In Vivo Caries Imaging Using Contrast-enhanced Dental MRI

O. Tymofiyeva[1], K. Rottner[2], F. Schmid[1], E-J. Richter[2], and P. M. Jakob[1]

[1]Dept. of Experimental Physics 5, University of Wuerzburg, Wuerzburg, Bavaria, Germany, [2]Dept. of Prosthodontics, Dental School, University of Wuerzburg, Wuerzburg, Bavaria, Germany

Introduction: For diagnosis of carious lesions and estimation of their extension X-ray imaging has been routinely used in clinical practice. However, the technique only provides two-dimensional projections, which yields only limited information regarding localization and size of the lesion. It has been demonstrated *in vitro* using high field MR systems that surrounding liquids penetrate into porous demineralised tooth substance and cause signal increase in proton MRI [1]. The need for high magnetic fields and long measurement times, and the lack of dedicated hardware hindered *in vivo* applications of the technique in the past. Recent advances in contrast-enhanced dental MRI for *in vivo* tooth surface digitization [2-4] enabled high resolution dental imaging on clinical MR systems. In this article the first *in vivo* demonstration of carious lesion visualization and quantification performed on a clinical 1.5 T whole-body system using contrast-enhanced dental MRI is presented.

Subjects and Methods: Four volunteers with an indication of caries lesions were examined on a 1.5 T whole-body scanner (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany) using a contrast-enhanced dental MRI procedure and agar-based contrast medium described in [3]. A 3D Turbo Spin Echo sequence was used with TR/TE=350ms/14ms, turbo factor=5, FOV=60×33mm^2, slab thickness=17.4mm. With a 192×106×56 matrix, the nominal resolution was 310×310×310μm^3, reconstructed to 58×64×68μm^3 by means of Fourier interpolation. The scan time was 8 min. The obtained MR data set was segmented and the surface of the tooth was reconstructed using 3D visualization software (Amira). Extension of the carious lesion was quantified in three spatial dimensions. In addition to MRI, an X-ray projection of the tooth was acquired and the lesion was quantified in two spatial dimensions. To estimate the geometry of the cavity without consideration of tooth demineralization, an impression of the tooth was made using a plastic impression material. A second impression was made after dental treatment, in which the carious tooth substance was removed.

Results and Discussion: A photo of one of the volunteer's teeth is shown in Fig.1a. Reconstruction of the carious tooth based on the MRI data set is shown in Fig.1b and c. A cross-sectional view from the MRI data set demonstrating quantification of the lesion depth is shown in Fig.1d. The results of the lesion quantification by means of MRI, X-ray and dental impression before and after excavation are presented in Table 1. Lesion quantification based on the X-ray projection was limited to only two dimensions and associated with a high measurement error caused by an uncertain projection angle. The size of the lesion determined with the help of MRI significantly exceeded the size of the cavity before excavation, which demonstrates that the contrast medium penetrated into the porous tooth substance. The lesion depth obtained using both X-ray and MRI data was smaller than the one estimated using an impression after excavation, which can be explained by precocious excessive excavation of the tooth substance which is not yet demineralised. In addition to the caries visualization, dental MRI enables simultaneous imaging of the tooth pulp (see Fig.1b) and can thus provide valuable information about the relative location of the pulp and lesion in three spatial dimensions. This information can improve dental treatment planning and identification of cases with the potential for pulp vitality preservation.

Table 1	Impression before [mm]	Impression after [mm]	X-rays [mm]	MRI [mm]
height	1.5±0.2	2.8±0.2	2.5±1	2.7±0.3
width	0.4±0.2	1.8±0.2	-	1.8±0.3
depth	0.4±0.2	2.3±0.2	1.1±0.5	1.0±0.3

Conclusion: The presented results demonstrate three-dimensional visualization and quantification of carious lesion *in vivo* using contrast-enhanced dental MRI for the first time. Advantages of this innovative technique for caries diagnosis include the three-dimensionality of lesion visualization and quantification, the possibility to determine relative position of the lesion in relation to the pulp and the absence of ionizing radiation.

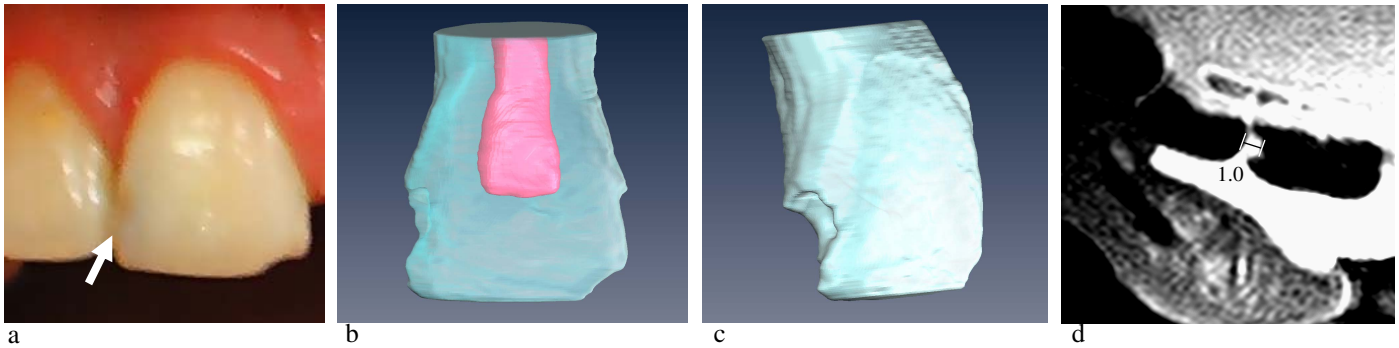

Fig. 1. a) Photo of an upper incisor tooth with a suspected carious lesion (marked with an arrow). b) and c) 3D visualization of the tooth based on the MRI data set. d) cross-sectional view from the MRI data set.

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