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Research Article

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Endodontic-Periodontal Lesion Diagnosis, Prognosis and Decision Making

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Abstract:

In clinical practice, an often-encountered enigma is that of the endo-perio lesion. A source of confusion and dilemma to the dentist. As proper treatment protocol is a necessity for such a commonly encountered problem, also an in-depth knowledge is required in this subject. The approach to the treatment varies according to the etiology and the complexity in each case encountered. The resolution of the lesion also depends on the accurate diagnosis and the correct treatment methodology. 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 In challenging cases like that of endo-perio lesions, it is necessary that a multidisciplinary approach is undertaken. First and foremost, the etiology of the endo-perio lesion has to be identified which requires accurate diagnostic ability and skill. The treatment varies according to the major cause of the endo-perio lesion. The future dental MRI in clinical application is challenged by its limited availability and high cost. Therefore, technical development for short scanning times using simple and inexpensive equipment's that sustain the demand for dental imaging are required.

1. Introduction

The pulp and periodontium are so interrelated that they are termed as the pulp-periodontium complex; this interrelationship makes it more difficult to treat as well as to understand. Any of the infections might arise either of the endodontic origin or of periodontic origin and even due to a combination of both. The relationship between periodontal and pulpal disease was first described by Simring and Goldberg in1964. This provided the origin of the term endo-perio lesion.

The pulp-periodontium interrelationship:
The pulp and periodontium are closely interrelated since the developmental stage. The presence of various pathways of communication enables the spread of infection from pulp to periodontium as well as vice versa. An anatomical, as well as functional relationship is also seen in the complex

as coined by Simring and Goldberg. The various pathways seen are [2]:

Anatomical pathways:

- Apical foramen, accessory canals/lateral canals
- Congenital absence of cementum exposing dentinal tubules
- Developmental grooves.

Pathways of Pathological Origin:

- Empty spaces on the root created by Sharpey's fibers
- Root fracture following trauma
- Idiopathic root resorption-internal and external
- Loss of cementum due to external irritants.

Pathways of Iatrogenic Origin:

- Exposure of dentinal tubules following root planning
- Accidental lateral root perforation during endodontic procedures
- Root fractures during endodontic procedures.

Commonest used classification of endo-perio lesions given by Simon, Glick and Frank in 1972 [3]:

1. Primary endodontic lesion
2. Primary periodontal lesion
3. A primary endodontic lesion with secondary periodontal involvement
4. A primary periodontal lesion with secondary endodontic involvement
5. Truly combined lesion.

Primary endodontic lesion:
Necrotic pulp is present, communicates to the sulcus area leading to infection. The pocket is narrow with no prominent periodontal findings. Sinus tract channel should be traced by placing gutta-percha cone to find the origin. Prognosis is quite good with root canal treatment leading to resolution [3].

Primary periodontal lesion:
In such lesion, chronic periodontitis is seen, which progresses apically. Pathogens causing periodontal diseases are the major factor. Generalized periodontitis with plaque and calculus can be seen. Depending on the stage of periodontal progression and efficacy of periodontal treatment, results will be seen [3].

A primary endodontic lesion with secondary periodontal involvement:
The untreated primary endodontic left, when left for a longer time, may involve the periodontium. Sometimes, it may be due to inefficient root canal treatment or maybe iatrogenic in nature, caused by root fractures or perforations while placing posts, pins. The degree and severity of inflammation of the periodontal tissues will depend on the exact cause and duration of the lesion. A basic protocol of multi seating root canal treatment and basic oral hygiene procedures is advocated initially. Accordingly, in specific causes, like root fracture efficiency of reparative treatment with newer materials like MTA, will guard the prognosis [3].

A primary periodontal lesion with secondary endodontic involvement:
Periodontal infection progressing apically leads to endodontic manifestations; infection may spread through the apical foramen or accessory canals. Initial oral hygiene therapy is necessary. Such lesions have a poorer prognosis. If required, periodontal surgery may be advocated. The results will also depend on the number of apical extensions [4].

Truly combined lesion:
Such lesions occur infrequently and are seen due to the combination of endodontic infection progressing coronally and periodontal infection progressing apically. The prognosis is guarded in such case, especially if the independent infection has joined together. Radiographically, these lesions appear similar to that of the tooth with vertical fractures. Root canal therapy, advanced endodontic surgery and advanced periodontal surgery may be required. Advanced lesions which are difficult to diagnose should be considered endodontic lesion [4].

Diagnosis of perio-endo lesions:
In diagnostics, it is easier to diagnose endodontic lesion due to the presence of teeth with infected and non-vital pulp and in the primary periodontal lesion, tooth presents healthy and vital pulp. It is the other three which put up similar manifestations and are difficult to diagnose. The following steps in diagnosis, aids in deciding an appropriate treatment plan [5].

2. Examination

1. **Visual examination of lips, tongue, teeth are done.** A special checkup is done to detect caries, fracture lines, cracks or chip off. Magnifying loupes and microscopes may also be used [5].

2. **Radiographs:** intraoral periapical radiographs are specially required to detect caries, fissures, cracks, or fracture lines in the tooth. Periodontal manifestations especially bone loss, can be detected only after a certain degree. Defective restorations, periodontal ligament widening also can be seen [5].
3. **Pulp testing:** Pulp vitality indicates the absence of endodontic issues. The intense reaction shows signs of pulpitis whereas no reaction indicates pulp necrosis [5].
4. **Pocket probing:** this helps in differentiating between endodontic and periodontal lesion. A singular deep pocket indicates the presence of periodontal issues. Also, the generalized presence of plaque and calculus can be seen in such cases [6].
5. **MRI** is increasingly used as a diagnostic tool for visualizing the dentoalveolar complex [7,8].

The complex anatomy of the dentomaxilofacial 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 mandible with the intraosseous course of the inferior alveolar nerve, the teeth, its root 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 [9,10].
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, (VII) and Operative Dentistry which is still missing [8].
The current literature 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 [8].
Specific protocols regarding the miniature anatomy of the dentofacial complex, the presence of hard tissues and foreign body restoration are used along with dedicated coils for the improved image quality of the facial skull [8].
Dental MRI poses a clinically useful tradition-free imaging tool for visualizing the dentoalveolar complex across dental specialties when respecting the indications limitations [8].

3. 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 between2010 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 young age group, however orthodontic appliances might be present. Steel (orthodontic) appliances cause artifacts that deteriorate image quality and may considered a contraindication for MRI [11,12].
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 0.7mm^3 [13,15].
The vascularization of the dental pulp and differentiation between a healthy and inflamed pulp were displayed with contrast agents [13,14].
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* [16].
Hyper-perfusion of the pulp correlated with a high signal, and T2 values related to presumed inflammation and adjacent to caries were mapped using incremental echo times [14].
The degree of perfusion of the dental pulp correlated with the signal in MRI and terminated perfusion and pulp necrosis show no signal[13,14,17].
MRI may detect periapical inflammation at early stage due to edema and subsequently signal enhancement, even without demineralization or bone resorption [17].
In the case of periapical granulomas or cysts, a signal hyperintensity appears in MRI, contrary to radiolucency in CBCT, 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 [19].
The comparison of MRI and CBCT implies an over-estimation of lesions in MRI [20].
MRI detects regions with edema that are not visible in CBCT, therefore, MRI's more accurate representation is hypothesized [21,23].
The referenced studies mostly did not use contrast agents to display periapical lesions [18,20,21,23].

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 [25-28].
Ruetters., et al. Measured the marginal attachment in MRI and periapical radiographs using contrast agent [25].

Table 1. *MRI for the display of the dental pulp. Technical information is given in supplementary*

Authors	Study Design Subjects	Research Question	Findings
Assaf., et al 2015 [13]	Seven participants (8-17 y), 23 teeth	Visualization and measurement of revitalization of the dental trauma using MRI; comparison of signal intensity of trauma affected and non-affected teeth.	Reperfusion of pulp after dental 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 [14]	12 participants (34.4±7.3y), 72 teeth	Quantification of dental pulp signal in teethe 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 [22]	70 participants (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 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 [15]	Five participants	Comparison of intraoral coil with conventional head and surface coils and CBCT in terms of SNR and visibility.	• Acceptable scan time (5-7min) • Spatial resolution with intraoral coil comparable to CBCT. • Improvement of SNR in vivo with intraoral coil.

CBCT: *Cone-Beam;* ***PCE:*** *Pulpal Contrast Enhancement:* ***SNR:*** *Signal- to- Noise Ratio.*

Table 2. *Studies on the use of MRI for the display of the periapical region. Technical information is given in supplementary table 2.*

Authors	Study Design Subjects	Research Questions	Findings
Geibel., et al. 2015 [21]	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 lesion with MRI compared to CBCT. • More detailed characterization of lesions with MRI. Weighted sequences showed heterogeneity of periapical pathologies.
Geibel., et al. 2017 [22]	13 participants (41+27y); 15 teeth	Assessment of periapical lesion and characterization of lesion with MRI using different contrast weightings; correlation with histopathology.	• Weighted images for identification of lesion. Weighted images for further characterization of lesions. • Differential diagnosis of periapical lesion possible by assessing homogeneity/heterogeneity of signal inside the lesion compared to surrounding tissues. • Differences in signal intensity between and weighted images.

Juerchott., et al. 2018 [15]	11 participants (mean 39.5y range21-60y); 11 teeth	Assessment and characterization of periapical lesion 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 weighted images. • Differentiation of peripheral run, lesion center and surrounding tissue with contrast-enhanced and weighted sequence. • MRI characteristics in accordance with result of histopathological analysis.
Lizio., et al. 2015 [19]	34 participants	Diagnostic reliability and accuracy of MRI for periapical lesions correlation with histology	End osseous 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 [23]	20 participants (mean 52, range 34-56)	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 of 75% of patients with atypical odontalgia and chronic pain. • 3D CISS redundant for periapical diagnosis without radiological correlate displayed finding in MRI. 40% of patients with odontalgia had changes in region in MRI.
Casseta., et al. 2012 [18]	10 participants (mean age: 38.8y 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 weighted images respectively. • Contrast agent administration resulted in thin rim enhancement in weighted images.

CBCT: *Cone-beam CT;* ***3D CISS:*** *Three-Dimensional constructive Interference in Steady State.*

Table 3. *Studies on the use of MRI for the display of caries lesions. Technical information is given in supplementary*

Authors	Study Design Subjects	Research Question	Findings
Bracher., et al. 2013 [24]	40 participants (161 lesions)	Is UTE MRI clinically applicable for the identification of caries lesions?	• 14 teeth with local image artifacts not evaluated. UTE MRI applicable for caries detection with similar sensitivity that X-ray. UTE MRI more sensitive that TSE for caries detection.

TSE: *Turbo Spin Echo;* ***UTE:*** *Ultrashort Echo-Time.*

Carries Detection:

Carries is delineated in MRI with a hyperintense signal due to its porous characters and infiltration of liquid [24].

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 3 studies on the use for the display of caries lesions). **Table 4.** studies on the use for the display periodontics.

Table 4. *MRI for indications in periodontics. Technical information is given in supplementary table 4.*

Authors	Study Design Subjects	Research Question	Findings
Ruetters., et al. 2018 [25]	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 in MRI.
Juerchott., et al. 2020	22 patients	Comparison of CBCT and MRI for the assessment of periodontal	• Excellent intra-and interrater agreement for MRI for the

[15]		bone support in molar teeth (furcation involvement)	assessment of furcation involvement; High levels of agreement for MRI and CBCT.
Hilgenfeld., et al. 2018 [26]	5 volunteers	Reliability of MRI measurements of the thickness of the palatal mucosa	• Assessment of palatal mucosa thickness and location of greater palatal artery highly reliable with MRI (mean intra observer ICC 0.989. Mean interobserver ICC 0.987).
Probst., et al. 2021 [27]	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 the sites with probing depths (3mm) and pathological conditions (3mm) was highly significantly different.

CBCT: *Cone-Beam CT;* ***ICC:*** *Intraclass Correlation Coefficient.*

Treatment of endo-perio lesions

For primary endodontic lesions, conventional root canal treatment was the gold-standard; follow up visits are advised to check the successful resolution. Often calcium hydroxide is advised as an intracanal medicament. Endodontic surgeries and periodontal invasive surgeries are to be avoided in such lesions [29].

For primary periodontal lesions, initial periodontal is advised, the response will depend on the severity of the disease, efficacy of the treatment and also the patient's oral hygiene habits. Yet prognosis is poorer than primary endodontic lesions [30,31].

Combined lesions require both endodontic and periodontal treatment modalities; surgical intervention may also be required. Before surgery, basic periodontal therapy and root canal treatment should be completed. The prognosis of combined diseases mainly rests with the efficacy of periodontal therapy [32].

4. 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 dedicated and ramified anatomy of the pulp are required.

Specific intraoral coils enable a high image resolution of around $0.3mm^3$ for two to three and might be particularly interesting for endodontic indications, however, they have not been used in this specific field [33.34].

Studies published until 2007 have two major constraints. Image resolution was low ($<1.0mm^3$), and a contrast agent was used to observe signal intensity in the dental pulp [35,36].

In vivo studies focused on the age-related perfusion and detection of pulp vitality and perfusion after the tooth replantation and transplantation, respectively [13,35,36].

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 lesion was published [24].

In summary, the degree of perfusion of the dental pulp correlates with the signal in MRI physiological perfusion shows MRI [25, 26] signal enhancement after administrating of contrast agent [33].

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 [37,38].

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 [20,21].

For differentiation of a granuloma and radicular cysts, either contrast-enhanced T1 or T2 weighted images have been advocate [22].

Several authors could verify diagnosis in MRI images with histopathological analysis and reported the high correlation of findings [18,19,21,22].
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, the deliver a high image resolution. MRI could compliment 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 self-built intra-oral coil that is not commercially available [39].
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 a periodontal disease.
Findings are mainly collected clinically; however panoramic radiographs substantiate the diagnosis.
In specific cases attachments loss, CBCT may be used to display defect configuration.
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 tissues 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 [37].
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 [25,26].
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 [25].

5. Conclusion

The diagnosis of endo-perio lesions is a complex task and requires a piece of thorough knowledge and scientific bent of mind. Multifactorial involvement like the original cause, the immune response of the patient, the source of infection makes it a challenging endeavor. Hence, a multidisciplinary approach and sequenced treatment plan are necessary for long term successful results.
In summary, MRI is applicable to a broad spectrum of indications in dentomaxilofacial imaging as an alternative to conventional radiography 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 artifacts 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.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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