## Application of 1H and 31P Single Point Imaging (SPI) of teeth using silent gradients

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## Introduction

Presently, teeth can be imaged using many, often destructive, techniques. While information provided by clinical radiography during endodontic treatment is often imprecise, MR microscopy may be a useful alternative for non–destructive *in vivo* imaging of teeth. Recent reports on the use of MRI in dentistry (1) have generated interest in the development and improvement of MRI techniques for the study of teeth. The major problem with solid materials in MR research is their inherently short spin-spin relaxation time ($T_2$). Single Point Imaging, a pure phase encoding technique, has found many useful applications in the imaging of solids and semi-solids (2). However, due to the rapid switching of gradients, SPI often overheats the gradient coils and produces significant acoustic noise. In this work we propose the use of a modified SPI sequence for the study of teeth. Using shaped gradients greatly reduces problems with noise and gradient overheating (3).

## Methods

All MRI and NMR spectroscopy experiments were performed on a 11.7T (500 MHz) Magnex (Magnex Scientific Ltd. Yarnton, UK) vertical bore magnet equipped with self-shielded, water cooled, gradient set (Magnex, UK) producing a maximum gradient strength of 550mTm$^{-1}$. A Bruker (Milton, ON) Avance DRX console with a ParaVision2.1.1 operating system was interfaced to the magnet. The rf-probe was home built and consisted of a holder containing a Helmholtz rf-coil tuned to 500MHz ($^1$H) and an orthogonally positioned three turn rf-solenoid tuned to 202MHz ($^{31}$P). The cylindrical sample chamber was 12mm x 12mm (l x d). $^1$H images were obtained using a data matrix of 96x96x32 with a FOV of 3x3x4cm$^3$, a detection time (Tp) of 125µs was used in combination with a 10 µs excitation pulse and a repetition time of 15ms. The gradients were sinusoidally shaped with a ramp time of 1.0 ms for optimal acoustic noise reduction. The resulting total experiment time was 1hr:20min. $^{31}$P images were obtained using a 32x32x8 data matrix with a FOV of 3.5x3.5x3.5cm$^3$, a 10µs excitation pulse, $T_p$=100µs and a repetition time of 1s, resulting in a total experimental time of 2hr:17min.

## Materials

Teeth were obtained (with consent) from the University of Manitoba Dental School. Samples were refrigerated and kept in distilled water in closed containers. Prior to the MRI experiment a tooth was removed from the container, blotted dry with tissue paper and acclimatized to room temperature.

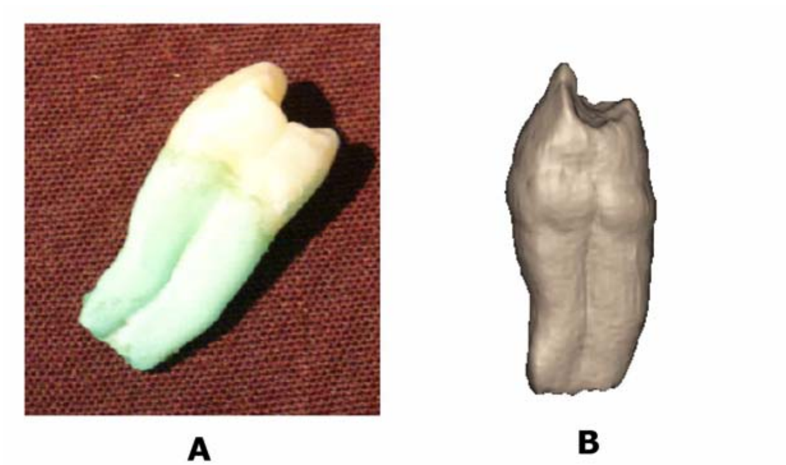


Figure 1.
A) Digital photograph of a human molar.
B) Surface reconstruction of $^1$H SPI data obtained from the same molar as in A).

## Results and Discussion

Fig. 1A shows a photograph of a human molar, obtained with a digital camera, Fig 1B shows the surface reconstruction of the $^1$H SPI data from the tooth in Fig. 1A. $^1$H relaxation time studies indicate that teeth can be characterized by two different water reservoirs, resembling enamel and dentin. This relaxation difference can be used to visualize the different components in volume rendered reconstructions. Surface reconstructions showed excellent correspondence with the digital photographs. The observed $^{31}$P $T_1$ for teeth at 11.7T is very long (79+/-19s), due to relaxation by chemical shielding anisotropy. Low-resolution, 32x32x8, SPI images were obtained which showed that the concentration of phosphate minerals/hydroxyapatite is highest in the enamel of the tooth. Relaxation and line-shape analysis showed that only a small amount of the total water in the tooth is present in the enamel while the majority of the water resides in dentin. Silent SPI can be used as an analytical tool to study both tooth surface as well as tooth volume. Presently an in-plane resolution of 310x310µm$^2$ was achieved, however this can be further improved. The acoustic noise levels of all SPI experiments were kept close to background level (65dB), using sinusoidally shaped gradients with a 1.0ms ramp time (3).

## References

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