Towards dental MRI: Zero TE imaging of compromised equine teeth

S. Zwick[1], J-B. Hövener[1], J. Leupold[1], F. Schellenberger[2], and D. v. Elverfeldt[1]
[1]Department of Radiology, Medical Physics, University Hospital Freiburg, Freiburg, Germany, [2]Dr. Frank Schellenberger Hypo Dental

Introduction: More than 80 % of endodontal tooth diseases are not diagnosed because of unspecific symptoms and lack of diagnostic means. Only years after onset of the disease, if at all, secondary manifestations may allow diagnosing the initial cause. In the meanwhile, behavioral symptoms may range from depression to high-grade aggressiveness and sometimes even rendering the horse unrideable. Even state of the art oral examination together with x-ray and computer aided tomography may be unable to detect early changes to the pulp. To date, restorative treatment of the tooth at an early stage is not possible and extraction at the late manifestation remains the ultima ratio. Here, we investigate the potential of contrast-agent free dental MRI. Components of a tooth like adamantine and dentin have very short T_2 times (of the order of µs) thus can't be imaged with conventional MRI methods (TE ≈ ms). Novel methods like zero TE (ZTE) imaging acquire the FID signal directly and may allow for direct detection of the components of teeth. Here, we investigate whether it is possible **(a)** to image the solid components of a horse tooth directly and obtain significant contrast, **(b)** visualize the inherent structural differences between healthy and impaired pulps.

Materials:

Samples: Differently compromised molars of warm-blood horses (7 y and 13 y) were examined less than 1 w after extraction. The teeth were diagnosed to apical infection.

MRI methodology: A small animal MRI (B_0 = 9.4 T, BioSpec 94/20, Bruker, Germany) equipped with a quadrature mouse coil (inner diameter (I.D.) = 3.1 cm, straight shaped equine tooth) and a linear rat coil (I.D. = 7.1 cm, convex shaped equine tooth) fitting the compromised teeth were used. In combination with the ZTE sequence provided by the manufacturer (1), minimal isotropic resolution of 235 (470) µm was achieved (paravision 5.1, TR = 4 ms, bandwidth = 312,5 (200) kHz, polar undersampling = 5.28 (3.58), acquisition time = 13 (90) min, 5 averages, duration of acquisition window 410 (640) µs, FOV = 6 (12) cm for mouse (rat) coil, respectively). The homogeneity of the static field B_0 was optimized using iterative adjustments of 1st and 2nd order shim.

Results:

(a) The described method allowed to image the solid components of the tooth. Strong contrast was observed between different constituents, which was confirmed by a photography of the chewing surface (Fig. 1a/b). Dentin, cement, adamantine and pulp was identified. Note the strong signal of relatively humid dental pulp.

(b) The three-dimensional (maximum-intensity-projection) reconstruction of the ZTE dataset clearly displays five strains of pulps (Fig. 1c, windowed to suppress the signal of solid material). While four strains exhibit homogeneous signal, one appears disrupted and of spongious structure (Fig. 2).

Discussion and outlook:

The spatial resolution of the current setup is limited by two points: (1) ZTE detects solid materials of the tooth as well as those of the coil, i.e. requires a large FOV (proton-free materials such as polytetrafluoroethylene / Teflon). (2) The maximum acquisition matrix is currently 256³, restricted by the hardware. Despite these limitations, ZTE imaging widens the field of dental MRI. The method exhibits superior contrast between the solid constituents of the tooth compared to previously employed methods (2,3). Clearly, MRI at all is no veterinarian standard and dental MRI in humans no clinical routine. Its application to selected cases, however, seems feasible. Less extensive methods like digital volume tomography should be evaluated, too. Its application to humans may be feasible thus reducing the to-date obligatory exposition of the sensitive head-neck region to x-rays.

References

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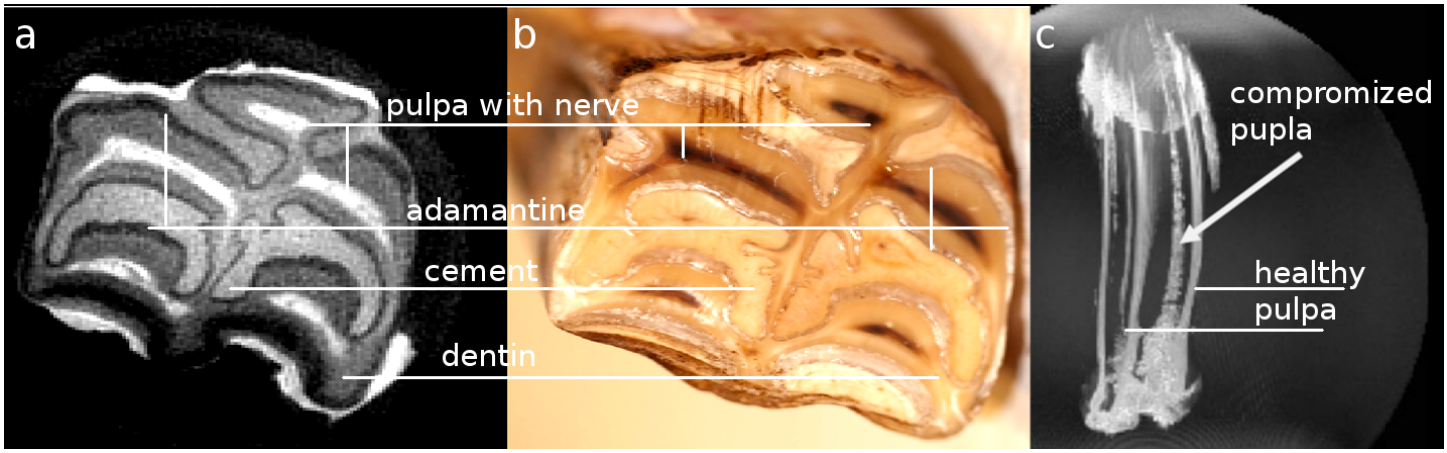

Fig.1: Zero-TE imaging (a, c) and photography (b) of a healthy and compromised horse tooth. High resolution ZTE images showed excellent contrast of the solid constituents of the extracted tooth (a), strongly resembling a photography of the chewing-surface (b). Note: image in (a) lies approx. 3 mm below the surface. A pathologic tooth exhibited one strain of inhomogeneous pathologic pulp (c). For acquisition parameters, see text.