Content available at: https://www.ipinnovative.com/open-access-journals

IP International Journal of Maxillofacial Imaging

Journal homepage: www.ijmi.in

Review Article

Dental magnetic resonance imaging: A new era of radiation- free oral diagnosis

Rutuja Joshi[1*], Bhakti Patil[1], Deepa Das[1]

[1]Dept. of Oral Medicine and Radiology, YMT Dental College and Hospital Kharghar, Navi Mumbai, Maharashtra, India

Abstract

This narrative review explores the evolving applications of Magnetic Resonance Imaging (MRI) in the field of dentistry, highlighting its potential as a non-invasive, radiation-free diagnostic modality with superior soft tissue contrast. Despite initial limitations—including motion artifacts, lower spatial resolution for hard tissues, and susceptibility to metal-induced distortion—recent technological advances have significantly expanded MRI's clinical utility in dental practice. This review discusses the current and emerging roles of MRI in evaluating temporomandibular joint (TMJ) disorders, salivary gland pathologies, soft tissue lesions, and in pre-implant planning. Enhanced imaging techniques, including the development of dedicated dental coils, rapid acquisition protocols, and metal artifact reduction sequences, have improved both image quality and diagnostic accuracy. While not yet commonplace in routine dental settings due to cost and accessibility constraints, this review emphasizes MRI's growing relevance as a complementary tool alongside cone-beam computed tomography (CBCT) and conventional radiography. Continued interdisciplinary research is essential to fully realize MRI's potential in comprehensive dental diagnostics.

Keywords: Magnetic resonance, Imaging, ddMRI, MRI, Dentistry, Endodontics, Implantology, Maxillary sinus, Dental materials, CBCT.

Received: 28-05-2025; **Accepted:** 22-06-2025; **Available Online**: 17-07-2025

For reprints contact: reprint@ipinnovative.com

1. Introduction

Magnetic resonance imaging (MRI) forms images by exciting hydrogen nuclei in a strong magnetic field and recording the radio-frequency (RF) signal they emit as they relax. Because that signal is captured without ionising radiation, MRI eliminates the stochastic cancer risk inherent to X-ray-based techniques such as periapical films, panoramic radiographs and cone-beam CT (CBCT). At the same time, MRI offers unrivalled intrinsic contrast for soft tissues—nerves, vessels, mucosa, disc structures—and, with modern ultrashort-echo-time (UTE) or zero-echo-time (ZTE) sequences, diagnostically useful contrast for mineralised tissues (enamel, dentine and bone). These qualities make dental MRI an attractive upgrade for paediatric, pregnant and recall patients who would otherwise accumulate dose from repeated radiographs.

2. Technical Foundations

Conventional head and neck MRI systems typically operate at field strengths of 1.5 to 3 Tesla (T). More recently, low-field systems around 0.55 T have been introduced to reduce susceptibility artifacts caused by dental fillings and orthodontic brackets, while ultra-high-field 7 T research scanners maximize signal-to-noise ratio (SNR) for advanced enamel imaging using ultrashort echo time (UTE) and zero echo time (ZTE) sequences. These sequences, with echo times (TE) as short as 0 to 0.1 milliseconds, are crucial for capturing signals from short T2 tissues such as root dentine and cortical bone before their rapid signal decay. Additional

*Corresponding author: Rutuja Joshi
Email: rutujasjoshi98@gmail.com

https://doi.org/10.18231/j.ijmi.2025.010

pulse sequences like black bone, Short tau inversion recovery (STIR), and T2-weighted Sampling Perfection with Application optimised Contrasts using different flip angle Evolution (T2 SPACE) provide fluid-suppressed images that enhance visualization of marrow and periapical lesions.[3]

Table 1: Historic evolution of dental MRI[1,2]

Year	Milestone	Notes
1946–1952	Bloch & Purcell describe nuclear magnetic resonance; Nobel Prize	Foundation of MRI physics
1973	Paul Lauterbur publishes the first NMR image	Introduces magnetic field gradients
1977	First whole-body human MRI scan.	Clinical feasibility
1989	Early TMJ studies demonstrate MRI can show condylar disc displacement	First dental use
2000s	Implementation of intra-oral surface coils boosts signal-to-noise ratio (SNR)	Dedicated research coils
2014–2020	UTE/ZTE sequences allow direct imaging of teeth and cortical bone	Short-T2 capture
2022	0.55 T “High-V” low-field scanner with 80 cm bore (MAGNETOM Free.Max) released, plus first dental-dedicated MRI (ddMRI) prototypes	Improves patient comfort
2024	Prospective clinical trials show ddMRI-guided implant planning and wisdom-tooth follow-up are feasible	Accuracy within ≈1 mm

Table 2: Dental applications of MRI

Domain	What MRI Adds	Key Evidence
Temporomandibular Joint (TMJ)	Gold-standard for disc position, joint effusion & marrow oedema without radiation	AAFP rapid review: MRI preferred for soft-tissue derangements[6]
Implantology	0.4 mm isotropic ddMRI guides allow CAD/CAM surgical-guide fabrication; mean 3-D deviation ≈ 1.3 mm	Prospective 45-implant study[2]
Endodontics	Contrast-enhanced T1-w & high-res UTE depict pulp perfusion, periapical inflammation, vertical root fractures (VRF) with sensitivity comparable to CBCT	Wiley 2024 pulp review; VRF MRI vs CBCT meta-analysis[5]
Periodontology & Peri-implant Bone	ddMRI quantifies marginal bone level & furcation defects; no ionising follow-up	2025 Diagnostics technical report[4]
Orthodontics & Craniofacial Growth	3-D cephalometry, airway volume, condylar cartilage thickness without exposure—advantage for children	ddMRI University of Minnesota update
Salivary & Soft-Tissue Pathology	Multiparametric MRI (T1/T2, DWI, SyMRI) differentiates Warthin’s tumour from pleomorphic adenoma; avoids iodinated contrast	MDPI 2024 algorithm study[4]
Hard-Tissue Research	31P- and 1H-SWIFT spectroscopy maps mineralisation and fluoride uptake in enamel ex vivo	Nature SWIFT study
Functional & AI-assisted Imaging	fMRI tracks pain networks in TMD; CNNs segment discs and condyles on low-field data for real-time reporting	arXiv 2025 TMJ segmentation[7]

3. Technical Foundations

Conventional head and neck MRI systems typically operate at field strengths of 1.5 to 3 Tesla (T). More recently, low-field systems around 0.55 T have been introduced to reduce susceptibility artifacts caused by dental fillings and orthodontic brackets, while ultra-high-field 7 T research scanners maximize signal-to-noise ratio (SNR) for advanced enamel imaging using ultrashort echo time (UTE) and zero echo time (ZTE) sequences. These sequences, with echo times (TE) as short as 0 to 0.1 milliseconds, are crucial for capturing signals from short T2 tissues such as root dentine and cortical bone before their rapid signal decay. Additional pulse sequences like black bone, Short tau inversion recovery (STIR), and T2-weighted Sampling Perfection with Application optimised Contrasts using different flip angle Evolution (T2 SPACE) provide fluid-suppressed images that enhance visualization of marrow and periapical lesions.[3]

Advancements in coil technology, particularly the use of flexible intraoral loop or paddle coils placed in the vestibule, have significantly improved MRI imaging of the jaw. By positioning the coil closer to the target anatomy, these intraoral coils can increase the signal-to-noise ratio (SNR) by over threefold compared to traditional external head coils. This improvement enables high-resolution ultrashort echo time (UTE) imaging with 0.3 mm isotropic voxels in scan times as short as two minutes—making detailed imaging practical for routine clinical use.

In addition, modern metal artifact reduction techniques such as MAVRIC SL and SEMAC effectively minimize distortions caused by metallic dental restorations, including crowns, fillings, and implants. When combined with low-field MRI—which inherently reduces susceptibility artifacts—these methods significantly enhance image quality in patients with metal hardware.

Together, these innovations allow for faster, clearer, and more accurate imaging of dental and maxillofacial structures, even in complex clinical scenarios.[3-5]

4. Discussion

Magnetic resonance imaging (MRI) has long been recognized for its superior soft tissue contrast and absence of ionizing radiation, but its adoption in dentistry has historically been limited. However, recent technological advancements are bridging the gap between MRI's capabilities and the specific diagnostic needs of dental professionals. Dental MRI offers superior soft tissue contrast without ionizing radiation, making it ideal for evaluating soft tissue lesions and temporomandibular joint disorders. Unlike CBCT, which excels in hard tissue imaging, MRI provides safer, repeated imaging for complex diagnostic needs.[6] This review discusses the current applications, benefits, limitations, and future directions of MRI in dental practice.

MRI also plays a vital role in the diagnosis of salivary gland pathologies. It can accurately differentiate between inflammatory, obstructive, and neoplastic processes without the need for contrast media in many cases. MRI sialography has emerged as a non-invasive method for evaluating ductal architecture and glandular parenchyma, especially in cases of Sjögren's syndrome or salivary gland tumors.[7]

In implantology, MRI has historically been underutilized due to its limited capacity to depict mineralized tissues. However, the development of ultrashort echo time (UTE) and zero echo time (ZTE) sequences now enables visualization of bone structures with sufficient resolution for pre-surgical planning.[8] These sequences, combined with dedicated dental coils and metal artifact reduction techniques, allow for improved delineation of cortical and trabecular bone structures, as well as implant positioning relative to neurovascular structures such as the inferior alveolar nerve.

Additionally, MRI offers unique advantages in endodontics and periodontology. Periapical lesions, inflammatory changes in the periodontal ligament space, and early bone marrow changes may be detected earlier with MRI than with radiographic techniques.[9] Furthermore, the use of diffusion-weighted imaging (DWI) and dynamic contrast-enhanced MRI (DCE-MRI) is being investigated for characterizing lesions and differentiating between benign and malignant oral pathologies and recurrent oral cancers.[10]

Despite these promising applications, several barriers hinder the routine clinical use of MRI in dentistry. These include high operational costs, limited availability of dental-specific MRI protocols and equipment, and the need for specialized radiological expertise. Moreover, patient motion, long acquisition times, and the presence of metallic restorations can degrade image quality.[11] Nonetheless, recent advances in faster imaging protocols, including compressed sensing and parallel imaging, have significantly reduced scan times, improving patient comfort and diagnostic efficiency.[12]

The integration of artificial intelligence (AI) and machine learning into MRI data analysis is another emerging frontier. AI-assisted image interpretation and segmentation can enhance diagnostic accuracy and workflow efficiency, particularly in complex cases requiring detailed anatomical mapping.[12] When combined with three-dimensional reconstructions, these tools offer promising applications for surgical planning, orthodontic assessment, and personalized dental care.

One of the most well-established uses of MRI in dentistry is in the evaluation of the temporomandibular joint (TMJ). MRI is considered the gold standard for imaging the TMJ soft tissues, including the articular disc, synovial fluid, ligaments, and surrounding musculature.[13] It allows for dynamic assessment of disc position and joint function, aiding in the diagnosis of internal derangements and degenerative joint diseases.[14] Unlike CBCT or conventional radiographs, which provide excellent bone detail but limited soft tissue visualization, MRI offers a comprehensive evaluation of both soft and hard tissues in a single imaging modality.

3.1. Advantages

MRI presents several compelling advantages that position it as a transformative imaging modality in dentistry. Foremost among these is its radiation-free nature, which completely eliminates cumulative radiation exposure—a significant benefit, particularly for children and pregnant patients, where radiation safety is paramount.[9]

One of MRI's most distinguishing features is its exceptional soft tissue contrast. It allows for detailed visualization of anatomical structures that are typically invisible or poorly defined on cone-beam computed tomography (CBCT), including nerves, blood vessels, dental pulp, temporomandibular joint (TMJ) discs, and gingival tissues.[13,14]

In terms of imaging capabilities, MRI offers multiplanar, isotropic imaging with high spatial resolution. Images can be reconstructed in any desired plane using voxel sizes smaller than 0.5 mm, which enhances anatomical accuracy and facilitates precise evaluation in complex regions such as the maxillofacial area.[8]

Moreover, MRI extends beyond structural imaging by providing quantitative data through advanced techniques like T1/T2 relaxometry, diffusion-weighted imaging (DWI), and perfusion mapping. These allow clinicians to assess tissue vitality, inflammation, vascular status, and bone quality, introducing a biomarker-driven approach to diagnostics and treatment planning in endodontics, periodontics, and implantology.[10]

Together, these capabilities highlight MRI's growing potential as a comprehensive, non-invasive, and functionally informative tool for modern dental imaging.

5. Limitations & Challenges

While dental MRI offers numerous clinical advantages, several practical limitations currently restrict its routine use in dental settings.

Firstly, cost and accessibility are major concerns. MRI systems require a significantly higher investment than CBCT units, both in terms of equipment and operational costs. Additionally, dedicated dental coils, which enhance image quality for intraoral applications, are still not widely available and remain largely confined to research or specialized centers.

Secondly, scan duration can be a limiting factor. Although rapid sequences like UTE and ZTE have reduced scan times for jaw imaging to less than 4 minutes, more comprehensive protocols—including TMJ evaluation, full dental arch imaging, and soft tissue assessment—may still take up to 20 minutes, increasing the risk of motion artifacts and reducing workflow efficiency.

Artifacts caused by metallic restorations, such as crowns and orthodontic wires, also remain a challenge. These materials can distort the magnetic field (B_0), leading to image degradation. Although low-field MRI systems and metal artifact reduction (MAR) techniques have improved image quality, complete artifact elimination is not yet achievable.

Finally, there is a steep learning curve associated with MRI interpretation in dentistry. Most dental professionals are trained primarily in radiographic analysis, and the complexity of MRI requires familiarity with soft tissue imaging and advanced sequences. While AI-based interpretation tools are emerging, their integration into routine clinical practice is still evolving.

Addressing these limitations through technological innovation, professional training, and increased access will be key to realizing the full potential of MRI in dentistry.

6. Future Directions

Looking ahead, several emerging innovations have the potential to further transform the role of MRI in dental diagnostics and treatment planning.

One promising development is the introduction of portable low-field MRI units (≤ 0.3 T). These compact systems are being explored for chairside applications, including non-invasive caries detection, offering a radiation-free alternative for routine screening—particularly valuable in paediatric and preventive care settings.

Advancements in deep learning-based image reconstruction are also rapidly improving MRI performance. These AI-driven techniques can significantly reduce scan time while enhancing image quality, particularly for fine structures such as tooth surfaces and enamel-dentin interfaces, which have traditionally been difficult to resolve using MRI.

Furthermore, the concept of MR-guided interventions is gaining traction. Techniques such as navigated biopsies and potentially real-time MRI-guided endodontic procedures represent the next frontier in precision, minimally invasive dental care, with the added benefit of continuous soft tissue visualization.

Finally, the integration of MRI into the digital dental workflow is a key area of innovation. Emerging software platforms now enable the automatic fusion of diagnostic dental MRI (ddMRI) with intraoral optical scans, creating a comprehensive “radiation-free virtual patient.” This integrated model opens new possibilities for digital treatment planning, surgical simulation, and prosthodontic design—enhancing safety, precision, and patient-centered care.

7. Conclusion

From its early role in TMJ diagnosis to today’s dedicated 0.55 T “High-V” systems, dental MRI has evolved into a multi-purpose, radiation-free platform that can visualise both soft and hard tissues with sub-millimetre precision. Continued advances in pulse-sequence design, coil engineering and AI interpretation are reducing cost and scan time, positioning MRI as a viable complement—or, for specific indications, an outright replacement—for X-ray-based dental imaging.

8. Source of Funding

None.

9. Conflict of Interest

None.

References

1. Hilgenfeld T, Juerchott A, Jende JMJ, Rammelsberg P, Heiland S, Bendszus M, et al. Use of dental MRI for radiation-free guided dental implant planning: a prospective, in vivo study of accuracy and reliability. *Eur Radiol*. 2020;30(12):6392–401.
2. Siemens Healthineers. *MAGNETOM Free.Max Dental Edition* [Product brochure]. 2024. https://www.siemens-healthineers.com/magnetic-resonance-imaging/high-v-mri/magnetom-free-max-dental
3. More SS, Zhang X. Ultrashort Echo Time and Zero Echo Time MRI and Their Applications at High Magnetic Fields: A Literature Survey. *Investig Magn Reson Imaging*. 2024;28(4):153–73.
4. Flügge T. Dental MRI—only a future vision or standard of care? *Dentomaxillofac Radiol*. 2023;52(4):20220333.
5. Litjens G, Kooi T, Ehteshami Bejnordi B, Setio AAA, Ciompi F, Ghafoorian M, et al. A survey on deep learning in medical image analysis. *Med Image Anal*. 2017;42:60–88
6. Patel S, Dawood A, Pitt Ford T, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. *Int Endod J*. 2007;40(10):818–30.
7. van Ginkel MS, Glaudemans AWJM, van der Vegt B, Mossel E, Kroese FGM, Bootsma H, et al. Imaging in Primary Sjögren’s Syndrome. *J Clin Med*. 2020;9(8):2492.
8. Eggers G, Rieker M, Kress B, Fiebach J, Dickhaus H, Hassfeld S. Artefacts in magnetic resonance imaging caused by dental material. *MAGMA*. 2005;18(2):103–11.
9. Varghese J, Kirsch C. Magnetic Resonance Imaging of the Oral Cavity and Oropharynx. *Top Magn Reson Imaging*. 2021;30(2):79–83.
10. Vaddi A, Parasher P, Khurana S. Beyond x-rays: unveiling the future of dental diagnosis with dental magnetic resonance imaging. *Diagnostics (Basel)*. 2025;15(9):1153.
11. Matsubara R, Yanagi Y, Oki K, Hisatomi M, Santos KCp, Bamgbose BO, et al. Assessment of MRI findings and clinical symptoms in patients with temporomandibular joint disorders. *Dentomaxillofac Radiol*. 2018;47(4):20170412..
12. Lustig M, Donoho D, Pauly JM. Sparse MRI: The application of compressed sensing for rapid MR imaging. *Magn Reson Med*. 2007;58(6):1182–95.
13. Matheson EM, Fermo JD, Blackwelder RS. Temporomandibular Disorders: Rapid evidence review. *Am Fam Physician*. 2023;107(1):52–8.
14. Manfredini D, Chiappe G, Bosco M. Research diagnostic criteria for temporomandibular disorders (RDC/TMD) axis I diagnoses in an Italian patient population. *J Oral Rehabil*. 2006;33(8):551–8.
15. Maraghelli D, Pietragalla M, Cordopatri C, Nardi C, Peired AJ, Maggiore G, et al. Magnetic resonance imaging of salivary gland tumours: Key findings for imaging characterisation. *Eur J Radiol*. 2021;139:109716.
16. Han B, Chen N, Luo J, Afkhami F, Peters OA, Wang X. Magnetic resonance imaging for dental pulp assessment: A comprehensive review. *J Magn Reson Imaging*. 2025. doi:10.1002/jmri.29742.
17. Ivanov MI, Mendybaeva OE, Karyakin YE, Glukhikh IN, Lebedev AV. Segmentation of temporomandibular joint structures on MRI images using neural networks for diagnosis of pathologies. arXiv preprint arXiv:2505.12963. 2025.

18. Ivanov MI, Mendybaeva OE, Karyakin YE, Glukhikh IN, Lebedev AV. Segmentation of temporomandibular joint structures on mri images using neural networks for diagnosis of pathologies. arXiv. 2025 May 20. https://doi.org/10.48550/arXiv.2505.12963

Cite this article: Joshi R, Patil B, Das D. Dental magnetic resonance imaging: A new era of radiation- Free oral diagnosis. *IP Int J Maxillofac Imaging*. 2025;11(2):48–53.