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MRI Compatibility of Dental Materials

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Abstract

Magnetic resonance imaging (MRI) is widely used for the diagnosis, staging and follow-up of diseases. Due to the evolving advancements and advantages, MRI is also routinely recommended in dental treatment. With the global increase in life expectancy of patients, the incidence of utilizing MRI in diagnosis of various diseases of head and neck region is also exponentially high.

The presence of dental materials in patients' body during MRI is a contentious issue which has no uniform standing. There is difference of opinion among radiologists, some proceed without removal and some insists removing of dental materials like prosthesis and appliances prior to MRI. The fixed dental material is difficult to remove, refabrication is time consuming, economically not feasible and affects esthetics, thereby psychosocial wellbeing of the patient.

This article aims to compile the information regarding the safety and appropriate management of patients with dental materials during MRI.

Keywords: Magnetic resonance imaging; Artefacts; Dental materials.

Introduction

Imaging is a fundamental procedure in diagnosis in medicine and dentistry. Magnetic resonance imaging (MRI), introduced in the 1970s, is considered a powerful diagnostic method for whole body imaging which enables the visualization of entire body without the use of ionizing radiation.[1] MRI creates images using a strong unvarying static magnetic field and changing magnetic field gradients with radiofrequency magnetic field pulses which causes magnetisation of materials depending upon their magnetic susceptibility.[2] Although, use of MRI is conjoint in the field of oral and maxillofacial surgery, recently, it is also recommended routinely in various branches of dentistry like endodontics[3], prosthodontics[4,5], orthodontics[6] and diagnosis of dental caries.[7]

Maxillofacial region MRI images can be compromised due to the presence of dental materials like orthodontic appliances, maxillofacial prostheses, dental implants, restorative and endodontic materials.[8] The other undesirable effects include radiofrequency heating and magnetically-induced shift of the dental materials.[9] However, the literature exhibits conflicting results regarding the severity of undesirable effects triggered by different dental materials.

With the increase in the life expectancy of geriatric patients, the probabilities of undergoing MRI for various diseases and lesions of head and neck region are higher. This has led to the question of whether the dental materials in the craniofacial region are acceptable or need to be removed during the imaging procedure of MRI. The prosthesis or restoration removed need to be refabricated/ replaced after imaging procedure which is economically

not feasible, time consuming and psychologically disturbing to the patient.

The goal of this article is to scrutinize the potential influence of standard dental materials on diagnostic importance of MRI so that dental professionals and radiologists have clear understanding of the nuances of dental materials and their effect on MRI imaging.

Magnetic Resonance Imaging

MRI involves application of magnetic field to the human body and sensing & imaging the signal produced by the imaging apparatus. The three stages of MRI include magnetization, resonance and relaxation. [10] The magnetic field causes the nuclei of many atoms in the body, particularly hydrogen, to align with the magnetic field. The scanner directs a radiofrequency (RF) pulse into the patient, causing some hydrogen nuclei to absorb energy (resonate). When the RF pulse is turned off, the stored energy is released from the body and detected as a signal in a coil in the scanner. This signal is used to construct the MR image.

Relationship between MRI and Metals

A substance becomes magnetized when placed in an external magnetic and the degree of magnetisation varies for different substances.

The substances can be categorised as ferromagnetic, diamagnetic and paramagnetic based on their magnetic susceptibility. Ferromagnetic substances are magnetized even in lack of external magnetic field[1] and thus have a high potential for causing MRI artefacts e.g. iron, cobalt and nickel.[10]

The substances magnetized in opposite direction to the magnetic field are Diamagnetic substances e.g. copper, gold, mercury, silver and bismuth.[11] Paramagnetic substances are faintly magnetized by an external magnetic field e.g. titanium and aluminium.[10] Diamagnetic and paramagnetic materials have less chances of MRI artefact formation.[12]

Unwanted Effects

Disadvantages of MR imaging include relatively long imaging times and the potential hazard imposed by the presence of ferromagnetic metals in the vicinity of the imaging magnet. The three basic categories of unwanted effects caused by dental materials during MRI are artefact formation, magnetically-induced displacement effects and physical effects.[13]

Artefact formation- The severity of the artefacts depends on multiple factors including magnetic field strength, pulse sequence, echo time, image resolution, imaging plane, gradient field strength, type of dental material and distance between the object of interest and the material.[14]

Among the factors mentioned above, eddy currents induced by alternating radiofrequency (RF) magnetic fields and difference in magnetic susceptibilities of various dental materials and body tissues are the two potential sources.[3]

Schenck [14] categorised the dental materials into three groups according to the magnetic susceptibility difference:

Compatible material: Create no detectable distortion in MRI image e.g. Resin-based root canal sealer, glass ionomer cement, gutta-percha, zirconium dioxide and some composites.

Compatible I material: Noticeable distortions created in MRI image and acceptance depends on the application e.g. some composites, amalgam, gold alloy, gold-ceramic crowns, titanium alloy, Ni-Ti orthodontic wires.

Non-compatible: Strong image distortions produced in MRI image e.g. Stainless steel orthodontic appliances (wires and brackets), Co-Cr alloys and porcelain fused to metal alloys.

Magnetically-induced displacement effects: The strong magnetic fields may harm patients if they pull heavy

objects near the scanner at a great velocity (projectile effect). The ferromagnetic dental materials are strongly affected by translational attraction causing a potential hazard to the patient.[15] As per ASTM (American Society for Testing and Materials) International 2052-02, [18] deflection angle of the material less than 45^0 specifies that the deflection force induced by the magnetic field during MRI is less than force of gravity and thus the substance or material does not pose any risk.

Physical effects (radiofrequency heating): The metallic objects in the human body undergo radiofrequency-induced heating due to strong magnetic fields. The heat pain threshold of oral mucosa is $8 – 10^0$ C temperature rise and rise above 10^0 C for more than one minute constitutes the safety threshold for periodontal tissues. [15]

Behaviour of Dental Materials

Orthodontic materials

Artefacts: Fixed orthodontic treatment commonly involves the use of Ni-Ti and stainless steel arch wires with stainless steel brackets. According to Costa et al 78% of artefacts are caused by orthodontic metallic appliance during orofacial MRI scans.[16] The ferromagnetic metals nickel and chromium present in austenitic stainless steel cause large artefacts which makes MRI image analysis impossible. Therefore, it is recommended to remove metallic orthodontic appliances before performing head and neck MRI scans to reduce image artefacts.

Radiofrequency heating: Gorgulu et al recorded the maximum temperature of 3.04 °C for Ni-Ti-css (Ni-Ti arch wire and continuous stainless steel ligature wire) and 2.0°C for Ni-Ti-e (Ni-Ti arch wire and elastic ligature) using 3T MRI. Such rise in temperature is known to cause no deleterious effect on the pulpal, periodontal or mucosal health of the oral cavity.

Magnetic field interactions: Average deflection angle of 13° for brackets, 62° for NiTi wire and 71° for stainless steel wire were recorded by Gorgulu et al. which indicates removal of orthodontic wires before imaging. Orthodontic brackets do not pose any danger to the patient.[17]

Maxillofacial prostheses

Commercially available magnetic dental attachments consist of a magnetic assembly and a keeper made of stainless steel. Study by Hasegawa et al using 3 T MRI revealed a maximum temperature increase of 1.21°C for the keepers and 1.30- 1.42 °C for copings which were well within the limit of not producing any deleterious effect on oral tissues.

The deflection angles recorded for attachments during MRI were greater than 90°. However, the retention force of dental luting cement is 48–150N, which is adequately strong to avert dislodgement of the attachments.

It is also advisable to check the fixation of attachments to a dental prosthesis or abutment teeth before and after MRI to rule out the possibility of dislodgement due to cement degradation.

Dental crowns

Ceramics: Low magnetic susceptibility, compatible with minimal or no MRI artefacts.[1]

Zirconium dioxide: Compatible with minimal or no MRI artefacts.[2]

Metal and Metal ceramic: Non-compatible due to the presence of ferromagnetic materials and cause loss of signal around the material. They should be removed if dental MRI measurements are required.[20]

Gold and Gold–ceramic crown: Include traces of ferromagnetic metals and are categorised as compatible I.[8] They should not be present in the tooth of interest or its neighbours or antagonists if a true representation of the tooth surface is required.[20]

Restorations

Dental amalgam- Compatible due to the presence of non-ferromagnetic metal silver.[16]

Composite: Compatible or Compatible I because of the addition of iron oxide pigments by some manufacturers. It is advisable to use compatible composite materials in the tooth of interest or its neighbours or antagonists for high-resolution dental MRI applications, such as diagnosis of caries or MRI-based dental impressions as the smallest distortion is critical and can result in wrong measurements.[20]

Glass Ionomer Cement- Compatible with no influence on dental MRI.[20]

Dental implants: Titanium alloy used in dental implants contains ferromagnetic materials which cause drop out of signal near the metallic surface and is therefore categorised as Compatible I [20]. Various studies conducted have concluded that implants resolutely fixed to the bone are not affected by MRI-induced displacement[22] and the radiofrequency induced temperature change is insignificant[10] reducing the potential hazards to the patients.

Osseous fixation plates: Titanium plates and screws are frequently used in trauma and reconstructive surgeries of fractured maxillofacial skeleton to achieve osteosynthesis. All Titanium plates induce significant MRI artefacts which depend on the implant or plate size, configuration, magnetic field strength, MRI protocol and sequence parameters. Reducing the magnetic field strength to 1.5 T instead of 3 T MRI reduces metal artefacts. Also the reduction of plate thickness and height may help to improve image quality and diagnostic value. Alternatively materials like polylactic acids, magnesium (Mg) and glass fibre reinforced composites (GFRCs) may be used instead of titanium which have less susceptibility to produce MRI artefacts.[21]

Conclusion

The knowledge about the composition, magnetic properties, amount and scattering of artefacts induced by various dental materials is very important for the dental practitioners. They need to expect problems and take necessary deemed precautions prior to MRI scan in patients. This required knowledge of the MRI and the behaviour of the dental materials during MRI scan help the Radiologist and Dental Surgeon to treat patients comprehensively.

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