

## Intraoral RF loop coil in the occlusal plane, orthogonal to $B_0$ , for dental imaging

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**Introduction** The use of MRI for diagnostic imaging in dentistry is becoming more attractive due to the continued development of methods allowing the direct imaging of hard tissues including dentin and enamel, tissues that have little water and very short  $T_2$  relaxation times. To date there are at least three clinically viable short  $T_2$  sensitive MRI methods; i) Ultrashort TE (UTE)<sup>1-4</sup>, ii) SWEEP Imaging with Fourier Transformation (SWIFT)<sup>5-7</sup>, and iii) FID-projection imaging also called BLAST, RUFIS or zero TE (ZTE) techniques<sup>8-11</sup>. Dental MRI could be more informative than x-ray by imaging noninvasively the hard and soft tissues simultaneously and in three dimensions. However clinical MRI has yet to attain the resolution of Cone Beam Computed Tomography (CBCT) in 200- 300 microns for all the regions of teeth and associated structures required for dental applications. The SNR and resolution for dental MRI is highly dependent on the construction of the RF coil and field-of-view (FOV). The specifics of short  $T_2$  imaging do not allow the use of slice or slab selections, and to avoid signal folding, the encoded FOV must include the entire sensitive volume of the coil. Therefore, extra-oral surface coils result in low filling factor, low resolution<sup>7</sup> and include non-informative high amplitude signal from the cheek located next to the coil. So, ironically, the resulting images will contain larger signal from less important parts and *vice versa*. The resolution and SNR can be increased by using a loop coil positioned intra-orally, between the teeth and cheek<sup>6,12</sup>, but due to space restrictions and the need for comfortable positioning of the coil, the root tips of the teeth are unavoidably outside the coil sensitive volume and therefore are not well visualized.

Another approach is to place the coil between the teeth in the occlusal plane which is orthogonal to the static magnetic field,  $B_0$ . When orienting the coil plane perpendicular to  $B_0$ , the longitudinal component of the  $B_1$  field which is usually exploited in surface coils becomes useless, because it is parallel to  $B_0$  and thus cannot excite spins. In this approach, however, the transverse component of the  $B_1$  field comes into play. We found that, in the occlusal orientation, the sensitive volume of the coil covers the most important dental structures, on both sides of the coil, and effectively excludes the less informative tissues. Below we present images and simulated data showing the advantages of using such a coil in dental imaging applications.

**Methods** A single loop coil was built with copper foil of 10 mm width (Figure 1) with the shape and size of an adult dental arch (radius about 25 mm). The foil was covered by sticky foam. The phantom and *in vivo* SWIFT images presented here were acquired at 4 T by a MRI scanner equipped with an Agilent DirectDrive™ console. The water phantom was a 15 cm diameter glass cylinder loaded with tap water. The coil (electrically isolated by a plastic bag) was immersed in water and fixed to the edges of the cylinder. The longitudinal and transverse components were imaged by changing the orientation of the whole cylinder to avoid changing the coil tuning and loading conditions. *In-vivo* images were obtained from a normal adult volunteer with the intraoral RF coil in the occlusal plane. Acquisition parameters:  $b_w = 62.5$  kHz,  $TR = 4.6$  ms, flip angle =  $8^\circ$ , number of projections = 65000,  $FOV = 12^3$  cm<sup>3</sup> and total acquisition time was 5 min. 3D radial SWIFT data were processed using an in-house program developed in LabVIEW (National Instruments) and MATLAB (Mathworks). For the MATLAB simulation a Biot-Savart's magnetostatic approximation of the  $B_1$  field was used.

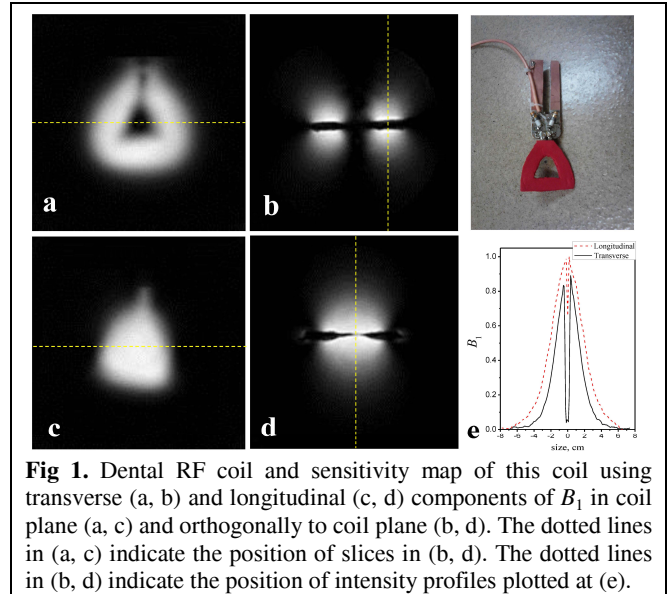
**Results and Discussion** Figure 1a-1d shows phantom experiments comparing the sensitive volumes of the RF coil oriented in two orthogonal positions. The intensity profiles plotted for these different coil orientations are about the same (Figure 1e). The shape of NMR sensitive volume of such a coil using the transverse components resembles two adjacent doughnuts and/or two arches of human jaw. Thus, the sensitivity of such coil in the occlusal position is high for the most important dental structures, such as teeth and associated bone, and is significantly diminished at the cheeks, lips and tongue, which usually have less informative but very intense signals. As expected, the signal from the cheek and tongue appear with lower intensity (Figure 2). Experimental results presented in Figure 1 and Figure 2 agreed with simulated data (not shown).

**Conclusions** The transverse  $B_1$  field component from both sides of a surface coil can effectively be used for imaging of teeth and associated structures.

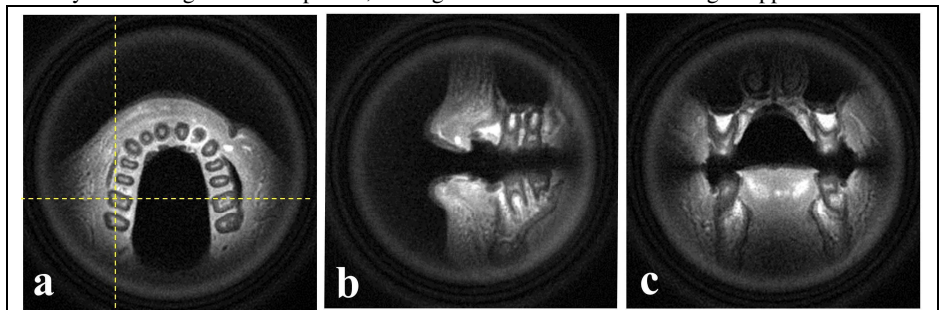
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**Fig 1.** Dental RF coil and sensitivity map of this coil using transverse (a, b) and longitudinal (c, d) components of  $B_1$  in coil plane (a, c) and orthogonally to coil plane (b, d). The dotted lines in (a, c) indicate the position of slices in (b, d). The dotted lines in (b, d) indicate the position of intensity profiles plotted at (e).



**Fig 2.** Orthogonal slices of 3D *in vivo* image obtained with transverse component of  $B_1$  field.