Review Article

DOI : http://doi.org/10.64805/jnda.v25i2.202606

Dental-Dedicated Magnetic Resonance Imaging in Orthodontics: A Narrative Review on Emerging Advancement in Imaging Modalities

Sukeshana Srivastav,[1] Peter Bangsgaard Stoustrup,[1] Rubens Spin-Neto[2]

[1]Section for Orthodontics, Department of Dentistry and Oral Health, Aarhus University, Denmark

[2]Section for oral radiology and endodontics, Department of Dentistry and Oral Health, Aarhus University, Denmark

Correspondence :

Sukeshana Srivastav Email: sukeshana@dent.au.dk

ABSTRACT

Introduction: Dental-dedicated magnetic resonance imaging (ddMRI) is emerging as a radiation-free imaging modality capable of visualizing both soft and mineralized tissues relevant to orthodontic diagnosis. Advances in coil technology and ultrashort echo-time sequences have expanded MRI's suitability for hard-tissue imaging, positioning ddMRI as a potential alternative to cone-beam computed tomography (CBCT).

MRI acquisition and image processing workflow: A standard ddMRI workflow includes an initial low-resolution scout scan for anatomical localization, followed by a high-resolution three-dimensional acquisition covering the maxillofacial region. Scout images are commonly acquired using T1-weighted gradient-echo sequences, providing rapid anatomical orientation. Compressed sensing techniques are frequently employed to reduce acquisition time without substantial loss of image quality, resulting in total examination times typically under 10 minutes, including patient setup.

Rationale: This review synthesizes current developments in ddMRI, with particular emphasis on image acquisition and processing in dentomaxillofacial imaging. Visualization of facial hard tissues and anatomical landmarks is essential for orthodontic diagnosis and treatment planning. A key technological advancement enabling ddMRI is the use of ultrashort echo-time (UTE) and zero echo-time (ZTE) sequences, which allow signal detection from tissues such as enamel, dentin, and cortical bone, in addition to soft tissues.

Evidence and current limitations: Current evidence demonstrates that ddMRI enables accurate evaluation of impacted teeth, temporomandibular joint anatomy, airway volume, growth-related structures, periodontal conditions, and pulpal health, without exposure to ionizing radiation. Technological innovations now support high-resolution three-dimensional datasets suitable for digital orthodontic analysis. However, challenges remain, including motion susceptibility, acquisition time, limited accessibility, and the need for standardized imaging and measurement protocols.

Conclusion:ddMRI represents a significant step toward comprehensive, radiation-free orthodontic imaging. With its expanding capabilities, it offers valuable diagnostic information for clinicians and researchers, particularly in paediatric orthodontics and temporomandibular joint evaluation. Broader clinical adoption will depend on continued workflow optimization, reliability studies, the establishment of standardized clinical protocols, and the maintenance costs of the machines.

Keywords: Dental dedicated MRI; orthodontics; radiation-free imaging.

Citation

Srivastav S et al. Dental-Dedicated Magnetic Resonance Imaging in Orthodontics: A Narrative Review on Emerging Advancement in Imaging Modalities. J Nepal Dent Assoc. 2025 Jul-Dec;25(41):36-41.

INTRODUCTION

Orthodontic diagnosis and treatment planning are fundamentally dependent on accurate imaging of the dentofacial complex. Conventional imaging modalities including panoramic radiography, lateral cephalometry, and cone-beam computed tomography (CBCT) are routinely used to evaluate dental alignment, skeletal relationships, root morphology, and treatment outcomes. These techniques provide clinically valuable information and have become integral to contemporary orthodontic practice. However, all of them rely on ionizing radiation, which remains a relevant consideration, particularly in growing patients.

Children and adolescents constitute most of the orthodontic population and often require repeated imaging during diagnosis, treatment, and follow-up. Although radiation doses from modern dental imaging are relatively low, cumulative exposure over time has prompted increasing emphasis on dose reduction strategies and adherence to radiation protection principles.[1] As a result, there is growing interest in imaging approaches that can reduce or eliminate radiation exposure without compromising diagnostic accuracy.[1,2] Magnetic resonance imaging (MRI) is well established in medical imaging and is widely regarded as the reference standard for soft-tissue visualization. Its ability to depict soft tissues without the use of ionizing radiation makes MRI particularly attractive for applications involving pediatric patients. In dentistry and orthodontics, however, conventional MRI has historically played a limited role. The low signal intensity of highly mineralized tissues such as enamel, dentin, and cortical bone has restricted its usefulness for detailed evaluation of dental and osseous structures. Recent technological developments have led to the emergence of dental-dedicated MRI (ddMRI).[1] By combining specialized dental coils with advanced acquisition techniques, and tailored pulse sequences, ddMRI enables visualization of of both hard and soft tissues with elevated diagnostic image quality. These innovations allow the simultaneous assessment of teeth, alveolar bone, temporomandibular joint (TMJ), airway structures, and surrounding soft tissues within a single, radiation-free examination.[2,3,4,5]

As ddMRI technology continues to evolve, its potential role in orthodontics is gaining attention. While ddMRI is not intended to replace conventional imaging modalities in all clinical situations, it offers a promising complementary approach. Understanding the capabilities, limitations, and clinical relevance of ddMRI is therefore essential for evaluating its future integration into orthodontic diagnosis and treatment planning.[6]

MRI acquisition and image processing workflow

Magnetic resonance imaging (MRI) generates images by exploiting the magnetic properties of hydrogen nuclei in biological tissues. When subjected to a strong external magnetic field, these nuclei partially align with the field, producing a net longitudinal magnetization. Application of a radiofrequency (RF) pulse perturbs this equilibrium by tipping the net magnetization away from the longitudinal axis. As the nuclear spin system undergoes longitudinal (T1) recovery and transverse (T2) decay, it returns toward thermal equilibrium and emits electromagnetic signals, which are detected by receiver coils and used for image reconstruction.

Image contrast in MRI arises primarily from differences in tissue specific relaxation behavior. Longitudinal relaxation (T1) describes the process by which magnetization realigns with the main magnetic field, whereas transverse relaxation (T2) reflects the gradual loss of coherence among spins in the transverse plane. Variations in these relaxation times across tissues contribute to contrast differences in MR images. Signal intensity is additionally influenced by proton density, which reflects the local concentration of hydrogen nuclei and can be selectively emphasized depending on the pulse sequence used. Localization of the MR signal in space is achieved through magnetic field gradients applied along three perpendicular directions. These gradients enable frequency and phase encoding, allowing accurate reconstruction of two and three-dimensional datasets. By modifying acquisition parameters such as repetition time, echo time, and flip angle, different contrast weightings, including T1-weighted, T2-weighted, and proton-density-weighted (PD-weighted) images can be generated.

The world's first ddMRI was established for research and development purposes at the Section for Oral Radiology and Endodontics, Department of Dentistry and Oral Health, Aarhus University, Denmark.[1,2,3] Since then research has been continuously conducted to explore possibilities of ddMRI in dentistry and Orthodontics. ddMRI offers the ability to depict both soft and hard tissues using 0,55 T magnet strength, offering various advantages for dental use. It utilizes specialized magnetic coils positioned over the facial and dental regions during image acquisition. These coils are designed to improve the signal-to-noise ratio in area of interest, thereby enabling higher spatial resolution of the teeth, jaws, and surrounding structures.

A commonly used workflow includes an initial low-resolution scout scan to localize the anatomical area, followed by a high-resolution three-dimensional acquisition covering the maxillofacial region. Scout images are often obtained using a T1-weighted gradient echo sequence, which provides rapid anatomical orientation. Subsequently, a larger field-of-view acquisition may be performed using a proton density–weighted 3D sequence, such as PD-SPACE (Sampling Perfection with Application-optimized Contrast using different flip angle Evolutions). This type of sequence is well suited for dentomaxillofacial imaging, as it provides balanced contrast between different tissue types while enabling isotropic high-resolution reconstructions. The use of compressed sensing techniques is frequently incorporated to reduce image acquisition time without substantial loss of image quality, resulting in total examination times that are typically under 10 minutes, including patient setup.(Table 1) After image acquisition, ddMRI datasets are commonly exported in DICOM format and processed using image analysis platforms. Multiplanar reconstruction (MPR) allows visualization of the data in standardized anatomical planes, facilitating landmark-based analyses. For cephalometric applications, landmarks can be identified in the sagittal plane, reflecting the traditional approach used in lateral cephalometry.[7] Open-source applications such as 3D slicer can be used for orthodontic landmark annotation using dedicated markup tools, with coordinates stored within a defined anatomical reference system, such as the right–anterior–superior (RAS) coordinate framework.[7]

Table 1. MRI workflow: Pulse-sequence protocol used for ddMRI scanning in Orthodontics

Application	Basic Description	Resolution (mm)	FOV (h × w × d ; mm)	Acquisition time (min and s)	Basic scan parameters
Scout	GRE	1.4 x 1.4 x 1.0	263 x 350 x 350	1'10"	TR 8.10 ms, TE 2.25 ms, FA 12°, bandwidth 540 Hz/pixel, GRAPPA acceleration (x 2), averages 1.0, encoding A-P
Anatomy 3D overview	PD (SPACE)	0.5 x 0.5 x 0.5	160 x 196 x 192	3'0"	TR 600.0 ms, TE 34.00 ms, FA1 175°, FA2 90°, bandwidth 651 Hz/pixel, CS acceleration (x 5), averages 1.0, encoding A-P
Total scan duration				9'03"	

Abbreviations: 3D, three-dimensional; CS, compressed sensing; FA, flip angle; FOV, Field of View; GRE, gradient echo; Hz, Herz; PD, proton density; ms, milliseconds; SPACE, sampling perfection with application-optimised contrast using different flip angle evolutions; STIR, short-tau inversion recovery; TE, time to echo; TR, repetition time.

Rationale

Visualisation of facial hard tissues and landmarks is a crucial part of orthodontic diagnosis and treatment planning in orthodontics. Here, ddMRI can visualize a wide range of dentofacial structures within a single examination. These include tooth morphology and root structures, alveolar bone contours, TMJ components, airway soft tissues, periodontal tissues, and the dental pulp. This contributes to a more comprehensive anatomical evaluation than is typically achievable with conventional radiographic techniques such as lateral cephalogram. It should be noted that image appearance in ddMRI differs from that of CBCT or lateral cephalogram, particularly with respect to grayscale and contrast representation, which may appear inverted or unfamiliar to clinicians accustomed to radiographic imaging (Figure 1).

Another area of interest is the evaluation of the TMJ. ddMRI enables visualization of both the osseous contours of the condyle and soft-tissue structures such as the articular disc and retrodiscal tissue.[2] A feasibility study by Liedke et. al. demonstrated that ddMRI has potential as a radiation-free adjunct imaging modality for TMJ assessment, enabling simultaneous evaluation of soft and hard tissues.[2] Consistent with previous literature, CBCT showed a higher prevalence of osseous findings than MRI-based techniques, however, in this study, no statistically significant differences were found between CBCT and ddMRI for the detection of relevant bony changes. The study suggests that ddMRI may contribute meaningfully to TMJ bone assessment, despite not yet matching CBCT in diagnostic consistency. The combined assessment consolidates information that would otherwise require multiple imaging modalities into a single, radiation-free examination. The study also highlights the importance of MRI protocol optimisation. While multiple pulse sequences were used, the lack of inflammatory sequences in some cases likely contributed to difficulties in assessing joint fluid. Fat-suppressed and T2-weighted sequences were particularly valuable for identifying inflammatory or cystic changes.[2]

Other areas of current ddMRI ongoing investigations include the reproducibility of anatomical landmarks, agreement between measurements derived from ddMRI and CBCT, and inter- and intra-examiner reliability.[7] As research in this field progresses, demonstrating consistent reproducibility across different scanners and clinical centers will be critical for broader clinical

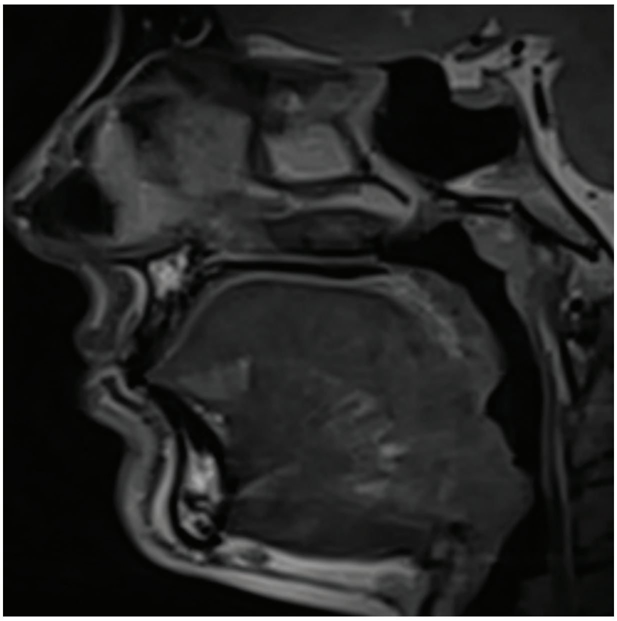

Figure 1. Sagittal ddMRI acquisition illustrating the anatomical structures in the midline plane

adoption and integration into routine orthodontic workflows. Additionally, ddMRI shows potential for assessment of upper airway structures, including soft palate thickness, tongue posture, adenoid tissue, and airway volume and shape. These soft-tissue components may be depicted with greater clarity using MRI-based techniques compared with conventional orthodontic imaging modalities. Although ddMRI can generate high-resolution volumetric datasets suitable for three-dimensional analysis, standardization of imaging protocols and measurement techniques remains essential.

Evidence and current limitations

Despite overall faster protocols, MRI acquisition currently takes longer (around 7 minutes) than CBCT if high-resolution images are expected. In our experience, there have been certain challenges while scanning children using ddMRI. Some children struggled to remain still during MRI acquisition, especially if they were younger than 8 years old. Optimization of scan times and increasing patient co-operation is vital for minimizing movement-related artifacts in MR scans of younger children. Modification of sequences to improve image quality and reduce scan time is being conducted at the Section for Oral Radiology, Department of Dentistry and Oral Health, Aarhus University, Denmark, for the same reasons. At the current scenario, dental radiologists and orthodontists also require training to interpret ddMRI images effectively. In addition to these, ddMRI requires specialized coils and MRI sequences are not yet widely available in dental settings. Therefore, this still needs some time to be available for general practitioners.

Metal-related artefacts represent a relevant limitation of MRI-based dentomaxillofacial imaging, particularly in patients with dental implants. In orthodontics, the presence of metal components as apparatuses for treatment is a major challenge for MR scanning during the treatment.[8] MR scanning with metal creates artifacts on the region where the metal is located. It is also a challenge to assess certain landmarks after the patient has been debonded, and the patient has fixed retainers on the lingual surface of either upper or the lower incisors and canines.[7] Recent evidence demonstrates that implant material and magnetic field strength critically influence artefact severity, with titanium implants producing substantially larger magnetic field distortions than zirconia.[7,8] Ex vivo field mapping has shown that titanium implants generate extensive dipole-shaped magnetic field distortions that increase with field strength, whereas zirconia causes smaller, more localized disturbances, a pattern that is consistent in vivo. Importantly, at the low field strength used in ddMRI (0.55 T), artefacts from both materials were predominantly confined to the crown region adjacent to the implant and were most often described as signal voids, with limited impact on overall diagnostic interpretability. This confinement is clinically relevant, as it suggests that ddMRI may remain suitable for assessment of adjacent soft tissues and joint structures, even in the presence of implants. However, artefact extent was influenced by implant number, position, and pulse sequence, underscoring the need for protocol optimisation and examiner training.

SUMMARY

ddMRI represents a promising transformative advance in orthodontic imaging in future. By providing comprehensive visualization of both soft and hard tissues without radiation exposure, ddMRI aligns with the evolving needs of modern orthodontics. Broader clinical adoption will depend on continued workflow optimization, reliability studies, and the establishment of standardized clinical protocols, as well as costs of the machines and burden of maintaining the machine.

While technical and logistical challenges remain, ddMRI shows strong potential for integration into routine clinical practice, particularly in pediatric orthodontics, TMJ evaluation, growth assessment, and orthodontic research.

REFERENCES

1. Greiser A, Christensen J, Fuglsig JMCS, Johannsen KM, Nixdorf DR, Burzan K, Lauer L, Krueger G, Hayes C, Kettless K, Ulrici J, Spin-Neto R. Dental-dedicated MRI, a novel approach for dentomaxillofacial diagnostic imaging: technical specifications and feasibility. Dentomaxillofac Radiol. 2024 Jan 11;53(1):74-85. doi: 10.1093/dmfr/twad004. PMID: 38214941; PMCID: PMC11003656. [PubMed |Full Text |DOI]

2. Liedke GS, Christensen J, Spin-Neto R. Evaluation of Temporomandibular Joint Structures and Conditions Using Dental-Dedicated MRI: A Feasibility Study. J Oral Rehabil. 2026 Jan;53(1):149-159. doi: 10.1111/joor.70071. Epub 2025 Oct 7. PMID: 41054386; PMCID: PMC12705298. [PubMed | Full Text | DOI]

3. Fuglsig JMCES, Sampaio-Oliveira M, Spin-Neto R. Dental-dedicated magnetic resonance imaging in the follow-up of lower third molar removal. Oral Radiol. 2025 Apr;41(2):296-301. doi: 10.1007/s11282-024-00787-x. Epub 2024 Nov 26. PMID: 39586974; PMCID: PMC11909038. [PubMed | Full Text | DOI]

4. Nixdorf DR, Greiser A, Hayes C, Gaalaas L, Groenke BR, Fuglsig JMCES, Johannsen KM, Herman CR, Kaimal S, Moana-Filho EJ, Mulet M, Özütemiz C, Spin-Neto R. Comparison of a 0.55 T dental-dedicated magnetic resonance imaging system with a 1.5 T system in evaluation of the temporomandibular joint regarding subjective image quality assessment and rater agreement. Oral Surg Oral Med Oral Pathol Oral Radiol. 2025 Jul;140(1):113-124. doi: 10.1016/j.oooo.2025.02.011. Epub 2025 Feb 19. PMID: 40169337. [PubMed | Full Text | DOI]

5. Vaddi A, Parasher P, Khurana S. Beyond X-Rays: Unveiling the Future of Dental Diagnosis with Dental Magnetic Resonance Imaging. Diagnostics (Basel). 2025 May 1;15(9):1153. doi: 10.3390/diagnostics15091153. PMID: 40361971; PMCID: PMC12071207. [PubMed | Full Text |DOI]

6. Srivastav S, Spin-Neto R, Aiyar A, Stoustrup PB. Accuracy and reliability of magnetic resonance imaging in orthodontic diagnosis and treatment planning-a systematic review and meta-analysis. Eur J Orthod. 2024 Jun 1;46(3):cjae019. doi: 10.1093/ejo/cjae019. PMID: 38700388. [PubMed | Full Text | DOI]

7. Srivastav S, Stoustrup PB, Liu J, Federici MI, Christensen J, Spin-Neto R. Reliability of dental-dedicated magnetic resonance imaging for 2-dimensional orthodontic diagnosis: A pilot study of landmark identification. Imaging Sci Dent. 2026 Mar;56(1):36-44. doi: 10.5624/isd.20250201. Epub 2025 Nov 10. PMID: 41928841; PMCID: PMC13040238. [PubMed | Full Text | DOI]

8. Johannsen KM, Christensen J, Matzen LH, Hansen B, Spin-Neto R. Interference of titanium and zirconia implants on dental-dedicated MR image quality: ex vivo and in vivo assessment. Dentomaxillofac Radiol. 2025 Feb 1;54(2):132-139. doi: 10.1093/dmfr/twae071. PMID: 39693121. [Full Text | DOI]