Microstructural assessment of dental tissues by quantitative MRI using ultra-short echo times (UTE): in-vitro evaluation

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Introduction

Magnetic resonance imaging (MRI) is a non-invasive tool widely applied for diagnostic purposes in a variety of anatomic regions of the human body. However, its application to assess the structural feature of the dental hard tissue has not been reported, yet. The main limitation of MRI in this field results from the very short T2 and T2* values of the hard tissue, ranging from 70µs to 150µs (1, 2). Recently, the UTE pulse sequences have been introduced in various fields for imaging of short T2 and T2* components with sufficient SNR.

The goal of this contribution is to demonstrate the feasibility of UTE imaging for assessing the tooth tissue components including enamel, dentine, pulpa and root channels in-vitro.

Materials and Methods

Samples preparation: 72 extracted human teeth were fixed in formalin solution. These samples included incisors, canines, pre-molars and molars. In order to decrease susceptibility artifacts and mimic the biological conditions, all teeth were embedded in agarose gel, which was carefully degazed to avoid air bubbles and thus image artifacts in the final sample.

MRI Measurement: All measurements were performed on a 3 Tesla whole body MRI system (Achieva, Philips Medical Systems, Best, The Netherlands) equipped with gradient hardware capable of a maximum gradient amplitude of 40 mT/m using a maximum slew rate of 200 mT/ms. All data was acquired with a prototype two times two-element carotid artery coil sized 120 × 50 mm (Philips Research Europe, Hamburg, Germany). The internal coils measure 65 × 50 mm, each.

A non-selective short RF pulse was applied for excitation to ensure minimal echo times, which were only limited by the time required to switch the RF front-end from transmit to receive mode. K-space was encoded along a 3D radial trajectory covering a sphere at homogeneous angular density. The k-space data permit the reconstruction of spherically shaped 3D datasets at isotropic spatial resolution. The scan parameters for the UTE acquisitions were: FOV 80mm^3, α=10°, 3 signal averages, TR=9.4, TE=0.05, and 4 ms at a bandwidth of 357 Hz/voxel, with a total scan time of 37min. Images were reconstructed using an 400^3 matrix, yielding an isotropic resolution of 200µm^3. The 3D gradient echo parameters were FOV 80mm^3, α=10°, 3 signal averages, TR/TE =12.8/5.1ms while 3D spin echo parameters were FOV 80mm^3, α=90°, 3 signal averages, TR/TE =163.9/14.6 ms.

Results

Figure 1 shows images of a single slice of a tooth acquired with different TEs and different acquisition techniques (3D-UTE with TE = 50µs, 2ms 4ms, 3D-FFE with TE=4ms and 3D-SE with TE=5ms). The images in the bottom row are inverted images of those in the top row resulting in a more X-ray like appearance of the images.

As the only approach, in the 50µs echo time UTE images a clear delineation of the main tissue components including enamel, dentine, pulpa and root channel could be achieved with intensities differences, which differ significantly from noise. The quantitative assessment of mean image intensities of the major tooth components clearly demonstrates the qualitative findings **(Figure 2)**. The mean differences in image intensities between enamel-dentine, enamel-noise and dentine-pulpa-root channels showed significantly differing values with p-values below 0,001 obtained using paired student's t-test.

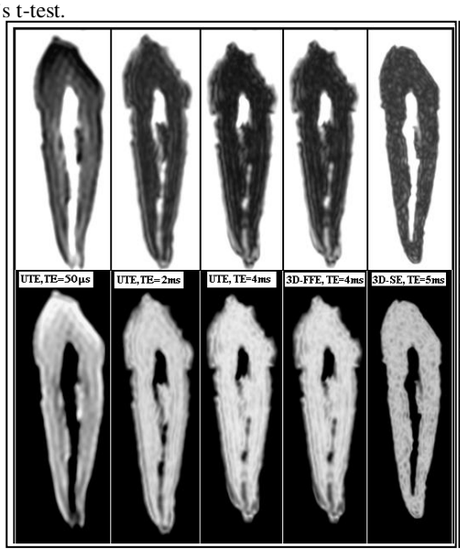

Figure 1: Images of the same slice at different TE with different acquisition approach. The images in 2nd row are inverted images of those shown in the 1st row.

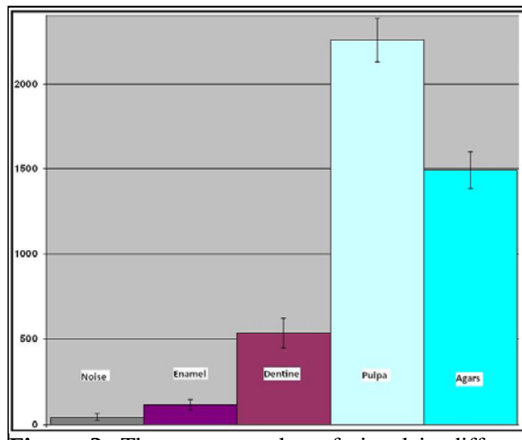

Figure 2: The average value of signal in different dental tissue components compared to noise and agarose (in arbitrary unit)

Discussion

The T2 values of enamel and dentine are 70µs and 150µs at 1.5T (1, 2). Hence, it is not possible to detect any signal from these structures using conventional sequences even with minimized TE. It was shown that high-resolution MRI with ultra-short echo times (UTE) enables assessment and delineation of the different hard dental tissues. High spatial resolution was necessary to avoid partial-volume and blurring effects that obscure or corrupt the signal from the transition between dentine and enamel.

Conclusion

In-vitro ultra-short echo time MR imaging (UTE) enables non-invasive delineation of the hard tissue features of teeth at high spatial resolution and sufficient contrast and resolution to clearly delineate enamel, dentine, pulpa and root material. This could have important diagnostic implications for the detection of early structural breakdown as well as offering a non-invasive means for assessing conservational dental therapy.

References: (1). Holmes JE et al, Radiography. 2005; 11: 163-74. (2). Robson MD et al, NMR in Biomed. 2006; 19: 765-80.