eor.istanbul.edu.tr

Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2025; 59(1): 58-67

Invited Review

# The evolving role of MRI in dentomaxillofacial diagnostics: a comprehensive review

**Melisa Öçbe**[1]

Magnetic Resonance Imaging (MRI) has emerged as a pivotal diagnostic tool in dentomaxillofacial radiology, surpassing conventional imaging techniques by offering superior contrast resolution for soft tissue lesions without the use of ionizing radiation. This comprehensive review explores the expanding applications of MRI in dentistry, highlighting its integration into routine diagnostic protocols and its significance in the evaluation of oral and maxillofacial structures. The article delves into the physics of MRI, detailing the various sequences such as Spin Echo (SE), Gradient Echo (GRE), and Short-Tau Inversion Recovery (STIR), each tailored for specific diagnostic needs. Advanced techniques like Dynamic Contrast-Enhanced MRI and Diffusion-Weighted Imaging (DWI) are discussed for their roles in assessing tissue perfusion and differentiating between benign and malignant lesions. The review emphasizes the necessity of appropriate coil selection and parameter optimization to enhance image quality, particularly in dental applications where artifacts from restorative and prosthetic materials can pose challenges. Furthermore, the article addresses the utility of MRI in visualizing dental hard tissues, the temporomandibular joint, and neurovascular structures, providing a comprehensive overview of its diagnostic capabilities. The integration of MRI into global health systems and the role of Personal Electronic Health Records in reducing redundant imaging are also examined. Conclusively, the review underscores the transformative impact of MRI on dentomaxillofacial diagnostics, advocating for its broader adoption in clinical practice to facilitate accurate diagnosis and effective treatment planning.

***Keywords:*** *Dental imaging, magnetic resonance imaging, radiology, dentomaxillofacial diagnostics*

## Introduction

Magnetic resonance imaging (MRI) has evolved into a well-established diagnostic tool in the oral and maxillofacial radiology as a gold standard with its superior contrast resolution in imaging of soft tissue lesions (1, 2-4). Avoidance of ionizing radiation distinguishes MRI from other advanced imaging methods and constitutes its non-invasive characteristics (5, 6). MRI utilizes powerful magnetic fields and radiofrequency pulses to generate detailed images of tissues. This process provides a comprehensive view of oral and maxillofacial structures with high resolution images. As this technology continues to evolve, considerations about its integration into dental practice requires further attention in the emerging dentomaxillofacial diagnostic methodologies (3, 7-13).

## Basic concepts of MRI in dental applications

Understanding the basic principles of MRI is vital for optimizing image quality and clinical data extraction. Dental clinicians need concise knowledge of imaging sequences to make informed decisions (14). MRI relies

*ORCID IDs of the authors: M.Ö. 0000-0003-1609-610X*

*[1]Kocaeli Health and Technology University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology, Kocaeli, Turkiye*

Corresponding Author: Melisa Öçbe

E-mail: melisa.ocbe@kocaelisaglik.edu.tr

Received: 11 March 2024
Revised: 30 April 2024
Accepted: 24 June 2024

DOI: 10.26650/eor.2024145664

***How to cite:*** *Ocbe M. The evolving role of mrı in dentomaxillofacial diagnostics: a comprehensive review. Eur Oral Res 2025; 59(1): 58-67.* DOI: 10.26650/eor.2024145664

on magnetic properties of atomic nuclei, particularly hydrogen protons, interacting with magnetic fields and radiofrequency pulses (15). Manipulating radiofrequency signals in pulse sequences controls hydrogen atom movement, crucial for image formation (16). Protons emit signals when aligned and disturbed, resulting in relaxation processes influencing image contrast (17). Regarding to these relaxation processes, T1 refers to the time constant for longitudinal relaxation, representing how quickly protons realign with the magnetic field, while T2 refers to the time constant for transverse relaxation, indicating how quickly protons lose phase coherence in the transverse plane (3, 14, 16, 17). MRI sequences are critical for identification of anatomical structures and pathological conditions. Each sequence of MRI offers unique advantages with various imaging parameters.

*T1 and T2-weighted images*

T1-weighted (T1W) and T2-weighted (T2W) images relies on the Time of Repetition (TR) and Time of Echo (TE) characteristics of the image. TR and TE can be manipulated to emphasize different properties in MRI. While short TR and TE emphasizing T1w images, long TR and TE emphasizes T2w images (3, 14, 16). Alterations in T1 and T2 properties are main parameters in generation of those sequences (2, 15, 18, 19).

*Spin Echo (SE) sequence*

SE is a commonly used MRI sequence particularly used in reducing artifacts and provides high-contrast images for the diagnostic process (14, 17). T1W SE sequences offer anatomical detail, while T2W SE sequences highlight water content differences which is critical in identification of pathological conditions (5, 20, 21).

*Gradient echo (GRE) sequence*

Gradient echo sequence is an MRI technique that uses variable flip angles and gradient fields which provides faster imaging with enhanced contrast (16, 17). It is specifically used for dynamic imaging of blood flow and functional MRI (fMRI), and commonly used for high-resolution anatomical imaging and detecting hemorrhages (17, 19).

*Short-tau inversion recovery (STIR) sequence*

STIR sequence is an MRI technique that suppresses fat signal by using an inversion recovery pulse. This technique is commonly used for detection of pathologies such as edema, inflammation, and tumors, as it provides high contrast between fat and water-containing tissues (18, 19) (Figure 1).

*3D fast low-angle shot (3D FLASH)*

The 3D FLASH sequence provides excellent contrast between tissues, particularly useful for visualizing anatomical structures and dynamic processes. It is commonly used in contrast-enhanced studies to assess vascular structures and abnormalities. (22).

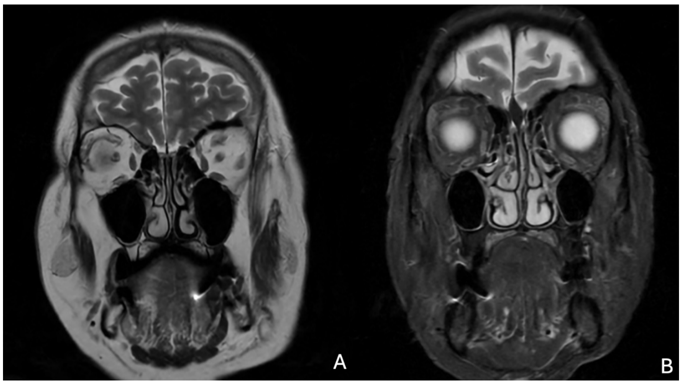


***Figure 1.*** *Coronal sections in T2W MRI showing Spin Echo (a) and STIR (b) sequences. Hyperintense appearance observed in maxillary sinus mucosal thickening and nasal cavity in the STIR image due to fat signal suppression.*

*Magnetic resonance angiography (MRA) and MR perfusion*

MRA sequences provide detailed images of blood vessels without the need for contrast agents by highlighting the flow of blood. In dentomaxillofacial imaging, MRA can be valuable for assessing vascular anatomy, arteriovenous malformations, and to evaluate the blood supply to tumors or other pathologies (23, 24).

Time-resolved angiography with interleaved stochastic trajectories (TWIST) or time-resolved imaging of contrast kinetics (TRICS) MR angiography is a method that delivers high temporal resolution images across arterial, capillary, and venous phases. This technique is effective for evaluating the feeding arteries, nidus, and draining veins of arteriovenous malformations in the dentomaxillofacial region (14, 25).

*Dynamic contrast-enhanced (DCE) MRI*

DCE MRI is an advanced technique for the analysis of microvascular parameters of tissue perfusion. It involves placing a region of interest within the tumor to calculate time-intensity curves and semiquantitative parameters (5, 16, 25).

*3D fluid attenuated inversion recovery (3D-FLAIR)*

3D-FLAIR suppresses the signal from cerebrospinal fluid to increase the visibility of lesions. It is commonly used for detecting abnormalities such as multiple sclerosis plaques, subarachnoid hemorrhages, and other pathologies (5, 8, 25).

*3D double-echo steady-state (3D DESS)*

3D DESS sequence captures both T2W and GRE images by simultaneously acquiring two echo signals with different weighting during each repetition of the sequences. In the dentomaxillofacial region, it is commonly used to visualize and assess the temporomandibular joint anatomy and disorders (14, 16, 25).

*Ultrashort echo time (UTE)*

UTE is a specialized method designed to capture images with extremely short echo times, typically less than 1 millisecond. This allows UTE MRI to visualize tissues with very short T2 relaxation times, such as cortical bone and ligaments. UTE MRI is particularly useful in orthopedic and musculoskeletal imaging for assessing bone structure, cartilage, and tendon integrity, as well as in imaging dental structures such as enamel and dentin (14, 25, 26).

*Diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI)*

DWI measures the random motion of water molecules within tissues, providing information about tissue cellularity and integrity. It is commonly used in the dentomaxillofacial region to evaluate lesions, such as tumors or abscesses, based on their cellular density and the restriction of water diffusion. DTI is an extension of DWI that assesses the directionality and coherence of water diffusion in tissues, allowing for the visualization of white matter tracts and nerve fibers. In the maxillofacial region, DTI can be used to map the course of cranial nerves or assess the integrity of neural pathways, aiding in the diagnosis and surgical planning for conditions like trigeminal neuralgia or facial nerve disorders (8, 25, 27, 28) (Table 1).

## Integration of spesific sequences

MRI offers sequence options for specific tissues or pathologies, facilitating precise diagnostic imaging. Proficiency in sequence selection is crutial for optimizing MRI examinations. Arteriovascular malformations or malignant lesions necessitate different sequence choices. Furthermore, variations in tissue characteristics may necessitate additional parameter adjustments in MRI protocols. Consideration of scanning duration may be a criterion for optimizing image acquisition. These factors collectively underscore the significance of sequence selection in MRI.

SE and GRE sequences offer contrast advantages, while STIR and DESS protocols improve lesion detection (13). To reduce image acquisition, quick overview scans could be achieved. For instance, by employing rapid T1W 3D FLASH sequences, allowing comprehensive evaluation of the jaw with isotropic spatial resolution within minutes at slightly reduced spatial resolution. This provides adequate anatomical detail for identifying specific areas. Integrating rapid overview imaging with subsequent high-definition local imaging of identified areas could lead to a significant decrease in the overall scan time, potentially reaching the 15-minute range (5, 22).

DCE MRI utilizes pharmacokinetic modeling to derive quantitative parameters like Ktrans, which has shown promise as a marker for tumor hypoxia and treatment response in squamous cell carcinoma. Tumor characteristics such as vascularity and perfusion can be evaluated such as angiogenesis, which lead to the differentiation of squamous cell carcinoma from benign lesions or other malignancies. However, the technique remains subjective and lacking full standardization due to variations in analysis, choice of regions of interest, scanner models, pharmacokinetic models, and treatment time points (25).

MRI of hard tissues as bone, enamel and dentin, presents a challenge due to their limited water content and solid structure. Conventional MRI sequences struggle with these tissues due to their ultrashort T2 relaxation times. However, addressing this specific challenge requires sequences that are sensitive to ultrashort T2 relaxation and can provide a detailed analysis of these tissues with high spatial resolution and signal-to-noise ratio. Ultrashort Time Echo (UTE) MRI is a sequence that fulfills these requirements, allowing for effective imaging of dental hard tissues by capturing signals from rapidly decaying echoes and overcoming the limitations associated with their short relaxation times (26).

Recently, there has been a surge in popularity of Diffusion Tensor Imaging (DTI) and Diffusion-Weighted Imaging (DWI) sequences in oral and maxillofacial imaging (8, 25, 27, 28). The degree of anisotropy and directional information obtained through DTI contribute to a more comprehensive understanding of the organization and integrity of tissue structures. Overall, DTI, by unraveling the complexities of water diffusion at a microscopic level, proves to be a pivotal tool in tissue microstructure and pathology (27, 29, 30). DWI and DTI can assist in characterizing lesions and evaluating treatment responses in dentomaxillofacial imaging. Specifically, the apparent diffusion coefficient (ADC) ratios derived from DWI and DTI can facilitate the differentiation between benign and malignant lesions (29-35). Koontz *et al.* (29) stated that DTI serves as a valuable predictor of malignancy in head and neck lesions, with the ADC values of malignant lesions

**Table 1:** *Commonly used sequences for strategic MRI ordering*

| Commonly used sequences | Justification |
|---|---|
| Spin Echo (SE) | Provides T1- and T2-weighted images with versatile soft tissue contrast |
| Griadient Echo (GRE) | Enables dynamic imaging and susceptibility-weighted imaging |
| Short-tau Inversion Recovery (STIR) | Suppresses fat signal for enhanced visualization of pathology |
| 3D Fluid Attenuated Inversion Recovery (3D-FLAIR) | Supresseses fluid signal and produces high-resolution 3D images |
| 3D Double-Echo Steady-State (3D DESS) | Provides multiple contrasts in a single acquisition |
| 3D Fast Low-Angle Shot (3D FLASH) | Offers high-resolution images with short acquisition times |
| Ultrashort Echo Time (UTE) | Able to view the dental hard tissue |
| Dynamic contrast-enhanced (DCE) | Assesses blood flow and tissue perfusion |
| Magnetic Resonance Angiography (MRA) | Visualizes blood vessels without the use of contrast agents |
| Diffusion Tensor Imaging (DTI) | Quantifies the direction and magnitude of water diffusion in tissues |
| Diffusion-Weighted Imaging (DWI) | Provides information about the microstructure and cellularity of tissues |

being significantly lower than benign lesions. In addition, Li *et al.* (31) found that not only the malignant lesions ADC values are lower, ADC values of benign solid lesions were significantly lower than cystic lesions. In the studies of Baba *et al.* (33, 34) it was found that ADC values were significantly higher in osteomyelitis when its compared with nasopharyngeal cancer.

## Evaluation of MRI databases in global health systems

In the context of escalating healthcare costs, healthcare providers bear the responsibility of seeking advanced imaging modalities. Dental clinicians are prompted to consider whether the prevailing clinical issue has been recently addressed through existing imaging resources. Oral and Maxillofacial Radiology consultations can provide insights into the appropriateness of the requested diagnostic workup (36). From a global perspective, Personal Electronic Health Records Systems (PEHRSs) are avaible in various countries network systems which allows to view the previous MRI records. PEHRSs have been widely utilized on a global scale. utilized by 82% of the Turkish population (e-Nabiz), with similar implementations in Denmark (e-Record), Estonia (e-Health Record), and Germany (Elektronische Patientenakte – ePA) (37, 38). The appropriate utilization of PEHRSs and familiarity with the aforementioned systems are importantant in avoiding unnecessary or redundant MR imaging, thereby addressing healthcare cost concerns. An extensive study involving 196,314 patients revealed a 7.7% repetition rate within 90 days when prior imaging data was inaccessible. Additionally, it was stated that 18% of the patients had at least one image in this cohort study. Findings indicated that accessing PEHRSs within 90 days subsequent to an initial imaging procedure significantly reduced the repetition of imaging. This underscores the significant increase in imaging redundancy in the absence of PEHRS access. To avoid repetitive and unnecessary imaging, it is crutial to consult PEHRSs prior to ordering new imaging studies (36).

In evaluation of the MRI data existing in the PEHRSs, another important consideration is sequence assesment with respect to targeted pathological condition. A majority of MR imaging is conducted for medical purposes which may be problematic in analyzing data for dentomaxillofacial diagnostic purposes. MR images acquired for other medical purposes may occasionally lack the adequacy needed for evaluating oral and maxillofacial conditions. For instance, SE or GRE MR images can be employed to assess the position and anatomical variations of the inferior alveolar nerve before surgeries involving the posterior mandibular region (39). Yet, if the objective is to discriminate between benign and malignant pathologies, pulse sequence MR imaging may prove insufficient, necessitating the application of different MR imaging techniques depending on the characteristics of the lesion (29, 31).

## Factors influencing image quality in MRI

*Coil selection*

In MRI, a coil refers to a radiofrequency (RF) coil, an essential component of the MRI system and play a crucial role in capturing detailed images, used to transmit radiofrequency pulses and receive signals during the imaging process (40). Different coils are tailored for specific body parts or imaging goals. The application of a specific coil enables a nuanced and differential diagnosis of suspicious lesions within the head and neck region (41). The choice of coil depends on the imaging requirements and the anatomical structures being examined (42, 43). While gradient coils and surface coils are the most commonly used coil in MR imaging (44), using spesific coils for dentomaxillofacial imaging improves the image quality (45). Although not common, intraoral coil design is implemented using an appliance placed inside the mouth. The current literature indicates that MR images obtained with this type of coil provide detailed dentomaxillofacial imaging (42, 43).

Al-Haj Husain *et al.* (9) reported a case of irritation fibroma. Imaging of the lesion prior to the excision was perfomed with a 15-channel mandibular coil. The STIR and DESS sequences was in that case report, while the authors stated that these sequences are best suited to overcome the limitations of hard tissue imaging in dentomaxillofacial imaging. According to the study of Grandoch *et al.* (45), MR imaging with an intraoral coil can be a non-invasive alternative of cone-beam computed tomography in dental treatment planning such as third molar extraction or implant procedures concerning mandibular posterior region.

In addition to coils, various imaging parameters such as Signal-to-Noise Ratio (SNR), Contrast-to-Noise Ratio (CNR), FOV, matrix size, slice thickness, bandwidth play significant roles in influencing image quality in MRI (14, 44, 46, 47).

*Signal-to-noise ratio (SNR)*

The primary objective of RF receiver coils is to maximize the SNR, which is influenced by the coil's loop size and electrical properties (44). SNR compares the level of the target signal to the level of background noise in an MRI image (14). An increase in SNR can lead to higher spatial resolution or faster scanning speeds, resulting in clearer, more detailed images and improved diagnostic accuracy (5, 44, 46).

*Contrast-to-noise ratio (CNR)*

CNR measures the difference in signal strength between two adjacent tissues compared to the background noise level. High CNR is vital for distinguishing between different tissues or structures in an image and is particularly useful for detecting lesions with low contrast. Improved image quality is associated with higher SNR and CNR values (47).

*Field of view (FOV)*

FOV refers to the extent of the area being imaged, typically measured in millimeters (14). Increasing the FOV may reduce spatial resolution, as the MRI scanner distributes the available imaging resources over a larger area, resulting in less detailed images (46).

*Slice thickness*

Slice thickness refers to the thickness of the anatomical slices captured during imaging, measured in millimeters. Thinner slices provide better spatial resolution and reduce partial volume effects, but may increase scan time and noise (44, 46, 47).

*Bandwidth*

Bandwidth in MRI refers to the range of frequencies used to encode the signal. Higher bandwidth can reduce image distortion and chemical shift artifacts but may decrease SNR, while lower bandwidth improves SNR but can increase artifacts and distortions (46) (Table 2).

## Dental materials and MRI

As stated in the 2020 guideline of the American College of Radiology, whether an implant or a foreign body, a ferromagnetic material can cause image distortion and signal loss artifacts (48). Materials employed in dental applications for restorative, endodontic, prosthodontic and orthodontic treatments may contribute to the occurrence of imaging artifacts (14, 49, 50). The severity and extent of artifacts were influenced by factors such as material location, size, and thickness, with orthodontic appliances covering a large area of the oral cavity being of particular concern.

*Restorative and endodontic materials*

In restorative dentistry, certain materials like glass-ionomer cements and composite resins exhibit minimal distortion on MR imaging. Amalgam contains various metals including non-ferromagnetic silver, which does not significantly affect MR image quality (14). In addition, resin-based sealer and gutta-percha seem not to produce detectable distortions on MRI as well (14, 46).

*Prosthetic materials*

In prosthetic dentistry, gold crowns exhibit minimal ferromagnetic effects. Ceramic and zirconia crowns typically do not produce artifacts (50-52), although Reda *et al.* (14) stated that there are conflicting statements regarding the effect of zirconia, with some comparing it to metal effects. Metal-ceramic restorations, often made with nickel alloys, tend to generate artifacts (14). (Figure 2).

*Dental implants*

Dental implants contributed to localized artifacts in the oral cavity, affecting the assessment of adjacent structures, and susceptibility artifacts were observed in brain imaging as well. Current conventional techniques, like employing lower field strength or utilizing a SE sequence, are available to mitigate artifacts. Research indicates that 3 Tesla MRI tends to produce larger artifacts compared to 1.5 Tesla MRI, and using a SE sequence has been shown to decrease artifacts when contrasted with a GRE sequence (14, 49).

*Orthodontic materials*

While artifacts from titanium and ceramic materials were mostly confined to the oral cavity, stainless steel alloy caused more widespread distortion of the magnetic field due to its ferromagnetic properties. Removal of orthodontic appliances before MRI may be necessary to mitigate artifact severity. The decision to remove the orthodontic wire prior to MRI acquisition should be considered based on the chosen sequence, irrespective of whether the brackets are retained.

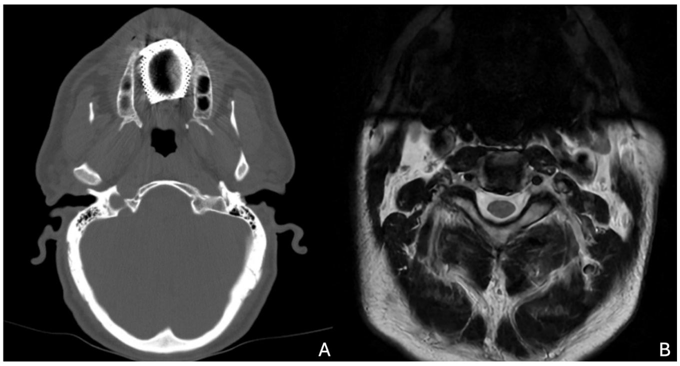


***Figure 2.*** *Computed tomography (a) and MRI (b) axial sections showing significant signal loss in the anterior region due to the removable prosthetics in the maxilla.*

**Table 2.** *Imaging parameters in MRI*

| Parameter | Definition | Effect on Image Quality | Impact |
|---|---|---|---|
| Signal-to-Noise Ratio (SNR) | A measure of the strength of the signal compared to noise | Higher SNR improves image quality, providing clearer details | Increased SNR results in higher image quality, essential for better visualization of structures and pathology. |
| Contrast-to-Noise Ratio (CNR) | Represents the difference in signal intensity between two regions relative to the noise. | Higher CNR enhances the visibility of differences between tissues. | Improved CNR aids in better differentiation of structures. |
| Field of View (FOV) | The size of the imaging area | Larger FOV captures a larger anatomical area | Larger FOV is suitable for imaging larger anatomical regions but may reduce spatial resolution for smaller structures. |
| Slice Thickness | The thickness of each imaging slice | Thinner slices provide better detail but may extend scan time | Thinner slices improve spatial resolution and are preferred for detailed imaging, although this may increase the overall scan time. |
| Bandwidth | The range of frequencies acquired during signal collection | Narrower bandwidth can improve image quality | Narrower bandwidth refines frequency resolution, potentially reducing chemical shift artifacts and improving overall image quality. |

Retainers crafted from gold or titanium generate insignificant artifacts, preserving diagnostic quality in dental and head/neck MRI. Conversely, ferromagnetic steel retainers induce notable artifacts, persistently compromising image quality, particularly with proximity to orthodontic retainers like rectangular steel and twistflex-steel, which can also impact remote anatomical structures (14, 49, 50).

## MRI of dentomaxillofacial structures

MRI in detecting the normal anatomy of dentomaxillofacial structures is crucial for the accurate detection of pathologies. Advancements in MRI technology have also enhanced its importance in evaluating bone structures for a comprehensive dentomaxillofacial assessments (46, 54-57).

*Dental anatomy*

The appearance of enamel and dentin in MRI is typically dark due to the absence of unbound protons. Surrounding structures are clearly visible, with cortical bone delineated as a black zone outlined by a moderate signal from external soft tissues (46) (Figure 3).

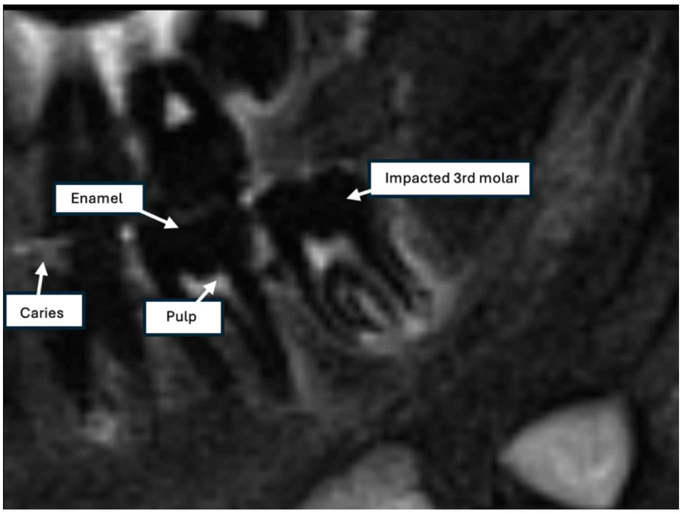


***Figure 3.*** *T2W SE MRI sagittal section showing dental structures. Mote that peripheral area of the impacted 3rd molar is hyperintense compared to the normal bone and the impacted tooth is in close relation with inferior alveolar nerve.*

It is recognized that a minimum of 30% mineral loss is necessary to identify a bony lesion through radiation-based imaging technique (53). In contrast, MRI can detect signal changes before significant mineral loss occurs, as it is sensitive to alterations in the number of water molecules within a lesion (54, 55). Bracher *et al.* (54) found that UTE-MRI may offer advantages in certain aspects of caries detection by visualizing hard tissues with limited water content. It was stated that UTE MR imaging can be applied for the identification of caries lesions wtih the ability to differentiate between dentine, enamel, and cementum. Despite the high sensitivity provided by this technique, the increased acquisition time (approximately 45 minutes) and the higher costs still represent a concrete obstacle for widespread clinical application of UTE-MRI (3, 55).

In the in vivo study of Assaf *et al.* (56), with 3 Tesla MR scanner, four sequences were tested: non-contrast-enhanced T1w, non-contrast-enhanced fat-saturated T1w, fat-saturated T2w, and constructive interference steady state. The findings revealed that the pulp chamber, periodontal space, and periapical lesions were observable without the need for contrast media. However, as anticipated, the differentiation between the enamel-dentin junction and the cementum-dentin junction of the teeth was limited. Dental MRI's characteristics enable the distinction between vital and nonvital teeth. When contrast media is employed, the vital pulp exhibits increased brightness, while older teeth display lower signal intensity due to reduced perfusion of the pulp. In contrast, nonvital or endodontically treated teeth do not exhibit any brightness (46, 56, 57).

*Floor of the mouth*

The mylohyoid muscle divides the sublingual space from the submandibular space, serving as a crucial landmark in imaging the oral cavity and upper neck. Surgical strategies are determined by a lesion's proximity to the mylohyoid muscle. Additionally, sublingual lesions often extend into the submandibular space at the muscle's posterior edge. Consequently, pre-surgical MRI of the floor of the mouth is important for assessing the submental area (58, 59).

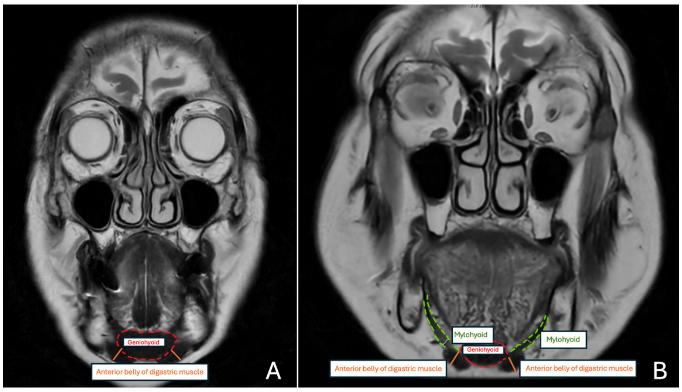


***Figure 4.*** *Coronal SE T2W images of submental muscle group. Note the geniohyoid muscle, mylohyoid muscle and anterior bellies of digastric muscle.*

## Neurovascular structures of dentomaxillofacial region

*Inferior alveolar nerve and lingual Nerve*

Inferior alveolar nerve and lingual nerve are branches of trigeminal nerve's mandibular division. The visualization of the inferior alveolar nerve and lingual nerve with various MRI sequences and field strengths were stated in the literature previously (10, 60-62). Borges and Casselman (63) stated that best sequences for neurovascular imaging are the non-contrast-enhanced fat-saturated T1W and T2W images. In T1W images, the outer cortical plate exhibits a dark appearance, diverging from the typical radiopacity observed in radiographs attributable to increased bone density. This manifestation in MRI results from the significant low signal, attributed to the absence of water or lipid protons. Conversely, the more organic cancellous bone presents a distinctly bright appearance in T1W images. Therefore, as

Malaro and Kolokythas (64) stated, the course of the inferior alveolar nerve and the mandibular trigeminal division can be followed with high-resolution T1W sequences (64).

*Nasopalatine nerve*

The nasopalatine nerve is a branch of the maxillary division of the trigeminal nerve which innervates the mucosa of the anterior hard palate, the lingual gingiva adjacent to the maxillary central and lateral incisors, and the lower part of the nasal septum. A study of Grandoch *et al.* (65), highlights the potential of employing a dedicated dental coil, revealing that MR imaging provides superior detail in both axial and coronal planes compared to CBCT for imaging the nasopalatine and inferior alveolar nerves. Nevertheless, Müller *et al.* (66) stated that SE sequences also offer precise diagnostic capabilities and imaging quality concerning the components of the trigeminal nerve. Imaging of the inferior alveolar canal and nasopalatine canal with conventional methods typically visualize the surrounding bone cortex rather than the contained nerve or vascular structures. Conversely, MRI enables the visualization of not only the bone cortex but also the neurovascular structures within it. Consequently, MRI holds potential for evaluation in cases where monitoring the relationship between lesions or teeth and neurovascular structures in the dentomaxillofacial region is necessary.

## Exploring temporomandibular joint (TMJ) through MRI

MRI offers superior visualization of the TMJ and masticatory muscles, with high spatial and contrast resolution without the use of ionizing radiation and enables detailed assessment of the TMJ anatomy, including the disc, articular surfaces, ligaments, and surrounding muscles. Additionally, MRI allows for the detection of pathologies such as disc displacement, degenerative joint disease, and inflammatory conditions (67) (Figure 5).

For the detection of disc displacement, MRI provides detailed images of the disc, comprised mainly of collagen, allowing differentiation from synovial fluid and vessel-rich retrodiscal tissue on proton density (PD) and T2W imaging. While MRI allows examination of bone marrow integrity and osseous component morphology, it is also useful for detecting joint effusion and evaluating soft tissue neoplasia or neoplastic-like lesions. Commonly used protocols involve T1W (or PD) and T2W imaging in closed and open mouth positions, with cross-sectional views including axially corrected sagittal oblique and coronal oblique sections along the long axes of the condyles. The closed mouth position helps assess disc position and soft tissue conditions, especially for detecting disc displacement, while the open mouth position aids in determining if a displaced disc was recaptured by the condyle upon opening (59-61) (Figure 6).

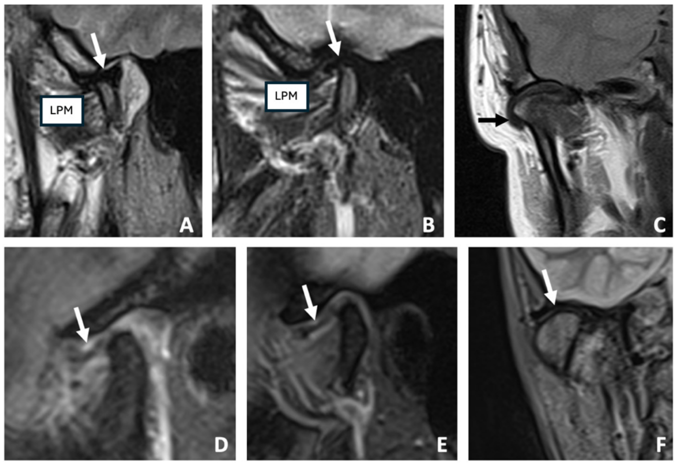


***Figure 6.*** *A and B: T2-weighted images in open (A) and closed (B) mouth positions, depicting normal disc position and lateral pterygoid muscle (LPM) C: Proton Density Turbo Spin Echo (PD TSE) image showing lateral disc displacement. D and E: T2-weighted images in open (D) and closed (E) mouth positions displaying anterior disc displacement. F: T2-weighted Spin Echo (SE) with Short Tau Inversion Recovery (STIR) sequence demonstrating the normal position of the disk in the coronal plane.*

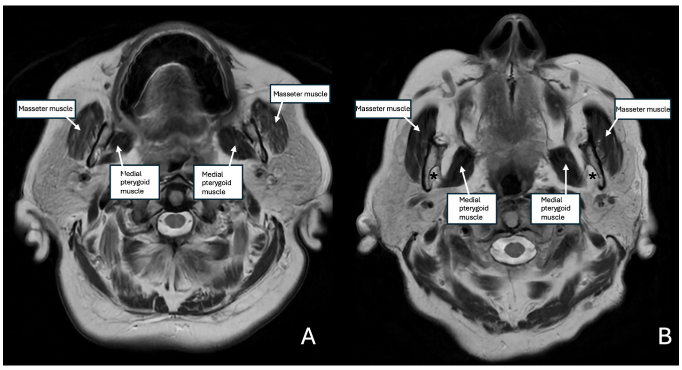


***Figure 5.*** *Axial T2W SE images showing masticatory muscles in axial plane. *: Mandibular foramen.*

Traditional MRI methods typically provide only static morphological and qualitative assessments of TMJ disorders, lacking the ability to capture the dynamic movement of the TMJ disc and mandibular condyle. In addition, while CBCT can depict osseous pathologies of the TMJ, such as arthropathies and osteoarthritis, MRI is still insufficient regarding bone pathologies of TMJ. A review of Xiong *et al. (67)* examines recent advancements in dynamic and quantitative MRI techniques, including DWI, T2 mapping, and UTE MRI, which show promise in TMJ imaging. Future directions in TMJ imaging involve the use of 7 Tesla MRI scanners with specialized sequences and improved SNR. While quantitative analysis of biochemical structures and MRI parameters has room for improvement, it remains achievable, particularly with ADC values (67, 68). In a retrospective MRI study by Jin Jeon *et al.* (68), 3 Tesla MR images of patients with TMJ disorders were analyzed using a specific sequence known as 'chemical shift-encoded magnetic resonance imaging', aiming to evaluate muscle parameters. Quantification of MR images through fat fraction analysis suggested its potential as a biomarker for TMJ disorders.

## Conclusion

In conclusion, the integration of MRI into dentomaxillofacial imaging represents a significant advancement, offering a non-invasive imaging method with high-resolution imaging capabilities. MRI provides valuable insights that contribute to more accurate diagnoses.

***Türkçe öz:** Dentomaksillofasiyal Tanıda MRG'nin Gelişen Rolünün Değerlendirilmesi**.** Manyetik Rezonans Görüntüleme (MRG), yumuşak doku lezyonları için üstün kontrast çözünürlüğü sunan ve iyonize radyasyon kullanmayan, dentomaksillofasiyal radyolojide geleneksel görüntüleme tekniklerine önemli bir tanı aracı altenatifi olarak ortaya çıkmıştır. Bu inceleme, MRG'nin diş hekimliğinde genişleyen uygulamalarını inceleyerek, rutin tanısal protokollere entegrasyonunu ve oral ve maksillofasiyal yapıların değerlendirilmesindeki önemini vurgulamaktadır. Spin Echo (SE), Gradient Echo (GRE) ve Short-Tau Inversion Recovery (STIR) gibi çeşitli sekansların her birinin belirli tanı ihtiyaçlarına göre özelleştirildiği MRG fiziğini ayrıntılı olarak ele almaktadır. Dinamik Kontrastlı MRG ve Difüzyon Ağırlıklı Görüntüleme (DWI) gibi ileri tekniklerin doku perfüzyonunu değerlendirme ve iyi huylu ile kötü huylu lezyonları ayırt etmedeki rolleri tartışılmaktadır. Özellikle restoratif ve protez malzemelerinden kaynaklanan artefaktların zorluklar oluşturabileceği diş hekimliği uygulamalarında görüntü kalitesini artırmak için uygun bobin seçimi ve parametre optimizasyonunun gerekliliği vurgulanmaktadır. Ayrıca, MRG'nin diş sert dokularını, temporomandibular eklemi ve nörovasküler yapıları görselleştirmedeki kullanımını ele alarak, tanısal yeteneklerinin kapsamlı bir özetini sunulmaktadır. MRG'nin küresel sağlık sistemlerine entegrasyonu ve kişisel elektronik sağlık kayıtlarının tekrarlayan görüntülemeyi azaltmadaki rolü de incelenmiştir. Sonuç olarak, MRG'nin dentomaksillofasiyal tanı sürecinde dikkate değer derecede olumlu etkisi olduğu, klinik uygulamalarda daha geniş çapta kullanılmasının doğru teşhis ve etkili tedavi planlamasınına sanılandan daha fazla katkısı olabileceği öne sürülmektedir. Anahtar kelimeler: dental görüntüleme, manyetik rezonans görüntüleme, radyoloji, dentomaxillofasiyal tanı*

**Ethics Committee Approval:** Not required.

**Informed Consent:** Not required.

**Peer-review:** Due to the invited nature of this review, the manuscript did not undergo standard peer review process. Instead, it was evaluated by the dentomaxillofacial radiology section editor, Prof. Dr. Alper Sinanoğlu, to ensure its quality and relevance. The section editor provided detailed feedback to the author, and subsequent revisions were made to enhance the manuscript's clarity and scientific rigor.

**Author contributions:** MO participated in designing the study. MO participated in generating the data for the study. MO participated in gathering the data for the study. MO participated in the analysis of the data. MO wrote the majority of the original draft of the paper. MO participated in writing the paper. MO has had access to all of the raw data of the study. MO has reviewed the pertinent raw data on which the results and conclusions of this study are based. MO have approved the final version of this paper. MO guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

**Conflict of Interest:** The author declared that they have no conflict of interest.

**Financial Disclosure:** The author declared that they have received no financial support.

## References

1. Lurie AG. Doses, Benefits, Safety, and Risks in Oral and Maxillofacial Diagnostic Imaging. Health Phys 2019;116:163-9. doi: 10.1097/HP.0000000000001030. [CrossRef]
2. Ekprachayakoon I, Miyamoto JJ, Inoue-Arai MS, Honda EI, Takada JI, Kurabayashi T, Moriyama K. New application of dynamic magnetic resonance imaging for the assessment of deglutitive tongue movement. Prog Orthod 2018;19:45. doi: 10.1186/s40510-018-0245-x. [CrossRef]
3. Mendes S, Rinne CA, Schmidt JC, Dagassan-Berndt D, Walter C. Evaluation of magnetic resonance imaging for diagnostic purposes in operative dentistry-a systematic review. Clin Oral Investig 2020;24:547-57. doi: 10.1007/s00784-019-03103-8. [CrossRef]
4. Xu J, Wang D, Yang C, Wang F, Wang M. Reconstructed magnetic resonance image-based effusion volume assessment for temporomandibular joint arthralgia. J Oral Rehabil 2023;50:1202-10. doi: 10.1111/joor.13551. [CrossRef]
5. Pykett IL, Newhouse JH, Buonanno FS, Brady TJ, Goldman MR, Kistler JP, Pohost GM. Principles of nuclear magnetic resonance imaging. Radiology 1982;143:157-68. doi: 10.1148/radiology.143.1.7038763. [CrossRef]
6. Lam EW, Hannam AG, Wood WW, Fache JS, Watanabe M. Imaging orofacial tissues by magnetic resonance. Oral Surg Oral Med Oral Pathol 1989;68:2-8. doi: 10.1016/0030-4220(89)90106-0. [CrossRef]
7. Hisatomi M, Asaumi J, Konouchi H, Shigehara H, Yanagi Y, Kishi K. MR imaging of epithelial cysts of the oral and maxillofacial region. Eur J Radiol 2003;48:178-82. doi: 10.1016/S0720-048X(02)00218-8. [CrossRef]
8. Terra GT, Oliveira JX, Hernandez A, Lourenço SV, Arita ES, Cortes AR. Diffusion-weighted MRI for differentiation between sialadenitis and pleomorphic adenoma. Dentomaxillofac Radiol 2017;46:20160257. doi: 10.1259/dmfr.20160257. [CrossRef]
9. Al-Haj Husain A, Schönegg D, Valdec S, Stadlinger B, Piccirelli M, Winklhofer S. Appearance of nasopalatine duct cysts on dental magnetic resonance imaging using a mandibular coil: Two case reports with a literature review. Imaging Sci Dent 2023;53:161-8. doi: 10.5624/isd.20220215. [CrossRef]
10. Burian E, Probst FA, Weidlich D, Cornelius CP, Maier L, Robl T, Zimmer C, Karampinos DC, Ritschl LM, Probst M. MRI of the inferior alveolar nerve and lingual nerve-anatomical variation and morphometric benchmark values of nerve diameters in healthy subjects. Clin Oral Investig 2020;24:2625-34. doi: 10.1007/s00784-019-03120-7. [CrossRef]
11. Li M, Yuan Z, Tang Z. The accuracy of magnetic resonance imaging to measure the depth of invasion in oral tongue cancer: a systematic review and meta-analysis. Int J Oral Maxillofac Surg 2022;51:431-40. doi: 10.1016/j.ijom.2021.07.010. [CrossRef]
12. Kennerley AJ, Mitchell DA, Sebald A, Watson I. Real-time magnetic resonance imaging: mechanics of oral and facial function. Br J Oral Maxillofac Surg 2022;60:596-603. doi: 10.1016/j.bjoms.2021.10.008. [CrossRef]
13. Al-Haj Husain A, Stadlinger B, Özcan M, Schönegg D, Winklhofer S, Al-Haj Husain N, Piccirelli M, Valdec S. Buccal bone thickness assessment for immediate anterior dental implant planning: A pilot study comparing cone-beam computed tomography and 3D double-echo steady-state MRI. Clin Implant Dent Relat Res 2023;25:35-45. doi: 10.1111/cid.13160. [CrossRef]
14. Reda R, Zanza A, Mazzoni A, Cicconetti A, Testarelli L, Di Nardo D. An Update of the Possible Applications of Magnetic Resonance Imaging (MRI) in Dentistry: A Literature Review. J Imaging 2021;7:75. doi: 10.3390/jimaging7050075. [CrossRef]
15. Calle D, Navarro T. Basic Pulse Sequences in Magnetic Resonance Imaging. Methods Mol Biol 2018;1718:21-37. doi: 10.1007/978-1-4939-7531-0_2. [CrossRef]
16. Pooley RA. Fundamental physics of MR imaging. RadioGraphics 2005;25,1087-99. doi:10.1148/rg.254055027 [CrossRef]
17. Jackson EF, Ginsberg LE, Schomer DF, Leeds NE. A review of MRI pulse sequences and techniques in neuroimaging. Surg Neurol 1997;47:185-99. doi: 10.1016/s0090-3019(96)00375-8. [CrossRef]
18. Berger A. Magnetic resonance imaging. BMJ 2002;5:324-35. doi: 10.1136/bmj.324.7328.35. [CrossRef]
19. Tourais J, Coletti C, Weingärtner S. Chapter 1 - Brief Introduction to MRI Physics. In: Akçakaya M, Doneva M, Prieto C, editors. Advances in Magnetic Resonance Technology and Applications. Academic Press 2022;3-36. https://doi.org/10.1016/B978-0-12-822726-8.00010-5. [CrossRef]
20. Minami M, Kaneda T, Ozawa K, Yamamoto H, Itai Y, Ozawa M, Yoshikawa K, Sasaki Y. Cystic lesions of the maxillomandibular region: MR imaging distinction of odontogenic keratocysts

and ameloblastomas from other cysts. AJR Am J Roentgenol 1996;(4),943-9. https://doi.org/10.2214/ajr.166.4.8610578 [CrossRef]
21. Probst FA, Probst M, Pautke Ch, Kaltsi E, Otto S, Schiel S, Troeltzsch M, Ehrenfeld M, Cornelius CP, Müller-Lisse UG. Magnetic resonance imaging: a useful tool to distinguish between keratocystic odontogenic tumours and odontogenic cysts. Br J Oral Maxillofac Surg 2015;53:217-22. doi: 10.1016/j.bjoms.2014.10.014 [CrossRef]
22. Geibel MA, Schreiber ES, Bracher AK, Hell E, Ulrici J, Sailer LK, Ozpeynirci Y, Rasche V. Assessment of apical periodontitis by MRI: A feasibility study. Rofo 2015;187:269-75. doi: 10.1055/s-0034-1385808. [CrossRef]
23. Kramer M, Schwab SA, Nkenke E, Eller A, Kammerer F, May M, Baigger JF, Uder M, Lell M. Whole body magnetic resonance angiography and computed tomography angiography in the vascular mapping of head and neck: an intraindividual comparison. Head Face Med 2014;10:16. doi: 10.1186/1746-160X-10-16. [CrossRef]
24. Yang G, Wilson TD, Lehman MN, Cui D. Comparison of Magnetic Resonance Angiography and Computed Tomography Angiography Stereoscopic Cerebral Vascular Models. Adv Exp Med Biol 2019;1205:1-9. doi: 10.1007/978-3-030-31904-5_1. [CrossRef]
25. Widmann G, Henninger B, Kremser C, Jaschke W. MRI Sequences in Head & Neck Radiology - State of the Art. Rofo 2017;189:413-22. English. doi: 10.1055/s-0043-103280. [CrossRef]
26. Timme M, Borkert J, Nagelmann N, Schmeling A. Evaluation of secondary dentin formation for forensic age assessment by means of semi-automatic segmented ultrahigh field 9.4 T UTE MRI datasets. Int J Legal Med 2020;134:2283-8. doi: 10.1007/s00414-020-02425-7. [CrossRef]
27. Grover VP, Tognarelli JM, Crossey MM, Cox IJ, Taylor-Robinson SD, McPhail MJ. Magnetic Resonance Imaging: Principles and Techniques: Lessons for Clinicians. J Clin Exp Hepatol 2015;5:246-55. doi: 10.1016/j.jceh.2015.08.001. [CrossRef]
28. Norris CD, Quick SE, Parker JG, Koontz NA. Diffusion MR Imaging in the Head and Neck: Principles and Applications. Neuroimaging Clin N Am 2020;30:261-82. doi: 10.1016/j.nic.2020.04.001. [CrossRef]
29. Koontz NA, Wiggins RH 3rd. Differentiation of Benign and Malignant Head and Neck Lesions With Diffusion Tensor Imaging and DWI. AJR Am J Roentgenol 2017;208:1110-15. doi: 10.2214/AJR.16.16486. [CrossRef]
30. Bao D, Zhao Y, Wu W, Zhong H, Yuan M, Li L, Lin M, Zhao X, Luo D. Added value of histogram analysis of ADC in predicting radiation-induced temporal lobe injury of patients with nasopharyngeal carcinoma treated by intensity-modulated radiotherapy. Insights Imaging 2022;13:197. doi: 10.1186/s13244-022-01338-w. [CrossRef]
31. Li S, Cheng J, Zhang Y, Zhang Z. Differentiation of benign and malignant lesions of the tongue by using diffusion-weighted MRI at 3.0T. Dentomaxillofac Radiol 2015;44:20140325. doi: 10.1259/dmfr.20140325. [CrossRef]
32. Vidiri A, Minosse S, Piludu F, Curione D, Pichi B, Spriano G, Marzi S. Feasibility study of reduced field of view diffusion-weighted magnetic resonance imaging in head and neck tumors. Acta Radiol 2017;58:292-300. doi: 10.1177/0284185116652014. [CrossRef]
33. Baba A, Kurokawa R, Kurokawa M, Ota Y, Srinivasan A. Dynamic Contrast-Enhanced MRI Parameters and Normalized ADC Values Could Aid Differentiation of Skull Base Osteomyelitis from Nasopharyngeal Cancer. AJNR Am J Neuroradiol 2023;44:74-8. doi: 10.3174/ajnr.A7740. [CrossRef]
34. Baba A, Kurokawa R, Kurokawa M, Srinivasan A. Dynamic contrast-enhanced MRI parameters and apparent diffusion coefficient as treatment response markers of skull base osteomyelitis: a preliminary study. Pol J Radiol 2023;88:319-24. doi: 10.5114/pjr.2023.130383. [CrossRef]
35. Panyaping T, Tepkidakarn N, Kiatthanabumrung S, Wattanatranon D, Tritanon O. Usefulness of apparent diffusion coefficient values for distinguishing between squamous cell carcinoma and malignant salivary gland tumor of the head and neck. Neuroradiol J 2023;36:548-54. doi: 10.1177/19714009231163561. [CrossRef]
36. Vest JR, Kaushal R, Silver MD, Hentel K, Kern LM. Health information exchange and the frequency of repeat medical imaging. Am J Manag Care 2014;20:16-24
37. Nøhr C, Parv L, Kink P, Cummings E, Almond H, Nørgaard JR, Turner P. Nationwide citizen access to their health data: analysing and comparing experiences in Denmark, Estonia and Australia. BMC Health Serv Res 2017;17:534. doi: 10.1186/s12913-017-2482-y. [CrossRef]
38. Birinci Ş. A Digital Opportunity for Patients to Manage Their Health: Turkey National Personal Health Record System (The e-Nabız). Balkan Med J 2023;40:215-21. doi: 10.4274/balkanmedj.galenos.2023.2023-2-77. Epub 2023 Apr 28. Erratum in: Balkan Med J 2023;40:307. [CrossRef]
39. Kreutner J, Hopfgartner A, Weber D, Boldt J, Rottner K, Richter E, Jakob PM, Haddad D. High isotropic resolution magnetic resonance imaging of the mandibular canal at 1.5 T: a comparison of gradient and spin echo sequences. Dentomaxillofac Radiol 2017;46:20160268. doi: 10.1259/dmfr.20160268. [CrossRef]
40. Kozlov M, Kalloch B, Horner M, Bazin PL, Weiskopf N, Möller HE. Patient-Specific RF Safety Assessment in MRI: Progress in Creating Surface-Based Human Head and Shoulder Models. 2019;28. In: Makarov S, Horner M, Noetscher G, editors. Brain and Human Body Modeling: Computational Human Modeling at EMBC 2018 [Internet]. Cham (CH): Springer 2019. Chapter 13. [CrossRef]
41. Al-Haj Husain A, Sekerci E, Schönegg D, Bosshard FA, Stadlinger B, Winklhofer S, Piccirelli M, Valdec S. Dental MRI of Oral Soft-Tissue Tumors-Optimized Use of Black Bone MRI Sequences and a 15-Channel Mandibular Coil. J Imaging 2022;8:146. doi: 10.3390/jimaging8050146. [CrossRef]
42. Özen AC, Ilbey S, Jia F, Idiyatullin D, Garwood M, Nixdorf DR, Bock M. An improved intraoral transverse loop coil design for high-resolution dental MRI. Magn Reson Med 2023;90:1728-37. doi: 10.1002/mrm.29744. [CrossRef]
43. Tymofiyeva O, Rottner K, Jakob PM et al. Three-dimensional localization of impacted teeth using magnetic resonance imaging. Clin Oral Investig 2010;14:169-176. [CrossRef]
44. Gruber B, Froeling M, Leiner T, Klomp DWJ. RF coils: A practical guide for nonphysicists. J Magn Reson Imaging 2018;48:590–604. doi: 10.1002/jmri.26187. [CrossRef]
45. Grandoch A, Peterke N, Hokamp NG, Zöller JE, Lichenstein T, Neugebauer J. 1.5T MRI with a Dedicated Dental Signal-Amplification Coil as Noninvasive, Radiation-Free Alternative to CBCT in Presurgical Implant Planning Procedures. Int J Oral Maxillofac Implants 2021;36:1211-8. doi: 10.11607/jomi.8103. [CrossRef]
46. Di Nardo D, Gambarini G, Capuani S, Testarelli L. Nuclear Magnetic Resonance Imaging in Endodontics: A Review. J Endod 2018;44:536-42. doi: 10.1016/j.joen.2018.01.001. [CrossRef]
47. Demirturk Kocasarac H, Kursun-Cakmak ES, Ustaoglu G, Bayrak S, Orhan K, Noujeim M. Assessment of signal-to-noise ratio and contrast-to-noise ratio in 3 T magnetic resonance imaging in the presence of zirconium, titanium, and titanium-zirconium alloy implants. Oral Surg Oral Med Oral Pathol Oral Radiol 2020;129:80-6. doi: 10.1016/j.oooo.2019.08.020. Epub 2019 Sep 16. PMID: 31628073. [CrossRef]
48. American Collage of Radiology 2020. https://www.acr.org/Clinical-Resources/Radiology-Safety/MR-Safety
49. Bohner L, Hanisch M, Sesma N, Blanck-Lubarsch M, Kleinheinz J. Artifacts in magnetic resonance imaging caused by dental materials: a systematic review. Dentomaxillofac Radiol 2022;51:20210450. doi: 10.1259/dmfr.20210450. [CrossRef]
50. Juerchott A, Roser CJ, Saleem MA, Nittka M, Lux CJ, Heiland S, Bendszus M, Hilgenfeld T. Diagnostic compatibility of various fixed orthodontic retainers for head/neck MRI and dental MRI. Clin Oral Investig 2023;27:2375-84. doi: 10.1007/s00784-023-04861-2. [CrossRef]
51. Hilgenfeld T, Prager M, Heil A, Schwindling FS, Nittka M, Grodzki D, Rammelsberg P, Bendszus M, Heiland S. PETRA, MSVAT-SPACE

and SEMAC sequences for metal artefact reduction in dental MR imaging. Eur Radiol 2017;27:5104-12. doi: 10.1007/s00330-017-4901-1. [CrossRef]
52. Duttenhoefer F, Mertens ME, Vizkelety J, Gremse F, Stadelmann VA, Sauerbier S. Magnetic resonance imaging in zirconia-based dental implantology. Clin Oral Implants Res 2015;26:1195-202. doi: 10.1111/clr.12430. [CrossRef]
53. Bender IB, Seltzer S. Roentgenographic and direct observation of experimental lesions in bone: I. 1961. J Endod 2003;29:702-6; discussion 701. doi: 10.1097/00004770-200311000-00005. [CrossRef]
54. Bracher AK, Hofmann C, Bornstedt A, Boujraf S, Hell E, Ulrici J, Spahr A, Haller B, Rasche V. Feasibility of ultra-short echo time (UTE) magnetic resonance imaging for identification of carious lesions. Magn Reson Med 201;66:538-45. doi: 10.1002/mrm.22828. [CrossRef]
55. Bracher AK, Hofmann C, Bornstedt A, Boujraf S, Hell E, Ulrici J, Spahr A, Haller B, Rasche V. Feasibility of ultra-short echo time (UTE) magnetic resonance imaging for identification of carious lesions. Magn Reson Med 2011;66:538-45. doi: 10.1002/mrm.22828. [CrossRef]
56. Assaf AT, Zrnc TA, Remus CC, Khokale A, Habermann CR, Schulze D, Fiehler J, Heiland M, Sedlacik J, Friedrich RE. Early detection of pulp necrosis and dental vitality after traumatic dental injuries in children and adolescents by 3-Tesla magnetic resonance imaging. J Craniomaxillofac Surg 2015;43:1088-93. doi: 10.1016/j.jcms.2015.06.010. [CrossRef]
57. Kress B, Buhl Y, Hähnel S, Eggers G, Sartor K, Schmitter M. Age- and tooth-related pulp cavity signal intensity changes in healthy teeth: a comparative magnetic resonance imaging analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:134-7. doi: 10.1016/j.tripleo.2006.04.007. [CrossRef]
58. Macrae PR, Jones RD, Myall DJ, Melzer TR, Huckabee ML. Cross-sectional area of the anterior belly of the digastric muscle: comparison of MRI and ultrasound measures. Dysphagia 2013;28:375-80. doi: 10.1007/s00455-012-9443-8. Epub 2013 Jan 20. Erratum in: Dysphagia 2013;28:381. [CrossRef]
59. Otonari-Yamamoto M, Nakajima K, Tsuji Y, Otonari T, Curtin HD, Okano T, Sano T. Imaging of the mylohyoid muscle: separation of submandibular and sublingual spaces. AJR Am J Roentgenol 2010;194:431-8. doi: 10.2214/AJR.09.3516. [CrossRef]
60. Fujii H, Fujita A, Yang A, Kanazawa H, Buch K, Sakai O, Sugimoto H. Visualization of the Peripheral Branches of the Mandibular Division of the Trigeminal Nerve on 3D Double-Echo Steady-State with Water Excitation Sequence. AJNR Am J Neuroradiol 2015;36:1333-7. doi: 10.3174/ajnr.A4288. [CrossRef]
61. Mazza D, Di Girolamo M, Cecchetti F, Baggi L. Appearance of normal MRI anatomy of the lingual nerve using steady-state free precession sequences at 3-T. J Biol Regul Homeost Agents 2020;34:19-26. DENTAL SUPPLEMENT.
62. Al-Haj Husain A, Solomons M, Stadlinger B, Pejicic R, Winklhofer S, Piccirelli M, Valdec S. Visualization of the Inferior Alveolar Nerve and Lingual Nerve Using MRI in Oral and Maxillofacial Surgery: A Systematic Review. Diagnostics (Basel) 2021;11:1657. doi: 10.3390/diagnostics11091657. [CrossRef]
63. Borges A, Casselman J. Imaging the trigeminal nerve. Eur J Radiol 2010;74:323-40. doi: 10.1016/j.ejrad.2010.02.006. [CrossRef]
64. Miloro M, Kolokythas A. Inferior alveolar and lingual nerve imaging. Atlas Oral Maxillofac Surg Clin North Am 2011;19:35-46. doi: 10.1016/j.cxom.2010.11.003. [CrossRef]
65. Grandoch A, Oeser J, Zöller JE, Grosse Hokamp N, Lichtenstein T, Neugebauer J. Morphological Studies to Identify the Nasopalatine and Inferior Alveolar Nerve Using a Special Head and Neck MRI Coil. J Craniofac Surg 2023;34:1351-6. doi: 10.1097/SCS.0000000000009219. [CrossRef]
66. Müller S, Khadhraoui E, Khanafer A, Psychogios M, Rohde V, Tanrikulu L. Differentiation of arterial and venous neurovascular conflicts estimates the clinical outcome after microvascular decompression in trigeminal neuralgia. BMC Neurol 2020;20:279. doi: 10.1186/s12883-020-01860-8. [CrossRef]
67. Xiong X, Ye Z, Tang H, Wei Y, Nie L, Wei X, Liu Y, Song B. MRI of Temporomandibular Joint Disorders: Recent Advances and Future Directions. J Magn Reson Imaging 2021;54:1039-52. doi: 10.1002/jmri.27338. [CrossRef]
68. Jeon KJ, Choi YJ, Lee C, Kim HS, Han SS. Evaluation of masticatory muscles in temporomandibular joint disorder patients using quantitative MRI fat fraction analysis-Could it be a biomarker? PLoS One 2024;19:0296769. doi: 10.1371/journal.pone.0296769. [CrossRef]