MAGNETIC RESONANCE IMAGING IN DENTISTRY

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Abstract

Magnetic resonance imaging (MRI) is a noninvasive imaging modality that uses magnetic fields and radio frequency waves to produce three-dimensional images. In MRI, signals from protons are used to obtain anatomical images. MRI has disadvantages in the oral and maxillofacial region because it can be adversely affected by body movements, respiration, air in the oral cavity, nasal cells, implants and metal materials during image acquisition. The success of MRI in dentistry, especially in temporomandibular joint (TMJ) evaluations, visualization of salivary glands, lymph nodes, masses in the head and neck, thyroid and parathyroid gland, nasopharynx, soft tissue examinations such as tongue and muscle, has made its use widespread.

Keywords: Magnetic, resonance, imaging, dentistry

1.Introduction

Magnetic resonance imaging (MRI) is an imaging method that uses electric and magnetic fields and radiofrequency waves to create images instead of ionizing radiation. Especially in the examination of soft tissues, its use has become widespread due to the absence of ionizing radiation to the patient and its high contrast sensitivity (Brooks, 2003) (White, 2009) .

MRI consists of 3 parts: data acquisition section, computer system and imaging unit. The main part of the data acquisition section consists of magnets that create a very strong magnetic field. Inside this section, there are gradient coils that allow us to take cross-sections and RF coils that emit radiofrequency (RF) waves. The computer system is an advanced computer system that processes the data to create images (Brooks, 2003) (Moser, 2010).

The imaging unit is the monitor, which is also the control unit, where high-resolution images are selected and processed. To create a magnetic resonance (MR) image, the patient is first placed inside a large magnet. This magnetic field causes many atomic nuclei in the body, especially hydrogen, to align in the magnetic field. An RF pulse is sent from the scanner to the patient, causing some of the hydrogen nuclei to absorb the energy. When the RF pulse is stopped, the stored energy is released from the body and detected as a signal in the coil in the scanner. This signal is used to generate the MR image. In fact, the image is formed as a result of a distribution of hydrogen (Moser, 2010) (Müller, 2002).

The magnetic field in the MR imager is provided by a fixed external permanent magnet. An RF wave applied perpendicular to the magnetic field direction rotates the axis of rotation of the proton in the tissue towards the

XY (transverse) plane. The complete translation of protons to the XY plane at the end of a sufficiently long RF wave is called 'transverse magnetization'. After transverse magnetization, when the RF waves are stopped, the spins return to their original state is called 'relaxation'. The MR signal is generated by the signals obtained from transverse magnetization. The MR signal is attenuated by two independent processes. One of these is the T1 relaxation time, which is defined as the time it takes to regain 63% of the longitudinal magnetization. The T2 relaxation time is the time it takes for the transverse magnetization to decrease to 37% of its initial value (Brooks, 2003) (Moser, 2010) (Müller, 2002).

The degree of signal brightness generated by the tissues is called signal intensity. Black images corresponding to radiolucent images are called hyposignal or hypointense in MRI, while bright, light-colored images corresponding to radiopaque images are called hypersignal or hyperintense. The parts in the middle of these are called isointense. White and light tones indicate areas of increased signal. Dark black areas indicate little or no signal. Tissues appear in different signal intensities according to their characteristics (cyst, fat, blood, etc.) (White, 2009) (Moser, 2010).

Contrast agents (most commonly gadolinium) are administered intravenously to enhance tissue contrast. Gadolinium itself is not visualized, but it shortens the T1 relaxation time of the contrasted tissues, making them appear brighter. Therefore, it is only used in T1-weighted images. Contrast-enhanced tissues appear hyperintense on MRI. Allergic reactions to gadolinium are rare, especially mild compared to iodinated contrast agents (White, 2009) (Brooks, 2003).

Tesla (T) is used to express the magnetic field strength. 1 Tesla = 10,000 Gauss (Gauss: If the number of magnetic field lines passing through 1cm2 of magnetic field is 1, the strength of that magnetic field is 1 Gauss) . (White, 2009).

Devices with a magnetic field strength below 0.2 T are considered low Tesla devices, those with 0.2-1.5 T are considered medium Tesla devices and those above 1.5 T are considered high Tesla devices. 7 T and above devices are defined as ultra high field magnetic resonance imaging (UHFMRI) systems (Moser, 2010).

The need for higher resolution images has increased in clinical applications and MRI systems with high magnetic fields have become preferred. The areas of use of MRI and UYA-MRI systems are expanding in parallel with the technology and the quality of the images obtained is increasing. Side effects such as increased specific absorption rate (SAR) on the patient are being tried to be eliminated (Vargas, 2018) (Gallichan 2018).

In dentistry, MRI is especially used in the examination of pathological formations such as tumors and in the evaluation of the temporomandibular joint (TMJ). In addition, it is the most successful imaging method preferred in the evaluation of salivary gland diseases, lymph nodes, volumetric and pathological changes in muscles, adipose tissues, orofacial soft tissue lesions. In addition, it has recently been used in the evaluation of the mandibular canal course before implantation and impacted lower wisdom tooth surgery, especially in young patients (White, 2009).

2. MRI Sequences

Image sequences are obtained by varying the energy levels of the radio waves used and the duration of application. T1-weighted, T2-weighted, fluid-attenuated inversion correction (FLAIR), diffusion-weighted (DWI), susceptibility-weighted (SWI), 3D TOF (time of flight) angiography, proton magnetic resonance spectroscopy (1H MRS) and functional MRI (fMRI) sequences are commonly used in both MRI and NMRI (Vargas, 2018).

T1 weighted: It is used for anatomical evaluation because it provides very good soft tissue contrast . (Bittner, 1998)

T2 weighted: It is used to differentiate pathologic tissues due to the different signal characteristics of pathologies such as cysts and malignant neoplasms. (Bittner, 1998)

FLAIR: Allows comparison between T1- and T2-weighted images in conditions such as stroke, multiple sclerosis (MS) and infection . (De Coene, 1992)

Diffusion Weighted MRI (DWI): Shows the anatomical interaction of different parts of the brain by diffusion mapping of water molecules. It is used for treatment planning in cases of stroke and brain infection. It is considered partially successful because it can show the relationships between different parts of the brain, anomalies and lesions. However, in DWI, distortion is present due to the inhomogeneity of the magnetic field and image quality is not as high as in T1- and T2-weighted sequences (In, 2015).

Sensitivity Weighted MRI (SWI): An imaging technique that uses local magnetic field changes between tissues. It is used to show microhemorrhages, calcifications and iron deposits (De Coene, 1992).

3D TOF Angiography: It is a form of imaging routinely used in the clinic with 1.5T and 3T devices to visualize thrombi, atheroma plaques and vasculitis. It has been reported that UYAMRG may provide insight into perforations in the brain capillaries (De Coene, 1992).

1H MRS: Non-invasively provides information about the neurochemical state of the brain. It enables the analysis of metabolites in the brain such as glutamate, creatine and gamma aminobutyric acid (GABA) (De Coene, 1992) (In, 2015).

Functional MRI (fMRI): It allows visualization of hemodynamic changes occurring in the brain with cerebral activity. The most commonly used method is the blood-oxygenation level dependent (BOLD) method, which detects the blood supply level of active areas of the brain and converts the function into an image. This can allow motor cortex skills such as speech to be controlled during surgery (van der Zwaag, 2009).

3. Use of MR Imaging in Dentistry

The success of MRI in dentistry, especially in temporomandibular joint (TMJ) evaluations, visualization of salivary glands, lymph nodes, masses in the head and neck, thyroid and parathyroid gland, nasopharynx, soft tissue examinations such as tongue and muscle, has made its use widespread (Idiyatullin, 2007).

MRI is the best method used to visualize soft tissues such as the TMJ disc. The image of the joint is well defined on T1-weighted images. The articular eminence, zygomatic process and yellow bone marrow in the condyle have high signal intensity due to the short T1 time of fat. Soft tissues in the bilaminar zone and lateral pterygoid muscle have moderate signal intensity and the disc has low signal intensity. Cortical bone has low signal intensity, but bone anomalies such as osteophytes can be seen because they are surrounded by soft tissues with moderate signal intensity. MRI allows evaluation of the TMJ in the sagittal plane with the mouth open and closed. In some cases, images are obtained in the coronal plane for easier evaluation of the medial and lateral part of the disc. Sagittal images are used to determine the position of the disc relative to the condyle head (Dias, 2016).

T2-weighted images are useful for visualizing fluid and inflammatory changes in the joint. In most patients with TMJ disorders, the disc maintains its normal position. If the disc is in normal position but there is an increased retrodiscal area on T1-weighted images and very high signal intensity on T2-weighted images, inflammation should be considered. T2-weighted images are recommended for condyle fractures caused by acute trauma to the TMJ or in patients with intra-articular injuries (Arslan, 2009) (de Oliveira, 2013).

The diagnosis of trigeminal neuralgia is usually made clinically based on the patient's history. Atypical facial pain (AFP) is a non-localizable condition that causes intense, deep and persistent pain, usually affecting middle-aged women. MRI is the most effective imaging method for diagnosing such intracranial lesions. MRI is superior to CT and other methods in visualizing the intracranial portion of the trigeminal nerve associated with structural lesions. Studies recommend MRI to differentiate between intracranial and extracranial lesions in all patients with TN and AFP (Katzberg, 2005) (. Chiba, 2007).

Many diagnostic radiographs (panoramic films, periapical films) do not show the entire course of the mandibular canal. Computed tomography (CT) and cone beam computed tomography (CIBT) show the mandibular canal but are not effective in showing the mandibular nerve and its branches. On MRI, cortical bone is black on T1-weighted images, trabecular bone is bright, and soft tissues are seen as moderate signal. On T1- and T2-weighted images, the mandibular canal is isointense with the surrounding muscle with low signal intensity. In sagittal sections, the mandibular nerve is more clearly visualized in T2-weighted images than in T1-weighted images. In dental implant applications, MRI can be used to visualize the mandibular nerve and for dental implant planning. The disadvantage is that the bone cannot be visualized directly (Sano, 1995) (Krishnan , 2009).

Classical radiography, sialography, high-resolution ultrasonography, CT, MRI, radionuclide scintigraphy, and high-resolution ultrasonography are used to visualize salivary glands. MRI shows the internal structure of salivary gland masses, margins, and regional extension of the lesion into cavities or adjacent tissues better than

CT. Although MRI is the first choice for salivary gland imaging after ultrasound, it is not useful in the evaluation of salivary gland calculi. In addition, since ultrasound is not useful in visualizing deep lesions, MRI is particularly effective in diagnosing lesions larger than 3 cm and located deep in the parotid gland (Krishnan , 2009) (Goh, 2001) (Ikeda, 1996).

4.Advantages and Disadvantages of MR Imaging

The main advantages of this imaging modality are;

- No exposure to the harmful effects of radiation due to the absence of ionizing radiation

- High contrast resolution of the images

- Being a very effective imaging method in the diagnosis of soft tissue diseases

- The risk of allergic reaction to contrast agents used in this imaging method is lower than other imaging methods (Chau, 2012)

Main disadvantages;

- Long working hours and noisy

-Failure to stabilize patients during image acquisition

-Metallic objects, prostheses and biomedical devices in the body may be affected by the magnetic field and may harm the patient

-Artifacts may occur in the images due to metallic objects affecting the magnetic field (Probst, 2015)

5. Effect of Magnetic Resonance Imaging on Dental Materials

Magnetic susceptibility in MRI is divided into three categories: ferromagnetic materials, paramagnetic materials and diamagnetic materials:

- **Ferromagnetic materials:** These are the materials that are magnetized in the same direction as the magnetic field lines of that magnet when the magnet is in the environment. Steel, cobalt, iron, nickel are examples (Liu, 2014).

- **Paramagnetic Substances:** Substances that are slightly magnetized in a strong magnetic field and move in the same direction as the magnetic field. Magnesium, lithium, aluminum, molybdenum can be given as examples (Güneyli, 2014)

- **Diamagnetic Substances:** Substances that are slightly magnetized in a strong magnetic field and move against the direction of the magnetic field. (Liu, 2014)

Examples include gold, silver, zinc, wood, copper and bismuth. It is important to know the properties of materials containing metal, such as orthodontic appliances, wires, implants, metal-supported removable and fixed prostheses, which are widely used in dentistry, so that they do not injure the patient during MRI and do not affect the image negatively. Necessary precautions should be taken for these materials affected by the magnetic field (Liu, 2014)

The susceptibility of dental alloys to magnetic fields depends on their composition. These compositions include nickel, gold, silver, palladium and cobalt, as well as titanium and other elements. The presence of ferromagnetic materials in the environment during MRI can cause these materials to move. It has been reported that titanium is not ferromagnetic and interacts very little electromagnetically. Studies on dental amalgams have shown that microleakage and mercury release of dental amalgams increase after MRI. It has been reported that brackets, one of the materials used orthodontically, have a very low level of magnetic interaction and no movement, while the movements of stainless steel wires and Ni-Ti (Nickel-Titanium) may pose a risk to patients. In another study, it was reported that nickel-containing posts and crowns in the upper central teeth moved almost enough to dislodge the tooth during MRI. Studies of Ni-Cr (Nickel-Chromium), CoCr (Cobalt-Chromium) and $_{ZrO2}$ (Zirconium oxide) substructured restorations before and after MR imaging showed that there was no magnetic mobilization that would pose a risk. It is of great importance to take a detailed anamnesis about metal materials before MRI and to inform the patient about possible complications . (Meyer, 1991)

6.Conclusion

MR imaging is a widely used imaging technique in the head and neck region, especially in the imaging of soft tissues. With the increased use of MRI in dentistry, pathologies can be better understood and treated. While using this imaging technique, any movement that may be seen as a result of any metallic object in the patient's body being affected by the magnetic field can threaten the patient's life. All patients who will be asked to undergo MR imaging should have a detailed history of the metallic objects in their body, they should be evaluated in terms of magnetic interactions and heating of the relevant objects and the patient should be informed about the complications that may occur.

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