In Vivo and In Vitro T2* Quantification of Carious Lesions by Ultra-Short Echo-Time (UTE) MRI

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Background: Ultra-short echo time imaging techniques such as UTE (ultra-short echo-time imaging), ZTE (zero echo-time imaging) and SWIFT (Sweep Imaging with Fourier Transformation) have proven its potential for direct visualization of dental hard tissue structures [1-4]. These techniques enable the sensitive identification of carious lesions, which show a substantially higher MRI signal as the surrounding dentin or enamel. The signal enhancement in carious lesions is attributed to the increase in liquid content during the lesion formation. The local demineralization and concomitant accumulation of acids and saliva in the caries lesion lead to an increase in proton density and in the local T2/T2*. The objective of this study was to quantify the T2* in carious lesion in comparison to dentin.

Methods and Materials: In vitro and in vivo measurements were done on a clinical 3-Tesla whole body MRI (Achieva, Philips Medical, Best, Netherlands). The MRI protocol included multiple UTE sequences with constant TR = 10ms and varying echo time (in vivo: TE [µs] = (60, 150, 340, 500, 1000, 3000, 5000); in vitro: TE [µs] = (50, 100, 250, 500, 1000)). A conventional T1-weighted Turbo-Spin-Echo sequence was additionally applied to investigate the visibility of the lesions in spin-echo imaging. Sequence parameters are summarized in Table I.

	T1W spin echo	UTE
Technique	Multi-spin echo	Spoiled FID
k-space encoding	Cartesian	3D radial
Excitation	slice selective	non-selective
Flip angle [°]	90	10
Echo time [ms]: in-vivo	8.1	0.06 – 5.0
Echo time [ms]: in-vitro	8.1	0.05 - 1.0
Repetition time [ms]	625	10
Pixel BW [Hz]	240	800
# echoes	16	1
Acquired res. [mm³]	0.4x0.4x1	0.8x0.8x0.8
Recon res. [mm³]	0.4x0.4x1	0.5x0.5x0.5
Field of view [mm³]	230x230x8	120x120x120
Scan time	5:32	3:40

Table I: MRI Acquisition Protocol

In vitro: Nine extracted human teeth underwent the MRI investigation. In total, 10 caries lesions were observed in six teeth. Signal reception was done with a dedicated cylindrical small animal coil of 4cm diameter.

In vivo: Four volunteers with known caries lesions (moderate occludal (1), approximal (5) and secondary caries (4)) underwent the imaging protocol. All data was acquired with a prototype two times two-element carotid artery coil sized 120 × 50 mm. Two segments of the coil were located on one side of the jaw aligned with the teeth and fixated with a Vac-Lok neck cushion.

Data analysis: Caries lesions were identified as areas showing a signal enhancement of more than two times the standard deviation of the surrounding tissue. The images with different echo time were registered offline and the respective T2* time fitted by a mono-exponential model considering the Rician noise as a constant offset. Lesions were classified according to their X-ray visibility into two classes (CI - MRI only, 5 lesions; CII - MRI and XR, 5 lesions). Statistical relevance of the resulting differences was accessed applying a one-tailed student's t-test with a two-sample unequal (heteroscedastic) variance. Differences were considered significant for p values less than 0.05.

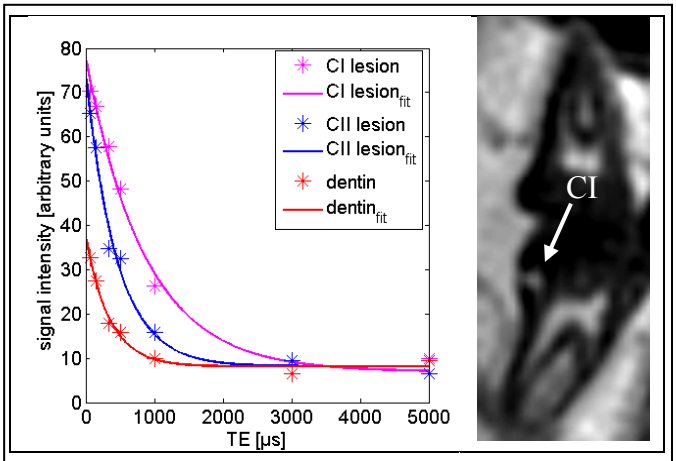

Figure 1: T2* decay curves for dentin and a CI and CII lesion. (b) example of CI lesion (arrow).

Results and Discussion: *In vitro*: T2* values of dentin resulted as T2* = 284±32µs and were significantly lower (p = 0.01) than in the caries lesions with T2* = 361±59µs.

In vivo: The mean T2* value of dentin in 16 analyzed teeth resulted as T2* = 324±94µs, which was significantly lower (p < 0.01) than the respective value of the ten analyzed lesions with T2* = 694±399µs. The 5 CI lesions showed a significant (p<0.05) lower mean T2* of 464±35µs than the 5 CII lesions, which had a mean T2* of 972±470µs. No lesion was visible in the spin-echo sequence.

Conclusion: The T2* of carious lesion is significantly larger than the T2* of dentin, but still well below 1ms in initial to moderate lesions. Thus the identification of caries lesions by MRI is possible, but requires ultra-short echo time techniques. Significant changes in T2* were observed even before the lesions got visible by XR. This indicates a huge potential of MRI to identify caries lesions at a very early stage before substantial breakdown of the mineral structure. The lower values for the dentin and the lesions in the extracted teeth may be attributed to the dehydration of the in vitro samples during the measurements.

References [1] Idiyatullin D, ISMRM 2007, 383; [2] Idiyatullin D, ISMRM 2010, 543; [3] Bracher AK, ISMRM 2010, 2974; [4] Boujraf S, ISMRM 2009, 4519