SWIFT Versus X-Ray In Dental Imaging

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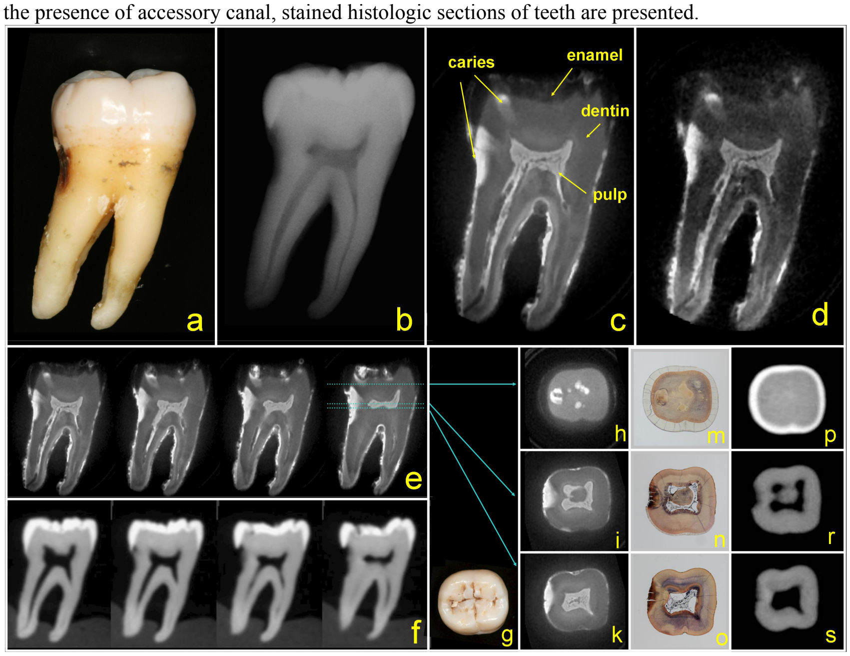
INTRODUCTION These days, imaging in clinical dentistry almost exclusively involves X-ray techniques using ionizing radiation. Although progress in radiographic technology during the past 30 years has led to a considerable decrease in the dose (*1*), potential risk from radiation exposure cannot be entirely avoided (*2*). Moreover, X-ray techniques lack sensitivity to detect early caries (*3*) and do not visualize the pulpal tissue. Traditional magnetic resonance imaging (MRI) is well suited for imaging the soft tissue but fails to image hard dental tissue having extremely short relaxation times. A recently developed MRI method called SWeep Imaging with Fourier Transformation (SWIFT) (*4*) overcomes many difficulties of detecting fast relaxing spins. SWIFT uses a swept RF excitation and virtually simultaneous signal acquisition in a time-shared mode in the presence of the field gradients which allows imaging of objects with truly ultra short spin-spin relaxation times with relatively low peak RF amplitude and greatly reduced demand on the field gradient efficiency of the scanner and therefore, is more applicable to human study (*5*). Here we describe an investigation of the potential of SWIFT for simultaneous imaging of soft and hard tissues of human teeth. We discuss the properties of SWIFT images in comparison with well established X- ray dental imaging techniques such as two-dimensional periapical radiographs and three-dimensional cone-beam CT. The sensitivity of SWIFT to soft tissue is tested and compared with conventional gradient echo (GRE) MR images. Additionally, to validate our conclusions regarding the ability of SWIFT to identify the presence and extent of caries, as well as the presence of accessory canal, stained histologic sections of teeth are presented.



METHODS The ***extracted teeth*** used for this work were harvested as waste tissue without maintaining any patient identifying data, which makes its use exempt under current IRB protocols.

Photographs. Digital images of the teeth were obtained using a SRL digital camera (Canon Rebel XT1i) and 100mm macro lens.

Radiographs. The traditional two-dimensional periapical radiographs were obtained on a digital sensor located at 50cm from the tube head and exposure times was 0.2sec at 12mA and 100 kVp.

CT. The three-dimensional cone-beam CT (17-19 iCAT, Imaging Sciences, Hatfield, PA) was obtained with a 6cm FOV at 37mA/sec for 27sec and 120kV with resolution of 0.2mm.

Histology. Dehydrated specimens were infiltrated with a light-curing embedding resin for 20 days, and then polymerized using 450nm light. The teeth were prepared to a thickness of 150μm on an EXAKT cutting/grinding system (*6, 7*), then polished to a thickness of 40-50 μm using a series of sandpaper discs followed by a final polish with 0.3μm alumina polishing paste. The sections of teeth were stained and mounted on a slide with coversliped.

MRI experiments. All MRI experiments were performed on a 9.4T Varian 31 cm bore system using a single 25mm loop RF coil. In the SWIFT sequence, RF excitation was performed with a hyperbolic secant (HS1) pulse (*8, 9*) having an excitation bandwidth of 125kHz and flip angle of 15°. A dead-time of 6 μs preceded acquisition in 256 pulse gaps (*5*). The repetition time, with a 2ms pulse length, was 2.5ms. The 256 complex data points were acquired and processes to a 128 point FID, in each of radial 32000 spokes for medium resolution and 128000 spokes for high resolution images. In the GRE sequence, experimental parameters were: flip angle 30°, TR= 13.5ms, TE= 3ms, an acquisition bandwidth of 80 kHz, with 256 complex points in each of 256x256 phase encode steps. Images were reconstructed with voxel size about 0.1mm.

EXPERIMENT AND DISCUSSION As example, the figure presents optical photos (a,g), traditional intra-oral dental radiograph (b), selected SWIFT images (c,d,e,h,i,k) and 3D cone-beam CT images (f,p,r,s) of mandibular right second molar with occlusal and interproximal caries. SWIFT (h,I,k) and CT images (p,r,s) are compared to non-decalcified histological sections (m,n,o) of the same orientation. The difference between the two SWIFT images (c and d) is the acquisition time, with 25minutes (c) and 100seconds (d). In the SWIFT images the dental anatomy, including the pulp tissue, dentin and enamel is well resolved. This includes intra-pulpal structures assumed to be the radicular neurovascular bundles. The caries on distal aspect of the crown (left side of tooth) are easily visualized with all imaging modalities. The hyper-intense signal in the SWIFT images (i,k) clearly delineate the extent of demineralization associated with disease when compared with the histological sections (n,o), something that neither the dental radiograph (b) nor cone-beam CT (r,s) is able to do. Both radiograph imaging modalities do not reveal the occulsal caries (b,p), something that is only suggested by the presence of staining within the pits and fissures of the tooth (g), but is well demarcated by SWIFT (h) when compared to the histological section (m). Additionally, the SWIFT images of different teeth with composite resin restorations, recurrent decay, and cracks having superior sensitivity will be presented and compared with traditional GRE and X- ray images.

The results of our study demonstrate that, in the *in- vitro* setting, SWIFT can simultaneously image both hard and soft dental tissue with high resolution in a time duration that is practical for clinical applications. SWIFT also has the ability to visualize minute details not otherwise observed with other currently available clinical techniques. SWIFT provides 3-dimensional imaging without the use of ionization radiation, which would be a major benefit compared to current techniques.

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REFERENCES [1]M. K. Nair, U. P. Nair, *J. Endod.* **33**, 1 (2007). [2]D. A. Schauer, O. W. Linton, *Health Phys.* **97**, 1 (2009). [3]I. A. Pretty, *J. Dent.* **34**, 727 (2006). [4]D. Idiyatullin, C. Corum, J.-Y. Park, M. Garwood, *J. Magn. Reson.* **181**, 342 (2006). [5]D. Idiyatullin, C. Corum, S. Moeller, M. Garwood, *J. Magn. Reson.* **193**, 267 (2008). [6] K. Donath, G. Breuner, *J. Oral Pathol.* **11**, 318 (1982). [7]M. D. Rohrer, C. C. Schubert, *Oral Surg. Oral Med. Oral Pathol.* **74**, 73 (1992). [8]M. Garwood, L. DelaBarre, *J. Magn. Reson.* **153**, 155 (2001). [9]A. Tannus, M. Garwood, *J. Magn. Reson.* **A 120**, 133 (1996).