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DENTIST'S DILEMMA ON MR SAFETY OF DENTAL MATERIALS

Dentistry

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ABSTRACT

Magnetic Resonance imaging (MRI) is non-invasive and non-ionizing imaging modality providing highly sensitive and specific soft tissue contrast. It can be used to assess intracranial and extra cranial lesions particularly those involving the soft tissues. MRI has the shortcoming of being prone to magnetic susceptibility difference artefacts, caused by the presence of metallic materials such as dental restorative materials, implants and orthodontic appliances. All substances when placed in a magnetic field are magnetized to a degree which varies according to their magnetic susceptibility. 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. However, the literature exhibits conflicting results regarding the severity of undesirable effects triggered by different dental materials. For the obvious advantages that MRI offers the probabilities of patient 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. This review will brief you regarding the MR imaging and its effects on various dental materials, dental materials compatibility and recommendations to dentist to inculcate practice of using MR Safety documentation.

KEYWORDS

Magnetic resonance imaging (MRI), dental materials, MR safety, artifacts in MR Image.

INTRODUCTION:

Advanced imaging modalities have definitely increased the horizons of health care practices, Magnetic Resonance Imaging (MRI) is one such imaging modality which is a non-invasive imaging technique widely used for evaluating various medical and dental conditions without involving ionizing radiation. In dentistry, MRI finds major applications in examining soft tissue lesions, salivary gland pathologies, and internal derangements of the temporomandibular joint(TMJ), benefiting from its exceptional soft tissue contrast resolution.[1] Researchers have noted MRI's superiority in detecting tumor staging, odontogenic cysts, and perineural spread compared to computed tomography (CT).[2] Despite its benefits, MRI is contraindicated in with ferromagnetic medical devices or dental materials in their bodies, as these can interact detrimentally with the MRI's magnetic field. Such interactions may result in undesirable effects like artifact production, radiofrequency (RF)-induced heating, and magnetically induced displacement of objects. Among dental materials, metallic dental devices like orthodontic brackets, metal crowns, and dental implants have been found to cause artifacts in oral and maxillofacial MRI, potentially complicating diagnostic interpretations.[3]

Magnetic Force And Types Of MRI:[1]

It is measured in tesla (T). MRI uses 1.0-1.5 T, more powerful MR scanner uses 3.0 T. Compared to earth's magnetic force (50 μT); it is 10,000 times more powerful.

Based On The Magnetic Field Strength: Low-field MRI scanners (0.23 T-0.3 T): They are typically identified as open MRI scanners, have decreased image quality and require a longer scan time compared to high-field MRI scanners.

High-field MRI Scanners (1.5 T to 3.0 T): These are typically identified as closed MRI scanners. A 1.5 T MRI scanner provides great image quality, fast scan times, and the ability to evaluate how certain structures in the body function. The 3.0 T MRI scanner is great for visualizing very fine detail, such the vessels of the brain or heart.

Ultra-high Field MRI Scanners (7.0 T to 10 T): It is not widely available and is typically used for research.

Implications Of Dental Materials On MRI

Dental materials have important implications on the use of MRI as a diagnostic imaging Modality which can be categorized into

a) Radio Frequency-driven Heating:

Dental treatments use metals for manufacturing crowns, orthodontic wires, implants, restorations etc., which are affected by radiofrequency driven heating, further resulting in its displacement or damage to its mechanics or damage to underling mucosa. The first potential method of displacement of the crown is that radiofrequency energy is absorbed, resulting in heating, compromising the adhesion of the crown to the tooth structure. Increases of less than 1^0C, remain well below natural variations induced while eating and drinking, and similar results have been confirmed for other intraoral and intracranial medical devices made of steel. There is estimated risk of injury from radiofrequency heating of metallic dental devices during 3.0T MRI. Relatively minor RF heating ($< 2^0$ C) of the dental castings in the normal mode should not pose a risk to patients, however orthodontic appliances may exhibit RF heating above the industrial standard; therefore, the wire should be removed from the bracket or a spacer should be given between the appliance and the oral mucosa during MRI.[4]

b) Magnetically Induced Displacement Forces

Other issue is with the crowns or the fixed prosthodontic crowns, causes of fixed prosthodontic retention loss include adhesive or cohesive failure of cement, excessive crown taper, short clinical crown length or recurrent caries. These factors may contribute but would be significantly coincidental given the timing of retention failure with the diagnostic scan. The strength of the magnetic field can have a "projectile effect" by pulling ferromagnetic materials. Due to this strong magnetic field stringent safety mechanisms are practiced.[5] Metal objects are removed by the patient prior and any medical implantable devices must to be checked for their compatibility with magnetic resonance. There is a relevant risk in the presence of inadequate bonding to the teeth. Thus, it is mandatory to check bond strength prior to a MRI examination. However, the 60N that is required to loosen a sufficiently strong bond is not even achieved by 3 Tesla.[6] The translational attraction and torque from magnetic field interactions may cause the movement or dislodgement of a ferromagnetic restorations, implant, fixed prosthodontic dentures resulting in possible injury to the patient. The translational attraction is dependent on the strength of the static magnetic field, the spatial gradient

magnetic field and the object's mass, shape and magnetic susceptibility. [4]Though the retentive force of the dental luting cement is reportedly 48-150N, which is sufficiently strong, the fixation of ferromagnetic devices to the dental prosthesis or abutment teeth should be checked before and after the MRI because of the possibility of cement degradation. The ferromagnetic components of the patient's crown may have created enough displacing forces to overcome the already compromised retentive force of the luting cement on the crown. It is recommended that ferromagnetic containing dental prosthesis are checked for retention prior to and after the MRI scan.[7]

c) Image Artefact

An 'artefact' may be defined as a distortion of signal intensity or void that does not have any anatomic basis in the plane being imaged. The size and shape of the artefact depends on the magnetic properties of the metal object examined, on its size and shape, space orientation and the homogeneity of the alloy.[8] Dental restorations usually contain precious metals such as gold (Au), silver (Ag), platinum (Pt) and non-precious alloys like chromium (Cr), cobalt (Co), molybdenum (Mo), nickel (Ni) and other metals like titanium (Ti) and titanium alloys. Many of these materials can influence the MR image quality and may cause artefacts to various degrees. [9]This clearly impedes identification of anatomical areas and the detection of pathology, ultimately hindering accurate medical diagnosis. Magnetic susceptibility artefacts in MRI typically involve image degradation of signal distortion occurring in tissues adjacent to the interfering compounds. These compounds become magnetized when placed in a large superconducting magnet, creating their own magnetic fields, and largely alter the precession frequencies of protons in adjacent tissues. The shape of the metal may alter the size and configuration of the metallic artefact on MR images, even if the volume and weight are the same.[5]

Common Materials Used In Dentistry:

Dental materials classified based on magnetic susceptibility as Ferromagnetic: These are those types of materials which are strongly attracted to a magnet. Their permeability is very high in the range of hundreds and thousands. Examples include chromium oxide,cobalt, ferrite (iron), cadolinium, nickel, rare earth magnet, magnetite, yttrium, etc. Paramagnetic: These are those materials which are not very strongly attracted to the magnet. They are slightly magnetized when placed in a strong magnetic field and act in the direction of the magnetic field. Their relative permeability is slightly more than one. Examples of such materials are magnesium, tin, platinum, lithium, tantalum, aluminum, molybdenum, etc. and Diamagnetic: These are those materials which are repelled by a magnet. They are slightly magnetized when placed in a strong magnetic field and act in the direction opposite to that of the magnetic field. Their permeability is slightly less than one. Examples are wood, zinc, copper, bismuth, silver, gold, etc., are diamagnetic materials. [10]

Compatibility Of Dental Materials:

Schenck Categorized The Dental Materials Into Three Groups According To The Magnetic Susceptibility Difference:[11]

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.

Recommendations For Dentist:

With the increasing use of MRI technology, dentists should be aware that dental materials affect MR images and MR technology affects dental materials. The two internationally recognized definitions for classifying MRI interactions with medical devices: "MRI safe" meant that the device does not trigger any significant effects on surrounding tissue when exposed to magnetic forces. This definition thus focused on patient safety, and the synonym "first-order MRI compatibility" was introduced by Schenck.[11] "MRI compatible" (or "second-order MRI compatibility") meant that a device, in addition to being MRI safe, would not generate any clinically relevant imaging artifacts.[5] However, these definitions were modified by the American Society for Testing and Materials (ASTM) in 2005. Since then, the term "MRI compatibility" has been formally abandoned. The new system defines three classes of risk: "MRI safe" means that a device poses no risk whatsoever to patients, medical staff, or any other individuals present within the controlled area while an MRI scan is being prepared or executed Conversely, "MRI unsafe" devices are expected to carry such a risk. A third class called "MR conditional" indicates that a device requires specific conditions to be safe, which are subject to mandatory labelling.[5]

For dental materials, there are currently no similar statements. Most manufacturers, when asked, recommend indiscriminately that appliances be removed prior to MR, although differentiation would be useful to eliminate the expense and discomfort of removing and reinserting fixed appliances.[12]

Guidelines To Prevent These Interactions

- Knowledge about the interaction of dental materials and MRI is essential for dentists and radiologists. MRI centers can be notified whether the restoration/appliance is MR friendly or not.
- Materials for prosthetic restoration should be selected based not only on their biological compatibility and functional and esthetic qualities, but also on whether they generate artifacts in MRI and MR safety. Prefer nonmetals like all ceramic restorations over metal ceramic. Even in metal ceramic it is better to choose a noble metal alloy.[13,14]
- Removable appliances/prosthesis are not a problem, since patient can remove it.[13]
- **Dental Amalgam-** Compatible due to the presence of non-ferromagnetic metal silver. [15]
- **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.[16]
- **Glass Ionomer Cement-** Compatible with no influence on dental MRI.[16]
- **Dental Implants:** The interaction with MRI may result in heating & mechanical movement which are negligible but artefacts will be produced. patient with dental implant can undergo MR imaging safely.[13]
- **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.[13]
- Fixed orthodontic treatment commonly involves the use of Ni-Ti and stainless steel arch wires with stainless steel brackets. The ferromagnetic metals nickel and chromium present in austenitic stainless steel cause large artefacts which makes MRI image analysis impossible. Magnetic field interaction results in 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]
- Treat all material as MR unsafe, if the dentist is not sure about the type of prosthesis/appliance. It is advisable to remove the prosthesis/appliances prior to MRI.

CONCLUSION:

Dental practice is having a paradigm shift, opening up new horizons which include treatments with materials which can influence the MR imaging. Knowledge of these materials and MR safety can reduce the unnecessary work up and difficulties the patient can face. Also avoid the life threatening incidences which can be just done by removal of these material sources from oral cavity. A small step towards adopting a change in the practice of incorporating use of mention or certification regarding the MR safety of materials can solve this dilemma efficiently.

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