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Research Article

DD MRI (Dental-Dedicated MRI) as a Diagnostic Tool for Endodontics and Periodontics Lesions. A Literature Review

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Received: June 19, 2023; **Published:** July 05, 2023

Abstract

Introduction: With the increasing demands on dentists and physicians to combine oral and general health aspects, new imaging techniques are gaining importance that have greater sensitivity in detecting early stages of disease, and inflammatory processes, this potentially opens new interdisciplinary fields of research between oral and systemic health.

Aim of the Work: To summarize research conducted on Magnetic Resonance Imaging (MRI) as a diagnostic tool for Endodontics and Periodontics > Lesions, based on the results of original scientific full-length papers from peer-reviewed journals listed in pubMed.

Materials and Methods: The search was conducting and performed with focused question When is MRI used for diagnosis in dental specialties,?" on PubMed MED/INE and Google Scholar database using MeSH terms and keywords relevant to the focused question.

Conclusion: MRI is applicable to a broad spectrum of indications in dentomaxillofacial imaging using specific surface coils for dental imaging. The future of dental MRI in clinical application is challenged by its limited availability and high cost.

Therefore, technical developments for short scanning times using simple and inexpensive equipments that sustain the demands for dental imaging are required.

Keywords: *MRI in Dentistry; Review*

Introduction

Leader companies have joined forces to explore the scientific introduction of MRI in dentistry. For the first time, researchers and leading scientists from North America and European universities along with the representatives from leader companies presented the current status of the joint research project for the of use MRI in the dental environment at the "Scientific Symposium on ddMRI" in Bensheim Germany [1].

As part of this scientific partnership, the two leader companies are working closely with renowned dental universities worldwide to broaden the awareness of advantages of magnetic resonance imaging in oral diagnostics and to jointly advance the current state of dental care [1].

Working with ddMRI has opened many new possibilities regarding how much can be achieved in dentomaxillofacial diagnosis. It adds value to the previously established imaging modalities and starts a new field of research for the coming years [1].

"I believe fully integrating this innovation into the dental clinic routine will be very straightforward" says Associate Professor Rubens Spin-Neto, DDs, PHD, dr. odont, Department of Dentistry and Oral Health, Section for Oral Radiology, Aarthus University Denmark, based on his experience thus far with ddMRI in the research project [1].

With the increasing demands on dentists and physicians to combine oral and general health aspects, new imaging techniques are gaining importance that have greater sensitivity in detecting early stage of disease and inflammatory processes. This potentially opens new interdisciplinary fields of research between oral and systematic health [1].

"The possibility to use MRI for dentistry represents a new milestone in oral diagnostics and connecting technology between oral and general health care that can make history" says Max Milz, Group Vice president Digital Platforms and Solutions at Dentsply Sirona. "We are therefore pleased to evaluate all options together with Siemens Healthineers and to shear scientific and technological expertise".

"It is our dedicated to bring MRI where it has not been used before. Therefore, we are excited to advance into new clinical territory and to explore the value of MRI in the dental field. MRI systems which are designed to flexibly fit new clinical areas are the ideal basis for this endeavour [1].

"Looking forward to working with the world's leading dental educational institutions to break the boundaries of preventing and curative dentistry", says Arthur Kaind, Head of Magnetic Resonance at Siemens Healthineers [1].

It is committed to enabling physicians to detect disease earlier and provide more effective therapies, ultimately improving patient care.

The leader companies in Magnetic Resonance Imaging harness the full potential of digital technologies such as artificial intelligence to deliver outstanding image quality while minimizing the examination time [1].

Background

MRI is increasingly used as a diagnostics tool for visualizing the dentoalveolar complex [2].

The complex anatomy of the dentomaxillofacial region challenges existing imaging techniques as it consists of conglomerate of various hard and soft tissues and air-and fluid-filled cavities.

Anatomical structures of primary relevance in dentistry include the maxilla and the mandible with the intraosseous course of the inferior alveolar nerve, the teeth, its roots canals, the periodontal apparatus, the paranasal sinuses, as well as the nasal and the oral cavities.

Metallic, ceramic, and composite foreign materials represent typical structures associated with oral restorations that place particular demands on imaging. X-ray based techniques like panoramic radiography or cone-beam computed tomography (CBCT) are currently the imaging standard.

However, MRI is increasingly used not only for head and neck imaging but also for dentoalveolar complex [3,4].

Previously MRI was used in the head and neck region predominantly for the temporomandibular joint, salivary glands and soft tissue pathologies.

Recently, the current indications and applications of MRI in the dental specialties of (I) Orthodontics, (II) Endodontics, (III) Prosthodontics, (IV) Periodontics, (V) Oral Surgery, (VI) Pediatric Dentistry and (VII) Operative Dentistry which is still missing [2].

The current literatures on dental MRI shows that it is used in detections of dental pulp inflammation, characterization of periapical and marginal periodontal pathologies of teeth, caries detection, and identification of its extensions [2].

Specific protocols regarding the miniature anatomy of the dentofacial complex, the presence of hard tissues and foreign body restorations are used along with dedicated coils for the improved image quality of the facial skull [2].

Dental MRI poses a clinically useful radiation-free imaging tool for visualizing the dentoalveolar complex across dental specialties when respecting the indications and limitations [2].

Methodology and Results

A systemic search was performed with focused question "When is MRI used for diagnosis in dental specialties?' on PubMed MEDLINE and Google Scholar database using MeSh terms and keywords relevant to the focused question.

A publication time frame between 2010 and 2023 was selected. This narrative review should provide the reader with comprehensive information on the advantage and limitations of MRI in dentistry.

Dental restorations causing imaging artifacts are not frequent in the young age group, however orthodontic appliances might be present. Steel (orthodontic) appliances cause artifacts that deteriorate image quality and may be considered a contraindication for MRI [5,6]. The use of contrast agents to show the vascularization of tissues is redundant in this indication.

Endodontics dentistry

Recent studies on MRI in endodontic indications reached high image resolutions of around 0.7 mm^3 [7-9].

The vascularization of the dental pulp and differentiation between a healthy and inflamed pulp were displayed with contrast agents [7,8].

However, signal enhancement in the dental pulp using contrast agents was discussed as a potentially valuable diagnostics tool and used more recently as a measurement for the healthy and inflamed pulp by Juerchott., *et al* [10].

Hyper-perfusion of the pulp correlated with a high signal, and T2 values related to presumed inflammation adjacent to caries were mapped using incremental echo times [8].

The degree of perfusion of the dental pulp correlated with the signal in MRI, and terminated perfusion and pulp necrosis show no signal [7,8,11].

MRI may detect periapical inflammation at early stage due to oedema and subsequently signal enhancement, even without demineralization or bone resorption [11].

In the case of periapical granulomas or cysts, a signal hyperintensity appears in MRI, contrary to radiolucency in CBCT [12] Several image characteristics in MRI, including signal intensity, signal homogeneity, margins, low intensity outline, and contrast distribution pattern, were established on the existing data to differentiate between cyst and granuloma [13].

The comparison of MRI and CBCT implies an over-estimation of lesions in MRI [14]. MRI detects regions with oedema that are not visible in CBCT, therefore, MRI's more accurate representation is hypothesized [15-17]. The referenced studies mostly did not use contrast agents to display periapical lesions [12,14,15,17].

Figure 1 present three different indications for MRI in endodontics with tooth fracture and pulp necrosis, an apical tumor in region 43 and an apical granuloma and sinus membrane swelling in region 16.

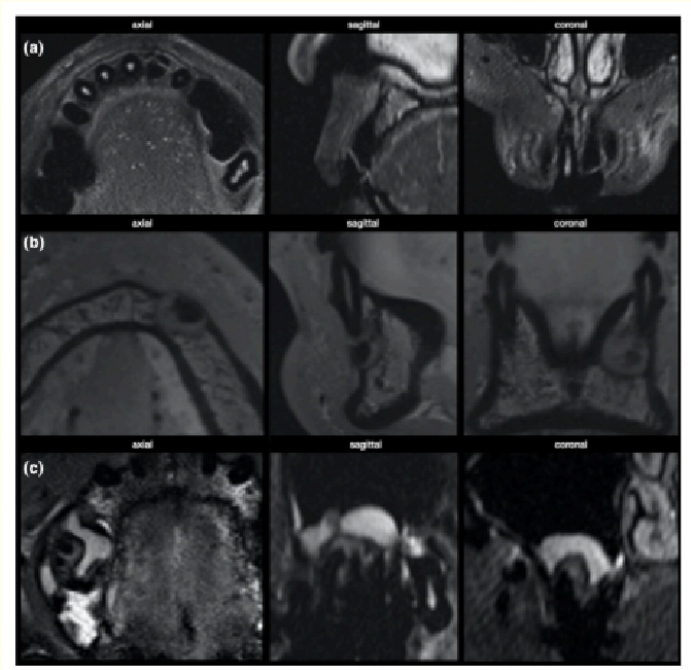

Figure 1: *MRI of different indications in endodontics. (a) Horizontal fracture of tooth 21 with loss of MR signal in the necrotic pulp. (b) Apical tumor of tooth 33 with calcified aspect and surrounding osteolysis. (c) Apical granuloma of tooth 16, accompanied by hyperplasia of the basal sinus membrane.*

Table 1 MRI for the display of the dental pulp.

Table 2 gives an overview of MRI studies on the periapical region.

Periodontics Dentistry

Four clinical studies used MRI and contrast agents to display marginal periodontal structures [19-22].

Ruetters., *et al*. measured the marginal attachment in MRI and periapical radiographs using contrast agent [19].

Authors	Study design subjects	Research question	Findings
Assaf., *et al*. 2015	Seven participant (8-17y), 23 teeth	Visualization and measurement of revitalization of the dental pulp after dental trauma using MRI; comparison of signal intensity of trauma affected and non-affected teeth	• Reperfusion of pulp after dental Trauma was diagnosed earlier with MRI compared to clinical examination. • Reperfusion occurred in majority of teeth that showed no clinical sign of vitality at 6 weeks. • Normal pulp signal at 3 months correlated with clinical signs of vitality. • Pulp visibility was best with fat-saturated sequences.
Cankar., *et al*. 2020	12 participants (34.4 + -7.3y), 72 teeth	Quantification of dental pulp signal in teeth with caries; correlation between signal and extent of caries lesion	• T2-maps with signal intensity of the dental pulp at different echo times were an indicator for inflammation Intact and affected dental pulps showed different T2 values; the extent of a caries lesion correlated to the intensity of the pulp signal.
Juerchott., *et al*. 2021	70 participations (three cohorts: 27.5± 3.1, 42.2± 11.6, 44.1 ± 14.6y), 1585 teeth	Investigation of PCE Patterns in dMRI in healthy teeth	• No significant differences in PCE comparing. age, Sex and jaw type. • Minor but significant differences between tooth types. • PCE is a stable intraindividual marker for healthy and diseased pulp.
Tesfai., *et al*. 2022	Five participants	Comparison of introral coil with conventional head and surface coils and CBCT in Terms of SNR and visibility	• Acceptable scan time (5-7 min). • Spatial resolution with intraoral coil comparable to CBCT. • Improvement of SNR in vivo with intraoral coil.

Table 1: *MRI for the display of the dental pulp. Technical information is given in supplementary table 1. CBCT: Cone-Beam CT; PCE: Pulpal Contrast Enhancement: SNR: Signal-to-Noise Ratio.*

Authors	Study design subjects	Research question	Findings
Geibel., *et al*. 2015	19 participants (43 + -13y), 34 teeth	Applicability of MRI for the assessment of periapical lesions and individual comparison of MRI and CBCT findings	• Overestimation of dimension of lesions with MRI compared to CBCT. • More detailed characterization of lesions with MRI. • T2 weighted sequences showed heterogeneity of periapical pathologies.
Geibel., *et al*. 2017	13 participants (41+ 27y); 15 teeth	Assessment of periapical lesions and characterization of lesions with MRI using different contrast weightings; correlation with histopathology	• T1 weighted images for identification of lesions. • T2 weighted images for further characterization of lesions. • Differential diagnosis of periapical lesions possible by assessing homogeneity/heterogeneity of signal inside the lesion compared to surrounding tissue. • Differences in signal intensity between - T1 and T2 weighted images.
Juerchott., *et al*. 2018	11 participants (mean 39.5y, range 21-60y), 11 teeth	Assessment and characterization of periapical lesions with MRI using different contrast weightings and contrast agent, correlation with histopathology	• All lesions were detected with MRI. • High reproducibility of lesions measurements in MRI. • No predictable differentiation of lesions with enhanced T1 weighted images. • Differentiation of peripheral run, lesion centre and surrounding tissue with contract-enhanced T1 and T2 weighted sequence. • MRI characteristics in accordance with result of histopathological analysis.
Lizio., *et al*. 2018	34 patients	Diagnostic reliability and accuracy of MRI for periapical lesions correlation with histology	• Endosseous lesions clearly visible in T1, T2 and contrast-enhanced T1 images. • Two diagnostic patterns established related to signal intensity, signal heterogeneity, margins, low-intensity outline and contrast agent distribution. • High interrater reliability for histopathological diagnosis of periapical lesions. • Specificity: 0.50 and 0.63, respectively, and sensitivity 0.94

Pigg., *et al*. 2014	20 patients (mean 52, range 34-56y)	Assessment of signal changes in MRI in patients with atypical odontalgia and correlation of MRI and CBCT	• MRI and radiographic imaging coincided with a finding in 75% of patients with atypical odontalgia and chronic pain, • 3D CISS redundant for periapical diagnosis without radiological correlate displayed findings in MRI • 40% of patients with odontalgia had changes in region in MRI
Casseta., *et al*. 2012	10 patients (mean age: 38.8 ym range 21-63y)	Assessment of MRI for intraosseous pathological findings, characterization of MRI findings and correlation to histopathology	• Odontogenic cysts appeared with homogenous high and intermediate signal intensity in water and fat T2 weighted images respectively, • Contrast agent administration resulted in thin rim enhancement in T1 weighted images

Table 2: Studies on the use of MRI for the display of the periapical region. Technical information is given in supplementary table 2. CBCT: Cone-Beam CT; 3D CISS: Three Dimensional Constructive Interference in Steady State.

Juerchott., *et al*. reported molar teeth, bone support and furcation involvement in CBCT and MRI [18,19].

A Clinical study using a dedicated surface coil for dental imaging assessed palatal mucosa thickness at several teeth using MRI [21].

Probst., *et al*. investigated the correlation between boneo oedema dedicated in MRI images and clinical findings in patients with generalized periodontitis [22].

Authors	Study design subjects	Research question	Findings
Ruetters., *et al*. 2018	5 patients (21 teeth)	Agreement of measurements of the periodontal bone support in periapical radiographs and MRI	• High intra- and interrater agreement for measurements in radiographs and MRI. • Strong correlation for both imaging methods. • Clinical measurements may not be transferred to MRI, as cement-enamel-junction is not visible on MRI.
Juerchott., *et al*. 2020	22 patients	Comparison of CBCT and MRI for the assessment of periodontal bone support in molar teeth (furcation involvement)	• Excellent intra – and interrater agreement for MRI for the assessment of furcation involvement; High levels of agreement for MRI and CBCT.

Hilgenfeld., *et al*. 2018	5 volunteers	Reliability of MRI measurements of the thickness of the palatal mucosa	• Assessment of palatal mucosa thickness and location off greater palatal artery highly reliable with MRI (mean intraobserver ICC 0.989. mean interobserver ICC 0.987).
Probst., *et al*. 2021	42 patients (28-79y, mean 56 ± 14.6), 34 healthy control (21 – 32y) mean 23 ± 1.9)	Correlation of MRI findings and clinical findings in patients with generalized periodontitis	• Bleeding on probing in at sites with probing depths (3 mm) and pathological conditions (3 mm) was highly significantly different.

Table 3 : *MRI for indications in periodontics. Technical information is given in supplementary table 4. CBCT: Cone-Beam CT; ICC: Intraclass Correlation Coefficient.*

Carries detection

Caries is delineated in MRI with a hyperintense signal due to its porous characters and the infiltration of liquid [18].

Due to the lack of gold-standard for measuring caries lesions, the congruence of its presentation in MRI and its actual size has not been studied.

One study addressed the use of MRI for caries diagnosis.

Table 4 studies on the use for the display of caries lesions.

Authors	Study design subjects	Research question	Findings
Bracher., *et al*. 2013	40 participants (161 lesions)	Is UTE MRI clinically applicable for the identification of caries lesions?	• 14 teeth with local image artefacts not evaluated. • UTE MRI applicable for caries detection with similar sensitivity that X-Ray. • UTE MRI More sensitive that TSE for caries detection.

Table 4: *Studies on the use of MRI for the display of caries lesions. Technical information is given in supplementary table 3. TSE: Turbo Spin Echo; UTE: Ultrashor Echo-Time.*

Discussion

MRI is vastly used to display the dentoalveolar process across various indications and specialties in dentistry.

In endodontics, a small image volume of one to three teeth, including the periapical area and a high image resolution showing the delicated and ramified anatomy of the pulp are required.

Specific intraoral coils enable a high image resolution of around 0.3 mm^3 for two to three and might be particularly interesting for endodontic indications, however, they have not been used in this specific field [23,24].

Studies published until 2007 have two major constraints. Image resolution was low (< 1.0 mm^3), and a contrast agent was used to observe signal intensity in the dental pulp [25,26].

In vivo studies focused on the age-related perfusion and the detection of pulp vitality and reperfusion after the tooth replantation and transplantation, respectively [7,25,26].

High signal intensity was correlated with a perfused, vital pulp and no signal with pulp necrosis.

As a differential diagnosis, a hyperintense signal indicates an inflammation.

Recently, one article on the characterization of pulp signal in MRI in the presence of caries lesions was published [18].

In summary, the degree of perfusion of the dental pulp correlates with the signal in MRI [25,26] physiological perfusion shows MRI signal enhancement after administrating of contrast agent [23].

The signal enhancement correlates with the perfusion level; however, the interpretation is difficult due to missing reference data.

Further *in vivo* studies are therefore required for image characterization of an inflammation.

Periapical lesions include granuloma, radicular cyst, or other tumorous processes. Whereas granuloma may completely recede after root canal treatment, cyst or tumors must be surgically resected.

Periapical lesions are diagnosed with good diagnostic accuracy using panoramic or intraoral radiographs when demineralization is extended to the cancellous bone or has reached the buccal and oral cortical bone plate [27,28].

At an earlier stage, periapical lesions might be present, however, not accessible to routine radiographic imaging. As an alternative to two-dimensional radiography.

CBCT may be used for a three-dimensional assessment of periapical demineralization. The character of the tissue or lesion substituting for bone, may not be identified with CBCT unless it contains mineralized parts that are displayed radiographically.

Furthermore, due to cost and radiation exposure, CBCT is not routinely performed to detect a periapical focus.

MRI allows for a more detailed characterization of periapical lesions [14,15].

For differentiation of a granuloma and radicular cysts, either contrast-enhanced T1 or T2 weighted images have been advocated [16].

Several authors could verify diagnosis in MR images with histopathological analysis and reported the high correlation of findings [12,13,15,16].

Caries is diagnosed clinically and radiographically using the periapical radiograph or bitewing technique.

Clinical diagnosis may not deliver information on the full extent of a carious lesion.

Imaging of caries requires a high image resolution in a relatively small image volume.

Bitewing or periapical radiographs are prone to overlying structures; however, they deliver a high image resolution.

MRI could complement routine radiographic imaging due to its property to account for inflammatory processes.

An inflammation of the pulp in correlation to a carious lesion could be demonstrated. A high image resolution was only fulfilled in one study using a self-built intra-oral coil that is not commercially available [29].

The costly hardware requirements for MRI and the lack of a proven and applicable protocol to display caries restrict its use in this indication.

In periodontics, the marginal bone level and its pathological recession are observed for the diagnosis of periodontal diseases.

Findings are mainly collected clinically; however panoramic radiographs substantiate the diagnosis.

In specific cases attachment loss, CBCT may be used to display defect configuration [30].

A large acquisition volume covering the maxilla and mandible is useful for image diagnosis. Not only anatomical structures but also the inflammatory status of the tissue is regarded. MRI could, therefore, be valuable tool for the diagnosis of periodontal diseases.

The visibility of periodontal structures and their dimensionally accurate delineation has been shown in cadaver porcine mandibles [27]. Clinical studies have shown that inflammatory periodontal disease might be detected using a contrast agent, and measurement of periodontal defects may be performed in MRI [19,20].

The compatibility of clinical measurements and tomographic imaging, MRI and CBCT is lacking, as the cemento-enamel junction as a clinical landmark for measurement of attachment loss is not shown with MRI [19].

Conclusion

In summary, MRI is applicable to a broad spectrum of indications in dentomaxillofacial imaging as an alternative to conventional radiography. LI Using specific surface coils for dental imaging or otherwise designed surface coils has helped achieve high image resolution within acceptable acquisition times.

The image resolution of MRI is comparable with CBCT for in-plane resolutions. However, for an isotropic image resolution, $0.4mm^3$ is currently the threshold value.

Shorter acquisition times and specific hardware for dental imaging have furthermore helped to reduce the occurrence of motion artefacts and enable the use of MRI in clinical practice.

The future of dental MRI in clinical application is challenged by its limited availability and high cost. Therefore, technical developments for short scanning times using simple and inexpensive equipment that sustain the demands for dental imaging are required.

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Volume 22 Issue 8 August 2023