MRI for Dental Applications

Husniye Demirturk Kocasarac, DDS, PhD[a,*], Hassem Geha, DDS, MDS[a], Laurence R. Gaalaas, DDS, MS[b], Donald R. Nixdorf, DDS, MS[c]

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• MRI • Dental MRI • UTE • SWIFT • ZTE • FLASH • Tooth • Jaw

KEY POINTS

- MRI is a well-developed medical imaging technology, being the imaging modality of choice for most soft tissue and functional imaging indications.
- The science and application of MRI continue to advance, with several recent developments having notable implications for the practice of dentistry.
- Although MRI has traditionally been considered prohibitively costly for use in routine dental practice, many of the recent technological advancements have the potential to greatly reduce the cost associated with manufacturing and operating an MRI scanner.

INTRODUCTION

Visualize an MRI scanner that is less expensive and designed to image a smaller field of view (FOV), like a knee, ankle, or wrist. Such anatomy-specific MRI scanners have been developed and are currently or soon to be available.[1] Facilitating this development is an MRI design shift away from using larger and more expensive magnets with excellent field homogeneity and toward accepting smaller, less homogeneous (or less perfect) magnetic fields produced by cheaper and smaller magnets. Image formation can remain feasible by computationally correcting for magnet inhomogeneity and technological advances in pulse sequences and coil design, allowing for MRI scanners to become even cheaper to manufacture.[1–3] Now, imagine optimizing these smaller FOV scanners to image teeth, the jaws, and face, and you have the design of an MRI scanner designed for dental use.

The physics of producing an image with magnetic resonance are more complex and quite different from computed tomography (CT) or cone beam computed tomography

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[a] Division of Oral and Maxillofacial Radiology, Department of Comprehensive Dentistry, University of Texas Health San Antonio, 7703 Floyd Curl Drive, San Antonio, TX 78229, USA; [b] Oral and Maxillofacial Radiology, Division of Oral Medicine, Diagnosis and Radiology, Department of Diagnostic and Biological Sciences, School of Dentistry, University of Minnesota, 7-536 Moos Tower, 515 Delaware Street Southeast, Minneapolis, MN 55455, USA; [c] Division of TMD and Orofacial Pain, Department of Diagnostic and Biological Sciences, School of Dentistry, University of Minnesota, 6-320 Moos Tower, 515 Delaware Street SE, Minneapolis, MN 55455, USA
* Corresponding author.
E-mail address: demirturk@uthscsa.edu

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(CBCT) using radiograph. Consequently, MRI has considerably more opportunity for producing useful depictions of human tissues. With the development of dental and face-specific MRI coils, plus the freedom found in sequence design and image processing, researchers can feasibly develop custom techniques to address any number of dental imaging indications: anatomic characterization of hard tissues including bone and teeth for "routine" dental indications like implant placement, caries detection, and fracture detection; anatomic and functional characterization of soft tissues, including periodontal/periapical inflammation, muscle and nerves to characterize neural and pain disorders, and pathologic tissue characterization to diagnose neoplasms and dysplasia without a surgical biopsy; blood flow imaging in both bulk and perfusion forms to assess tissue viability/inflammatory status; and finally, spectroscopy to provide molecular profiles of tissue. Related technological advances in pulse sequence design will likely lead us into uncharted knowledge about normal dental anatomy and physiology as well as pathology and pathophysiology.

In this article, the authors provide a brief overview of the use of conventional MRI techniques applied to dental indications, discuss relevant MRI physics in the various steps of image formation, and highlight recent hardware and software technical developments that contribute to (1) the cost/size of MRI decreasing significantly, allowing use in the typical dental clinic, and (2) the facilitation of very specific dental imaging applications that will solve clinical problems.

ESTABLISHED MRI TECHNIQUES APPLIED TO DENTAL INDICATIONS

The first MRI was acquired by Lauterbur in 1973.[4] With the evolution of the commercial medical MRI in the 1980s, several applications were performed in medical imaging (ie, cardiac, abdominal, cranial MRI).[5] Broadly, in medicine, MRI is fast outpacing any other modality for in vivo displaying of soft tissues and function in the human body without any invasive procedure and ionizing radiation.[6] Because of the inability of conventional MRI to image hard tissues, conventional MRI techniques in dentistry have been mostly used for soft tissue imaging, including the temporomandibular joints (TMJ), soft tissues, tumors, salivary glands, and maxillary sinuses.[7] Currently, TMJ imaging comprises the vast majority of dedicated MRI imaging for clinical dental indications with diagnostic accuracy of joint characterization and disc localization high enough that the modality is considered the gold standard.[8–10]

Other applications of MRI for dental indications include caries detection, pulpal/periapical disease characterization, and some efforts at inferior alveolar nerve identification. These efforts have been limited largely to research/experimental reports and have not been adopted clinically. The use of MRI to visualize dental caries was first described by van Luijk in 1981[11] with later studies stating that the caries under a restoration, which cannot be easily seen on a conventional radiograph, may be detected by MRI in the future.[5]

MRI for pulpal and periapical disease characterization appears promising with successful imaging of pulp morphology, visualization of pulpitis/pulp vitality, and assessment of pulpal regeneration.[12] MRI has demonstrated some experimental utility in identifying the location of the mandibular nerve in the context of mandibular dental implant and surgery planning.[13,14]

A BRIEF OVERVIEW OF MRI PHYSICS AND STEPWISE DESCRIPTION OF HOW AN MRI IS OBTAINED

Before recent developments in MRI research specific to dental imaging and as a matter of review are discussed, the following is a brief discussion of how diagnostic images are obtained using MRI.