head model (Duke) provided through the ITIS Virtual Family [2] was used, with and without the tongue touching the wire.

Results Phantom results show that the presence of an air gap between the wire and tissue increases the value of the electric field produced by the wire, as has been seen previously for insulated wires. However, the electric field drops off much more rapidly away from the wire, and so with a 5 mm air gap, the maximum SAR in the tissue is much lower (in fact equal to the SAR of the conductive phantom itself without the wire) than for the wire in direct contact with the phantom. Similar results are achieved for the in-vivo model. The presence of a 5 mm gap between the tongue and the wire results in the SAR being essentially identical to the case in which there is no wire present. In contrast, having the tongue touching the wire creates an SAR hotspot within the tongue itself.

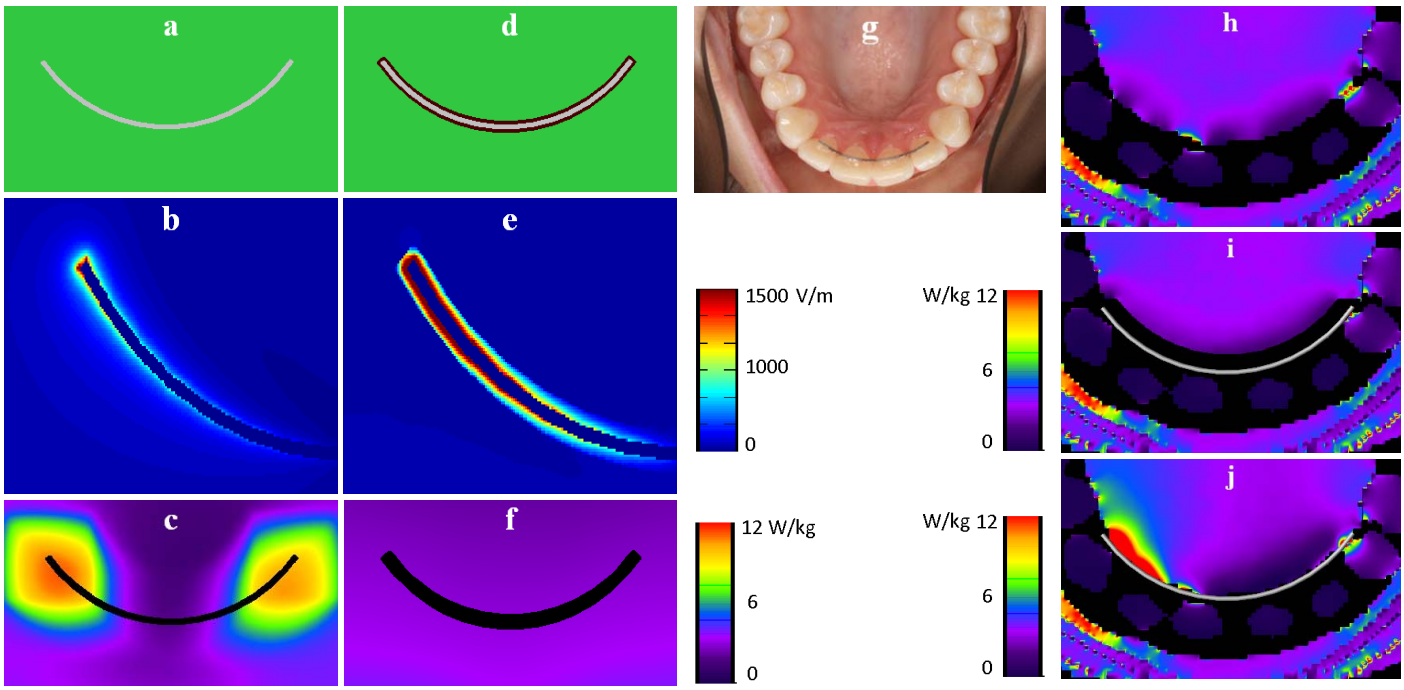

Figure 1. (a) Schematic of wire (white) placed in direct contact with a muscle-mimicking phantom (green). (b) Map of the electric field with maximum value ~6200 V/m. (c) Map of 1g SAR with maximum value 11 W/kg. (d) Schematic with 5 mm air gap (black) between wire and phantom. (e) Electric field map, maximum value ~11000 V/m. (f) 1g SAR map with maximum value 3.2 W/kg. (g) Photograph of wire place behind the teeth. (h) SAR map of teeth/tongue region with no wire in place. Max SAR 3.5 W/kg. (i) SAR map with 5 mm gap between wire and tongue. Maximum SAR 3.5 W/kg (j) SAR map with no gap. Maximum SAR value 40 W/kg.

Discussion Two competing effects determine the relative SAR for the case of the wire being in close contact with tissue or separated by an insulating gap. If the wire is close to tissue then the resonant half-wavelength dimension is much closer to the length of the wire. However, loading by the tissue also reduces the coupling between the transmit coil's electric field and the wire due to a much lower Q value. In the case of the wire in homogeneous tissue, the air gap increases the Q but also the resonant half-wavelength. Simulations suggest that the latter effect is predominant in this case. This is also found in the "in vivo" situation. Absolute numbers reported are, of course, overestimates given that thermal diffusion, convection and tissue have not been included, but the overall behaviour will remain the same. Based on these results, providing that a small air gap is introduced between wire and the tongue (using a mouthgard for example) there is no danger from wires behind the teeth at 7T.

References [1] AA. Schuller et al 2009 TNO report TNO/LS.2011.019. [2] Virtual Family ITIS ETH Zurich.