The Journey of Dental-Dedicated MRI at a School of Dentistry: The Aarhus Experience

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Abstract

Dental-dedicated magnetic resonance imaging (ddMRI) has recently emerged as a promising radiation-free imaging modality for dentomaxillofacial diagnostics. By combining a lower-field MRI system, a dedicated radiofrequency coil, and optimized pulse sequences, ddMRI enables simultaneous visualization of dental structures, bone, soft tissues, and inflammatory processes. Aarhus University was among the first institutions worldwide to implement and systematically investigate this technology within its school of dentistry. Through a series of experimental *ex vivo* and clinical studies, the researchers explored sequence optimization, workflow integration, and diagnostic feasibility across multiple dental disciplines. This perspective article summarizes the first years of ddMRI implementation in Aarhus, highlighting technological development, patient workflow, sequence optimization, and emerging clinical applications. The Aarhus experience illustrates both the potential and the current limitations of ddMRI and outlines key research that will be necessary for integrating MRI into routine dentomaxillofacial imaging.

Introduction

Diagnostic imaging is fundamental to modern dentistry and plays a key role in diagnosis, treatment planning, and follow-up across dental specialties [1, 2]. Conventional dental imaging relies predominantly on radiographic techniques, including intraoral radiography, panoramic imaging, and cone beam computed tomography (CBCT) [2]. These modalities provide excellent spatial resolution for mineralized tissues. However, they also expose patients to ionizing radiation and provide only limited information about soft tissues and inflammatory processes [1–3].

Magnetic resonance imaging (MRI) offers radiation-free imaging and excellent soft-tissue contrast. It has therefore long been considered a potentially valuable modality for dental imaging [4, 5]. However, MRI has historically played a limited role in dentistry due to infrastructural requirements, cost, and the technical challenges of imaging highly mineralized dental tissues [4, 5].

Recent technological developments have resulted in the emergence of dental-dedicated MRI (ddMRI), which combines lower-field MRI scanners (i.e., 0.55T), dedicated dental surface coils, and optimized pulse sequences tailored for dentomaxillofacial imaging [1–3]. These innovations allow improved visualization of dental structures and surrounding tissues while maintaining the intrinsic advantages of MRI, including multiplanar imaging and radiation-free acquisition [1–3].

The Section for Oral Radiology and Endodontics in the Department of Dentistry and Oral Health at Aarhus University, Denmark, was among the first clinical and academic environments to systematically explore this technology. Over the past several years, a series of technical *in vitro*, *ex vivo*, and clinical studies have evaluated ddMRI with respect to sequence development, workflow integration, and diagnostic feasibility. This perspective article summarizes the early "Aarhus experience" and discusses how ddMRI might influence the future of dentomaxillofacial imaging.

Technological foundations of dental-dedicated MRI

Dental-dedicated MRI differs from conventional MRI systems in several important aspects [3]. First, the only ddMRI system available operates at a lower magnetic field strength (0.55T). This system has a smaller footprint, requires less structural preparation of the building, and consumes fewer resources such as electricity and water. Also, lower field strengths have the major advantage of reducing the magnitude of susceptibility artifacts caused

by metallic restorative materials (e.g., fillings and implants) and air-tissue interfaces, which are frequently encountered in the oral cavity [6].

Second, ddMRI employs dedicated surface coils specifically designed to fit and cover the dentomaxillofacial region. These coils maximize signal-to-noise ratio in the region of interest and allow acquisition of high-resolution datasets approaching the spatial resolution required for dental diagnostics, which is typically higher than the image resolution used for "regular" MRI (e.g., 0.2–0.4 mm, versus the usual 0.5–1.0 mm) [7].

Third, pulse sequences must be optimized for dental tissues. Teeth and cortical bone exhibit low proton density and short relaxation times, requiring tailored acquisition parameters. Proton-density-weighted sequences have proven useful for anatomical depiction, whereas fat-suppressed sequences such as short-tau inversion recovery (STIR) highlight inflammatory processes such as edema associated with periodontal and periapical pathology.

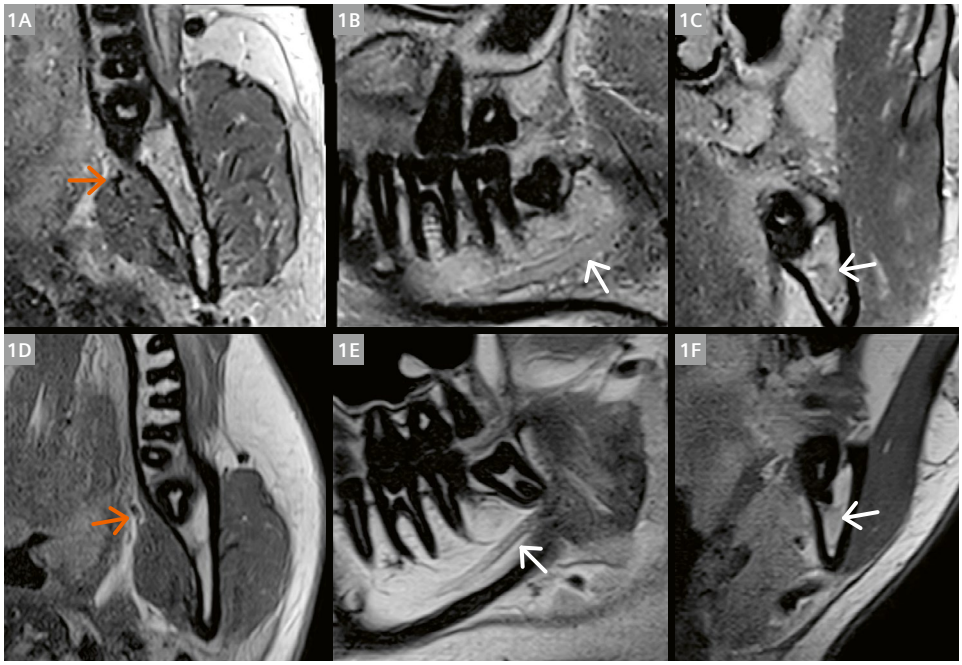
Together, these developments enable ddMRI to visualize dentomaxillofacial anatomy with increasing spatial resolution while maintaining the key advantage of radiation-free imaging.

Implementation of dental-dedicated MRI in Aarhus

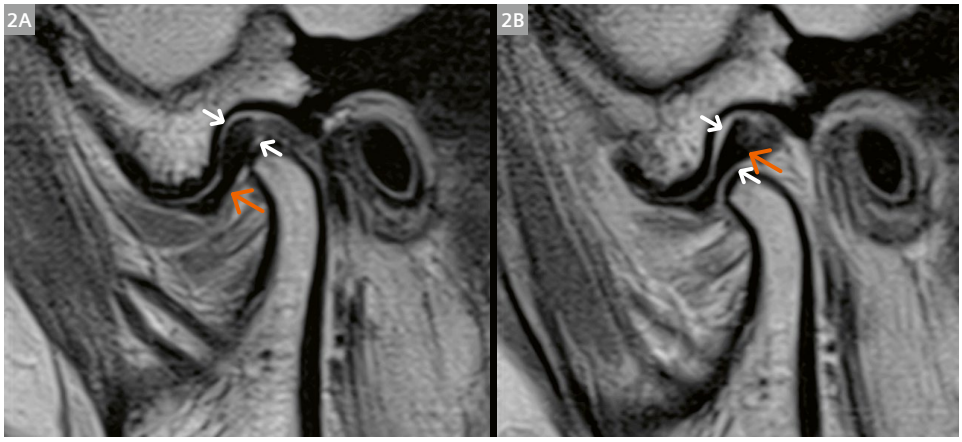
The introduction of ddMRI at Aarhus University was the earliest implementation of the technology within a dental academic setting. The system used in the Aarhus studies consisted of a lower-field, 0.55T MRI scanner equipped with a dedicated seven-channel surface dental receive coil (MAGNETOM Free.Max Dental Edition ddMRI system; Siemens Healthineers, Erlangen, Germany, and RAPID Biomedical, Rimpar, Germany).

The implementation required adapting conventional dental imaging workflows — including patient screening procedures and safety protocols — to MRI-specific requirements. It also involved developing optimized acquisition protocols that reflected the clinical demand (i.e., the diagnostic questions) and were tailored to the dental practice (e.g., point-of-care availability, ease of operation, shorter acquisition times). The process started in late 2022 and ended successfully with the finalization of the clinical trials that provided the evidence necessary for the system to achieve CE and FDA clearance in 2025.

Typical examinations begin with a scout acquisition followed by targeted sequences optimized for anatomical visualization, inflammatory assessment, and tissue differentiation. Acquisition times typically range from 10 to 25 minutes, depending on the clinical indication. These protocols were refined through a combination of phantom experiments, *ex vivo* studies, and clinical pilot investigations (Fig. 1). This translational workflow allowed rapid feedback between technical development and clinical feasibility. The current workflows reflect the basic steps for implementing the new diagnostic modality; they allow room for improvement, mostly by making the protocols more targeted to each application and avoiding redundancy.



1 Proton-density-weighted images of impacted inferior third molars. The orange arrows show the submandibular ganglion and its connection to the lingual nerve; the white arrows show the mandibular canal (**1A** and **1D**, axial view; **1B** and **1E**, sagittal view; **1C** and **1F**, coronal view). The images in the top row reflect the early pulse sequence development and had an acquisition time of 5 minutes and 12 seconds each. The images in the bottom row reflect the current status and had an acquisition time of 2 minutes and 38 seconds each.



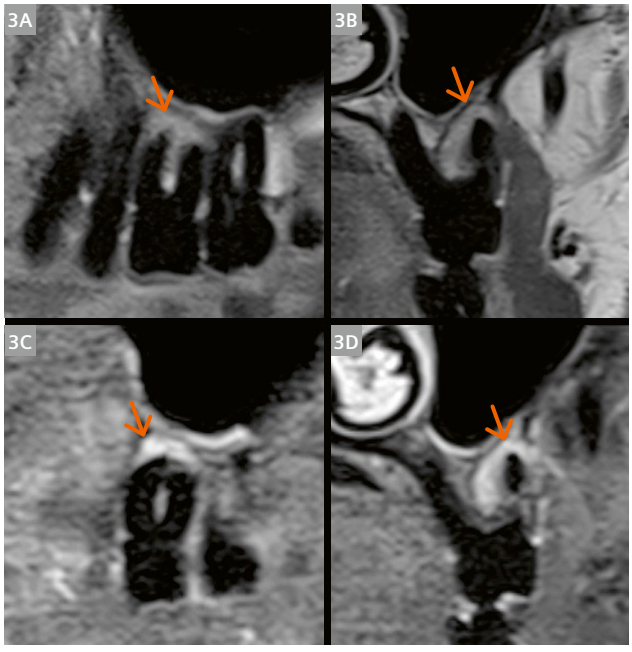
2 Proton-density-weighted images of the TMJ region. The orange arrows show the articular disc. The white arrows show the articular space. **(2A)** shows the disc anteriorly displaced while the patient had a closed mouth. **(2B)** shows the disc "recaptured" at the regular position when the patient opened their mouth.

Patient experience and clinical workflow

Introducing ddMRI into dental diagnostics requires consideration of patient acceptance and workflow integration. In ddMRI examinations, patients are positioned supine in the scanner, and the dental surface coil is positioned around the jaw. As with any form of dental-related imaging, the patients were not asked to change clothes.

In the workflow established at Aarhus University, patients were screened for MRI contraindications, including pacemakers, ferromagnetic implants, and severe claustrophobia. Early clinical pilot studies demonstrated that ddMRI examinations could be integrated into dental imaging workflows and that patient tolerance was generally good [3, 8–12].

Although scan times are longer than those of radiographic imaging, early experience suggests that ddMRI may be feasible for selected clinical indications where radiation-free imaging provides additional diagnostic value. The proposed workflows cover indications that commonly lead to referrals for diagnostic imaging in dental patients: temporomandibular joint (TMJ) assessment (Fig. 2), assessment of endodontic and periodontal diseases (Fig. 3), planning for the extraction of third molars (and other teeth), and orthodontic treatment planning [3]. Furthermore, basic oral anatomy and inflammation visualization are included in the proposed workflows.



3 Proton-density-weighted images without fat suppression (**3A** and **3B**) and with fat suppression (**3C** and **3D**) of an upper molar with apical periodontitis. The orange arrows show the area of the periapical lesion in the sagittal (**3A** and **3C**) and coronal (**3B** and **3D**) planes, visible as a hyperintense area, highlighted when fat-suppression techniques are used (in this case, STIR).

Sequence development and imaging optimization

Fine-tuning and optimizing sequences has been a central focus of the research so far. Proton-density turbo spin-echo (PD-TSE) sequences have been widely used for anatomical depiction of dental structures. Three-dimensional proton-density sequences (PD-SPACE) enable isotropic image resolution of approximately 0.5 mm, allowing multiplanar reconstruction and integration with digital surgical planning workflows. Fat-suppressed sequences such as STIR allow visualization of inflammatory processes including pulp inflammation and periapical pathology.

In addition to *in vivo* imaging, *ex vivo* experiments using phantoms and human cadaveric specimens have contributed to the understanding of signal characteristics of dental tissues, have helped optimize imaging protocols, and have provided insight into how the sequences could be made better and more efficient [3, 13].

Emerging clinical applications

Several possible clinical applications for ddMRI are currently being explored. Although a well-defined indication for the cases in which ddMRI would be a "must have" is currently lacking, research is progressing quickly on defining the cases to which ddMRI would add considerable diagnostic value.

In endodontics, ddMRI may allow assessment of pulp vitality and visualization of periapical inflammation [9]. In orthodontics, ddMRI has been investigated as a potential radiation-free alternative for cephalometric analysis. A pilot study demonstrated high reliability for identifying craniofacial landmarks on ddMRI datasets [14]. In oral surgery, ddMRI may improve visualization of anatomical structures such as the mandibular canal and surrounding soft tissues, potentially improving surgical planning for procedures such as third molar removal and implant placement [10]. MRI is already the reference standard for temporomandibular joint soft-tissue imaging, and ddMRI may allow simultaneous evaluation of TMJ structures and dental anatomy within a single examination [10].

Ongoing studies are addressing other possible uses of this novel imaging modality, specifically in the areas of dental implantology, oral rehabilitation, detection of osteonecrosis of the jaw, and trauma (especially in pediatric patients). In the coming years, results from these studies will help clarify the added value that ddMRI can bring to these areas of dentistry.

Future challenges and research priorities

Despite promising early results, a number of challenges must be addressed to increase the added diagnostic value of this novel modality, and to enable ddMRI to become widely integrated into routine dental practice.

First, clinicians require training to interpret ddMRI images of dentomaxillofacial structures, as these differ substantially from conventional radiographic images (e.g., panoramic images and CBCT volumes).

Second, even though image acquisition times are short compared to "regular" MRI, they are still longer than those of conventional, ionizing-radiation-based imaging modalities (e.g., minutes instead of seconds). Emerging technologies, including compressed sensing and AI-based reconstruction, may reduce scan times in future system upgrades, making them an even better fit for dental settings, where several patients must be imaged per hour.

Third, susceptibility artifacts from metallic restorations are a technical challenge that needs to be addressed from multiple perspectives [6]. While the lower field strength causes artifacts to be milder than those usually present in "regular" MRI, some dental materials (e.g., stainless-steel wires from orthodontic appliances) still compromise diagnostic image quality in their vicinity. Within this context, the causal relationship between diverse dental materials, ddMRI artifacts, and deterioration in diagnostic image quality must be investigated, and the technical possibilities for mitigating these artifacts must be further explored.

Finally, multicenter clinical validation studies will be required to establish diagnostic accuracy, clinical indications, and the cost-effectiveness of ddMRI compared with existing imaging modalities. We understand that this step will probably become routine in the coming years, when other schools of dentistry around the globe join the ddMRI initiative to reduce the use of ionizing radiation while adding diagnostic value to the images that dentists regularly acquire.

Conclusion

The early experience with ddMRI in the Department of Dentistry and Oral Health at Aarhus University has shown that this technology has the potential to expand diagnostic imaging capabilities in dentistry. By enabling radiation-free imaging with simultaneous visualization of hard and soft tissues, ddMRI is a promising complement to conventional radiographic techniques. Continued collaboration between dentistry, radiology, and MRI physics, as well as close partnerships between the life-science industry and universities will be essential to further develop this modality and determine its role in future dentomaxillofacial imaging.

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