ISSN:0975-1459
Journal of Pharmaceutical Sciences and Research
www.jpsr.pharmainfo.in

DENTAL MRI- A REVIEW

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Abstract

Imaging in medicine uses ionising and non-ionising radiation, both have their advantages and limitations. In maxillofacial region, with abundant soft tissue and neurovascular pathology, MRI is widely used for diagnostic purposes. Currently, we use conventional MRI with 1.5/2/3 Tesla machines. General MRI used by medical radiologists for head and neck imaging has its own limitations. CBCT has changed the face of dental imaging by replacing CT, similarly research is on to develop dental MRI. This paper reviews ongoing research in dental MRI and its possible applications in dental and dentofacial pathologies.

Keywords: Magnetic resonance imaging, Dentistry, UTE, ZTE, SWIFT, Intraoral coils in MRI.

INTRODUCTION

Magnetic resonance imaging (MRI) is an imaging technology that performs three dimensional (3D) imaging of body organs with high spatial resolution (< 1 mm). The primary advantage of MRI is to allow for obtaining cross-sectional anatomical information of the organs due to an excellent soft tissue contrast and excellent depth penetration. MRI usage has widely increased since early 1980's into the clinics (1). Medical diagnostic imaging is responsible for close to half (48 %) of human exposure to harmful ionizing radiation, with computed tomography (CT) accounting for roughly half of that amount (24 % of total). MRI is vastly becoming the area of interest for in vivo viewing of soft tissues in the human body as a non-ionising procedure. MRI involves the behaviour of hydrogen atoms (consisting of one proton and one electron) within a strong magnetic field which is used to create the MR image. This causes the nuclei of many atoms in the body to align themselves with the magnetic field. The machine applies a radiofrequency pulse to depolarize the atoms and the energy that is released from the body is detected and used to construct the MR image by a computer (2).The display of both hard tissue (enamel, dentin, cementum and bone) and soft tissue (gingiva, dental pulp, neurovascular bundle, mucosa, lips and facial tissues) is essential for diagnosis and treatment in various disciplines of dentistry. Some intraoral soft tissues, such as gingiva, are poorly distinguishable in CT and even more poorly so in CBCT, which is a clinically relevant drawback of these techniques (3). Wu et al (4) recently reported that the radiological exposure from 64-slice CT is associated with a non-negligible lifetime-attributable risk for cancer among the most radiosensitive patients. Despite these risks, CT and CBCT have shown to be useful for the three-dimensional (3D) visualization of the teeth. With Cone beam computed tomography, image quality and diagnostic accuracy is affected by the scatter and beam hardening artifacts caused by high intensity structures such as enamel and radiopaque materials this limits the imaging of soft tissues (5). Distortion of Hounsfield units, CBCT cannot be used for estimation of bone density and the scan times for CBCT are up to 15-20s with the patient being completely still along with the concern for radiation exposure ranging from 14.2mSv to 206mSv in case of CBCT (2). This leads us to the need of a, non-ionising diagnostic tool has made all to research on magnetic resonance imaging of the maxillofacial region.

DIFFERENT MODALITIES IN IMAGING USING MAGNETIC RESONANCE IMAGING

1. Ultra short echo time (UTE)
2. Zero echo time (ZTE)
3. Sweep imaging with Fourier transformation (SWIFT)
4. Intraoral coils

ULTRA SHORT ECHO TIME SEQUENCES:

UTE imaging uses MRI sequences that can be used to image tissues with a T2 shorter than 10ms.The sequence comprises of two RF pulses of negative and positive gradient which together result in the same scenario as a single complete excitation pulse; this being the working principle behind UTE. For imaging ultrashort T2 components, the signal should be acquired as soon as the signal excitation ends, fast transmit switching coils, and dedicated hardware are demanded to minimize the signal decay (1).

ZERO ECHO TIME SEQUENCES:

In ZTE sequences the encoding gradient is switched on before the RF pulse excitation, resulting in a TE theoretically equal to zero. ZTE acquisition method uses a short hard pulse excitation and small flip angle, while the gradients are gradually oriented in all three directions. Hence ZTE sequences have quite a lot more restrictions in flip angles and readout bandwidths compared to UTE. Two main limitations of ZTE are the development of speedy RF switching techniques and a software that can handle the large amount of data stands (1).

SWEEP IMAGING WITH FOURIER TRANSFORMATION:

SWIFT is to be considered as a combination of three types of nuclear magnetic resonance continuous wave, pulsed and stochastic. SWIFT is mainly based on swept RF excitation and acquisition scheme and hence suitable for ultrashort T2 components (6). SWIFT uses a frequency where the power is dropped thereby producing a small tip angle for spin excitation. The transmitter and the receiver are alternatively switched on and off with only 1-2 μs of signal acquisition delay between them. This allows efficient imaging of tissues with a shorter T2 value (7).

INTRAORAL COILS:

Ludwig et al had individually fabricated wireless, inductively coupled intraoral coils were shown used in ex vivo specimen and in vivo imaging whose coils were manufactured from insulated 1mm diameter copper wire. Ute Ludwig et al, constructed coils of two coaxial loops of 1.5 or 2 cm diameter insulated copper wire were used in different variants for in vivo and ex vivo applications (8) (Figure 2).

DENTAL MRI IN ROUTINE DENTAL PRACTICE:

The MR technique showed the display of cancellous bone, gingiva, mucosa,lip,dental pulp, periodontal apparatus and inferior alveolar nerve.Interesting finding published by Tabea et al was they visualised the individual branches of the inferior alveolar nerve bundle and the delineation of cortical bone which will help in diagnostics of implant surgery. With a cable-bound intraoral coil placed between the teeth, Idiyatullin et al. acquired images with an in-plane resolution of 300 µm3, a FOV of 12 cm3 within 4.5 min. The large FOV included the teeth of the upper and lower jaw; however, the periapical region, the alveolar bone and the inferior alveolar nerve were not displayed (3). Tymofiyeva et al introduced a wired intraoral coil that was used in combination with a contrasting agent consisting of an auto-curing agar solution in the oral cavity throughout imaging. It aimed to reproduce the tooth surface anatomy for fabricating dental restorations, rather than displaying the entire complex of dental tissues for diagnostic purposes (9). For the display of impacted teeth and the surrounding bone with a commercially available intraoral coil(3). Ludwig et al has done ex vivo and in vivo studies on wireless, inductively-decoupled intraoral coils with results that provided improved resolution and display of anatomic structures along with good depiction of inferior alveolar nerve. His approach was suitable for prior and post-surgical treatment planning in cases of implants in a time of approximately four minutes with high resolution (8). In a study done by Bracher et al on UTE imaging for identification of carious lesions, the results revealed that there was not a proper delineation of the different layers of the teeth as well image degradation of dental fillings when compared to a conventional x-ray image. Few teeth depicted artifacts and superposition due to the crowns placed on the viewed teeth. Further, the author pointed that majority of their lesions appeared substantially larger or smaller and less enhanced than x-ray image counterpart (9). One of the limitation mentioned by Bracher et al in the article published in 2010 was that the metal artificats were present in few of their findings and due to the lack of protons and very short spin-spin relaxation rates due to interfaces in the minerals (10). The cost of the increased sensitivity for very short-lived signals though, is some blurring caused by the pick-up of signal originating from outside the FOV. In the future, this can be avoided by using proton-free materials such as PTFE for construction of the coil. Enamel, visible on ZTE images, is not detected by UTE. Surface defects caused by caries are hyperintense due to residual moisture (11) (Figure 3). Soft tissues as well as solid state components are clearly depicted by ZTE. The contrast provided by the ZTE sequence allows differentiation between the components enamel, dentin, cementum and pulp. Enamel, recognized as the hardest component of the human body, yields the least signal, as it contains very few protons with short T2 relaxation time and hence appears very black on the image. Root channels containing nerve fibres and blood vessels exhibit the highest signal intensity and hence appear the most radiopaque. Contrary to in vivo imaging, the image resolution is sufficient to detect structures like secondary root channels (11). Carious lesions were also depicted by ZTE images. ZTE limitations arise from the RF hardware. Severe image degradation was noted in case of dental filling materials, according to the alloys used was noted in a case by Weiger et al. ZTE had a better image contrast when compared to a micro computed tomography show in work done by Weiger et al (12).

SWIFT gives a well-established tooth anatomy, delineating enamel, dentin and pulp but also detects early carious lesions (Figure 1). This is because SWIFT captures the ultrashort T2 relaxation times easily of enamel and dentine which possess a challenge due to less water content. It also demarcates the extent of demineralisation and fine details such as accessory canals which cannot be noted in any other radiographic methods. The relative variation in the intensities of enamel, dentin and pulp is in the order of 10:35:100 owing to the amount of water (8:20:100) in these structures respectively (7,13). SWIFT images of extracted teeth demonstrated visualization of tooth cracks as small as 20□m**,** which is 10 times narrower than the image voxel (14). Diagnosing recurrent caries adjacent to a radiolucent composite restoration or a radiopaque restoration is always quite a challenge when it comes to conventional radiographs, SWIFT helps in demarcating the reparative dentin without image distortion when compared to a CBCT image and thereby eliminating the likeliness to be misdiagnosed (7,13). SWIFT can capture the interface between water and dentin as a blur and depict the presence of accessory canals (13). Idiyatullin et al and Harshvardhan Talla have visualized the presence of microcracks or tooth fractures as small as 20□m (7,13). SWIFT imaging modality has also showed promising correlation with that of histopathological findings in three dimensional images of cortical bones and mandibular invasions in case of oral cancer. Advantages of SWIFT include no motion artifacts (no echo time), no distortion of the restorative materials, quieter than a normal MRI, depicts even a minute detail of pathology and anatomical variations (7).

CONCLUSION

MRI shows potential usage in imaging the soft and hard tissues intraorally with the use of non- ionising radiation thereby reducing the radiation dose which is currently higher in usage of CBCT as standard. With various imaging modalities being explained using MRI technique opens us to a wide step towards radiation-free dental imaging. Few obvious limitations common in all of these variants being the high cost of the machines, exportability, feasibility in reaching all patients still remains questionable. Hence, with all the newer techniques along with cost effectiveness would bring in a huge change in the world of MRI imaging modality.

Conflict of Interest: There is no conflict of interest.
Source of Funding: Self
Ethical Clearance: No ethical clearance needed for the study.

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