



## MRI and Its Implications in Dentistry

Lt Col (Dr.) Deepak Kalia<sup>1</sup>, Dr. Ulrika Diana Pereira Kalia<sup>2</sup>,  
Dr. Prerna Raje Batham<sup>3</sup>

<sup>1</sup> MDS (Prosthodontics), Reader, Dept of Prosthodontics, Army Dental Centre, R&R, New Delhi, India.

<sup>2</sup> MDS (Orthodontics), Ex Professor, Private practitioner, New Delhi, India.

<sup>3</sup> MDS(Orthodontics), Professor, Dept of Orthodontics & Dentofacial Orthopedics, Govt College of Dentistry, Indore, M.P., India.

**Conflicts of Interest:** Nil

**Corresponding author:** Lt Col (Dr.) Deepak Kalia

**DOI:** <https://doi.org/10.32553/ijmsdr.v6i4.933>

### **Abstract:**

Magnetic Resonance imaging (MRI) has become one of the most powerful diagnostic tools in radiology and diagnostic sciences. It is non-invasive and non-ionizing and the images are highly sensitive and specific with excellent soft tissue contrast. It gives excellent images of anatomic structures differing in proton density and other tissue characteristics. It can be used to assess intracranial and extracranial 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. Non precious dental alloys have the potential of causing image deformation or image voids.

Dentists are not the only professionals implanting metal devices. Heart pacemakers and defibrillators, aneurysm clips, cochlear implants, insulin pumps, vascular stents and artificial joints are widely used in various branches of medicine. In some cases, it is not possible to carry out MRI due to extensive dental hardware with a high ferromagnetic content. Severe image distortion or an inability to perform the MRI scan due to dental restorations is a rare problem, but cannot be completely eliminated. This article has been written to educate the dentists on the implications of metallic dental restorations on MRI scans.

**Keywords:** Magnetic resonance imaging, MRI, Dentistry, Dental materials, artefact, artifacts.

### **Introduction:**

Magnetic resonance imaging (MRI) is an imaging modality that uses a magnetic field and computer-generated radio waves to create detailed images of the organs and tissues in the body. It has increasingly been used since the

last 50 years being a non-invasive modality that does not involve the use of ionizing radiation & its superior soft tissue resolution. It is comprehensively being used in all organ systems for medical diagnosis like staging of

cancer and various diseases. MRI also has application in various branches of dentistry and can be utilized in the diagnosis of dental caries, jaw lesions, diseases of the Temporomandibular Joints (TMJ), endodontics, prosthodontics, orthodontics and diagnosis and treatment planning of implants to achieve better prognosis [1]. The increasing number of indications for MR examination of the head and neck region is accompanied by a rising number of patients with metallic compounds present in the oral and maxillofacial regions such as dental cast restorations, dental or orthopaedic implants, dental crowns, bridges, fillings and dentures [2-5].

Many a times patients with dental restorations require MRI of the head and neck to determine the progress of disease or to find out the cause of any symptoms unrelated to the dental restorations. The patient might also be referred for dental clearance or with a request from our medical colleagues for removal of a dental restoration/ prosthesis before undergoing MRI. Every dental professional should be aware of the interactions of MRI with the various dental materials and the distortion of the images or the dislodgement of the prosthesis, which thereby can cause injury to the adjacent tissues [6]. Magnetic susceptibility information is not readily available for many materials used in dentistry, especially those containing several components [1]. An understanding of the basic physics involved in MRI is essential to appreciate the relevance of dental materials in an MRI scanner [4].

### **Mechanism of Action of MRI**

MRI technology relies on a strong uniform magnetic field that results in a uniform alignment of protons within its field. A magnetic vector along the axis of the MRI scanner is consequently generated and radiofrequency waves are then directed towards these protons. The returning waveforms are detected by radiofrequency

receptors and converted into images reflecting the different tissue compositions [3].

### **Implications of dental materials on MRI**

Dental materials have important implications on the use of MRI as a diagnostic imaging modality. These implications can be divided into [3,4,7]:

- a) Radiofrequency-driven heating
- b) Magnetically induced displacement forces
- c) Image artefact

### **Radiofrequency-driven heating**

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 [4]. The temperatures that intraoral wires and brackets reach are not relevant. Increases of less than 1<sup>o</sup>C, 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 [7]. Hasegawa in his studies estimated the risk of injury from radiofrequency heating of metallic dental devices during 3.0T MRI and concluded that the relatively minor RF heating (< 2<sup>o</sup> 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 [8,9]. The heat-pain threshold of oral mucosa has already been studied. A temperature rise of approximately 8-10<sup>o</sup>C causes pain in the oral mucosa. An elevation of 10<sup>o</sup>C above the body temperature for 1 min constitutes the safety threshold for periodontal tissues, which is less susceptible to thermal injury than bone because of its greater vascularity [10]. Kenta et al in their study confirmed that metallic implant materials, such as implant bodies/ abutments, showed no

apparent translational attraction or heating in 7T, suggesting that those materials should be safe in MRI examinations. In contrast, dental magnetic attachment keepers were strongly attracted by the magnetic field, and must be prohibited from MRI examinations [11].

### **Magnetically induced displacement forces**

The temporal relationship between the crown dislodging and commencement of the MRI mechanism is indicative as the probable cause of the dislodgement. Other 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. Metal objects are removed by the patient prior and any medical implantable devices must to be checked for their compatibility with magnetic resonance [4]. 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 [7]. The translational attraction and torque from magnetic field interactions may cause the movement or dislodgement of a ferromagnetic implant, 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. While their magnetically induced torques were small enough, their magnetically induced deflection forces tended

to exceed the acceptable limit. 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 [8,9]. It is recommended that ferromagnetic containing dental prosthesis are checked for retention prior to and after the MRI scan [12].

### **Image artefact**

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 [13]. Many of these materials can influence the MR image quality and may cause artefacts to various degrees. This clearly impedes identification of anatomical areas and the detection of pathology, ultimately hindering accurate medical diagnosis. There are three major alloy types as enumerated in Table I. 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].

**Table I: Alloy Types [5,14,15]**

|   |   |  |
|---|---|--|
| <b>Ferromagnetic Materials</b>  | Strongly attracted by magnetic fields. Strongly amplify the magnetic field. Have a high potential for MRI artefacts   | Iron (Fe)<br>Cobalt (Co)<br>Nickel (Ni)  |
| <b>Paramagnetic Materials</b><br>(Having unpaired orbital electrons)        | Become magnetized in the magnetic field and demagnetized once the field is switched off. Slightly amplify the magnetic field.   | Chromium (Cr)<br>Manganese (Mn)<br>Aluminium (Al)                                |
| <b>Diamagnetic Materials</b><br>(Have few or no unpaired orbital electrons) | Induce weak magnetic fields in the direction opposite the magnetic field. Slightly weaken the magnetic field. Have a small negative magnetic susceptibility and are basically non-magnetic. | Copper (Cu)<br>Gold (Au)<br>Zinc (Zn)<br>Lead (Pb)<br>Carbon (C)<br>Bismuth (Bi) |

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 [14,15]. There are two main types of artifacts, known as susceptibility and non-susceptibility artifacts. Susceptibility artifacts occur due to signal loss caused by the discrepancy between magnetic susceptibility of neighbouring structures. Conversely, a non-susceptibility artefact is related to eddy currents, which are induced by the alternation of gradients and radiofrequency magnetic fields [16]. The strength of artefacts depends on many factors including magnetic field strength, pulse sequence, echo time, image resolution and the related gradient field strength, imaging plane, amount and shape of the dental material and distance between the object of interest and the material [17]. Tymofiyeva et al summarised the potential sources of artifacts in MRI. The first source is the eddy currents induced by alternating gradients and radiofrequency (RF) magnetic fields. The induced eddy currents distort the applied RF field  $B_1$  and this modifies the flip angle, leading to image distortion. The second source is distortion of the static magnetic field  $B_0$  due to the difference in

magnetic susceptibilities of materials and body tissues. In most cases,  $B_0$  effects are predominant. Body tissues are weakly diamagnetic and have a magnetic susceptibility,  $X$ , close to that of water,  $X_{\text{water}} = -9.05 \times 10^{-6}$ . Susceptibility differences between imaged substances affect the homogeneity of the magnetic field in the imaged volume and cause image distortions in MRI experiments. Susceptibility artifacts appear in gradient echo (GE) based images as loss of signal around the material due to dephasing within a pixel or a slice, and in spin echo (SE) based images as complex spear shaped artifacts resulting from slice selection and position-encoding distortions. In general, use of SE based instead of GE based, pulse sequences reduce susceptibility artefacts. The newer techniques for direct imaging of hard tissues are relatively insensitive to magnetic susceptibility artifacts owing to the short delay between excitation and acquisition. Additionally, specially designed sequences such as multiacquisition with variable resonance image combination and slice encoding metal artefact correction significantly reduce the size and intensity of susceptibility artifacts [1]. Depending on the MRI sequence and alloy used, artifacts of varying sizes can occur and significantly interfere with diagnostic information regarding

nearby anatomical structures that would normally be attainable [7].

Masumi et al in their study on a 0.1T MRI concluded that Au, Ag, Au-Ag-Pd and amalgam produced no defect; Ni-Cr, Co-Cr and SUS304 (stainless steel) expressed small MR defects but SUS405 (magnetic alloy), Pd-Co-Ni and Samarium- Cobalt (Sm-Co) expressed large defects. Au, Ag and Au-Ag-Pd are frequently used for fixed prostheses, amalgam is used in the restoration of cavities, Ni-Cr and Co-Cr are used in the construction of metal frames for both removable and fixed prostheses, stainless steels like SUS304 are used for making orthodontic brackets and wires while magnetic alloys like SUS405, Pd-Co-Ni and Sm-Co are used as magnetic attachments [18]. Blankenstein et al in their study found no significant artifacts at 1.5T around the titanium and Co-Cr specimens as well as one of the steel grades [7]. Shorter ECHO times greatly reduce artefacts. Additionally, slice thickness, as well as increasing the read-out bandwidth significantly improved image quality [19]. Murkami et al in their study concluded that for all scanning sequences, artefact volumes containing Au, Al, Ag and Au-Pd-Ag were significantly smaller than Ti < Ni-Cr alloy < Co-Cr alloy. If there is no reason to use any of the other sequences, Fast Spin Echo (FSE) sequences seem to be the proper choice, as this gives the least amount of artifacts. However, if other sequences such as Echo Planar Imaging (EPI) or Fast Imaging Employing Steady State Sequence (FIESTA) are necessary and materials such as Co-Cr alloy, Ni-Cr Alloy and Ti are encountered, it may be necessary to extract these materials before scanning [5]. Fakhar et al in their study concluded that Zr implants and abutments produce the least amount of artifacts as compared to Ti in MRI 3T [20]. Stainless steel and other metals used in prosthetic dentures and orthodontic braces have been found to create substantial artifacts that tend to obliterate image details in the facial area [14].

Hilgenfeld et al in their study proposed that implant supported prostheses may severely impair image quality due to artifacts. They reported that the fewest MR artifacts were observed with zirconia implant with monolithic zirconia crown. A titanium implant combined with a non-precious alloy crown was unfavourable in terms of artefact volume. Smaller and comparable artefact volumes were noted for titanium implants with porcelain fused to metal precious alloy, porcelain fused to zirconia and monolithic zirconia [21]. Bohner et al also concluded that artifacts for titanium were larger than those for zirconia dental implants. However, the distribution of artifacts was not influenced by the dental implant geometry. Artifacts were smaller for the TIW sequence in comparison to T2W sequence. Turbo spin echo was able to provide a better image quality in comparison to gradient echo. 1.5T MRI gave much smaller artifacts than 3.0 T MRI. [16]. Shafiei et al had stated that although some studies had reported no significant artifacts with titanium in spin-echo; their study confirmed the appearance of moderate magnitude artifacts from commercially pure titanium and titanium alloys in the TI FSE sequence which is least sensitive to metal artefacts. They also confirmed high magnitude artifacts in T2 FSE and GE sequences, which are highly sensitive to metal artifacts. They reasoned that the contradictory results in the literature might be due to differences in the parameters used in MRI, such as magnetic field intensity and specific sequences, trace amounts of ferromagnetic substances from the samples and geometric factors in imaging [15].

There are four classes of dental materials: metals, ceramics, polymers and composites [22]. Based on the classification proposed in the comprehensive review article on the role of magnetic susceptibility in MRI by Scneck, the materials were divided into three groups according to the susceptibility difference,  $\Delta\chi = \chi_{\text{Material}} - \chi_{\text{Water}}$ .

**Table II: Classification of Dental materials based on magnetic susceptibility of the materials by Schenck [1,4,17]**

| Classification       | Clinical Significance   | $\Delta\chi I$ | Materials   |
|----------------------|---|----------------|---|
| <b>Compatible</b>    | No image artefact or distortion on either SE or GE imaging  | <3 ppm         | Glass ionomers<br>Resin<br>Gutta Percha<br>Zirconium dioxide<br>some composites |
| <b>Compatible I</b>  | Limited image artefact or distortion localised to imaging site. Material produces noticeable distortions; acceptance depends on application | 3 < 200ppm     | Amalgam<br>Gold alloy<br>Gold<br>Ceramic crowns Titanium<br>some composites     |
| <b>Noncompatible</b> | Significant image distortions, even when imaging site distant from material   | >200 ppm       | Stainless steel<br>Cobalt-chrome  |

**Material precautions while using dental MRI (dMRI)**

Table II specifies that materials that belong to the group Compatible and can be present in the tooth of interest, even if a very precise reconstruction of the tooth surface is required. *e.g.* a digital dental impression for production of dental restorations using CAD/ CAM technology. Materials from the group Compatible I should be used with care if dMRI is considered. Such materials should not be present in the tooth of interest or its neighbours or antagonists if a true representation of the tooth surface is required. In case of dMRI applications with lower requirements for the precision of the reconstructed tooth surface, such as orthodontic treatment planning, presence of materials from the group Compatible I is not critical. The third group, Noncompatible, contains materials posing the highest difficulty for dMRI. Highly paramagnetic materials, such as stainless steel or Co-Cr cause loss of signal around the material owing to dephasing within a pixel or a slice in GE based images and complex spear

shaped artefacts in SE based images, for which slice selection and position-encoding distortions are responsible. Materials belonging to this group should not be present in the mouth if a dMRI measurement is considered [1].

Composites of some manufacturers had an almost perfect susceptibility match to water and were therefore compatible for dMRI, whereas others showed marked paramagnetic properties and caused significant distortions. The paramagnetic properties can possibly be explained by iron oxide pigments often used by manufacturers. The smallest contamination by ferromagnetic substances can drastically alter the susceptibility of a magnetically compatible material [17].

In case of fixed metallic orthodontic appliances such as stainless-steel retainers; though the retainers pose no risk to the patient when well fixed, the imaging quality suffers significantly. A better choice from the standpoint of dMRI is nickel-titanium alloys [17]. The local distortions caused by a nickel-titanium alloy

would not affect the diagnostic value of MR images acquired for orthodontic purposes [1].

### Discussion

MRI is a non-invasive method to detect the internal structures, differentiate between soft tissues and hard tissues and certain aspects of functions within the body. The principle behind the MRI is the use of non-ionizing radio frequency electromagnetic radiation in the presence of controlled magnetic fields to obtain high quality cross-sectional images of the body [14,23]. Initially its implementation was only up to the neuro-axis, but in recent times it extends to all parts of the body including the oral cavity, either solely or in combination with other techniques, to achieve highest diagnostic accuracy [23]. MRI has a vital role in formulating diagnosis of soft tissue elements, vascular components, intracranial involvement, tumors or complicated inflammatory conditions; abnormalities involving the skull base can be specifically detected. MRI is clinically indicated in retrocochlear sensorineural hearing loss, facial nerve paralysis and vertigo [24].

MRI techniques are currently being used in dentistry for the diagnosis of temporomandibular joint diseases which may lead to a degeneration of the discs, inflammatory conditions of the facial skeleton and in examination of the salivary glands, maxillary sinuses, masseter muscles, in the detection of early bone changes such as tumors, fractures, inflammatory conditions and hematomas. The growth of the facial skeleton can also be monitored by MRI with the help of control points. MRI has found application in implant dentistry by providing more precise information regarding the bone height, density, topography and contour. MRI technology can produce tooth surface digitization with an accuracy and precision sufficient for production of dental restorations and to detect root resorption in orthodontic cases. New approaches to the application of MRI in

various branches of dentistry like endodontics, prosthodontics, orthodontics and the diagnosis of salivary gland tumours, facial swellings and jaw lesions have been proposed [21,25].

The MRI works by obtaining a resonance signal from the hydrogen nucleus and therefore, is essentially an imaging of water in the tissue. Spin echo and inversion recovery are the two most commonly used imaging sequences whose modifications have resulted in enhancement of signal-noise ratio, contrast resolution and imaging time. Multi-slice multi-echo spin-echo imaging has become the major MR imaging technique used for clinical imaging. A standard spin-echo examination includes one set of spin-lattice relaxation time (T<sub>1</sub>)-weighted images, short repetition time (TR) and one set of spin-spin relaxation time (T<sub>2</sub>)-weighted images (long TR) [23,26].

The magnetic field is produced by three electromagnetic coils within the circle of imaging magnet. The coils surround the patient and produce a magnetic field that oppose and redirect the magnetic flux in three right angled directions to delineate individual volume of tissues (vowels) which are subjected to magnetic fields of higher strength. The local magnetic field with all hydrogen protons is segregated, at specific pixel to the same resonant frequency which is known as selective excitation. Initially when a Radio Frequency (RF) with a range of frequencies is used, it leads to the excitation of a pixel array of tissue at certain frequency and this excited pixel array radiates that typical frequency which recognizes and localizes it. The slice thickness is decided by the band width or spectrum of pulse frequencies of the RF pulse. Finally, the visual image of the part of the body that has been scanned is produced by the computer which is transferred to a film [23,25].

MRI plays a significant role in the diagnosis and management of diseases. It has many advantages along with a few drawbacks as illustrated in Table III [15,25]

**Table III: Advantages and Disadvantages of MRI [25]**

| ADVANTAGES  | DISADVANTAGES   |
|---|---|
| Non-invasive  | Claustrophobia  |
| No detrimental effect as it uses non-ionizing radiation                         | Expensive and very noisy  |
| Helps to differentiate soft tissues from one another due to contrast resolution | Contraindicated in patients with cardiac pacemakers, implantable defibrillators |
| Multiplanar image   | Bone marrow gives signal but not bone.  |
| Safe in pregnant ladies and children  | Distinction between malignant and benign tumors is difficult                    |
| Artifacts with dental filling are not seen.                                     |   |
| Manipulation of image can be done.  |   |

Metallic objects such as dental braces, dental implants, metallic dental crowns and restorations may reduce the image quality of MRI taken in the maxillofacial region and thus leads to magnetic field distortion and signal. Patients having metallic implants or other metallic objects should be evaluated by using ex-vivo techniques before the MRI is done, so that the degree and presence of ferromagnetism can be determined to make a proper decision to avoid the possible hazards associated with the use of MRI [27]. Metallic implants, abutments and crowns affect image quality by spoiling the homogeneity of the static magnetic field and by causing eddy currents in response to alternating gradients and radiofrequency magnetic fields [1,21]. Patients with particular ferromagnetic metallic implants or materials, as well as the other metallic objects that were determined to be non-ferromagnetic, can safely undergo imaging by MR scanners with static magnetic field strengths up to and including those used for the specific evaluations [28]. El-Bediwi et al in their study concluded that MRI exposure of 15-30 mins decreased the adhesion of veneering ceramic to commercially pure Ti and Ni-Cr alloy but the effect was less on Ni-Cr. MRI exposure increased the roughness and decreased the Vicker's hardness of Ni-Cr alloy and commercially pure titanium. They recommended Ni-Cr alloy over Ti for the fabrication of metal-ceramic restorations for

patients with a history of frequent exposure to MRI. They also suggested shielding metal-ceramic restorations with a non-magnetic material to protect the materials from MRI signals [29].

Up to 2005, there were 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 [17]. "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. Thus, the focus here was on diagnostic quality. In addition, there was the requirement that MRI must not compromise the function of any devices used on (or inside) the body. 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 Fig. 1. 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. Regrettably, diagnostic quality has been relegated to the back burner with this new classification. 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. [30].



**Figure 1: MR safety symbols of ASTM, classification in danger categories: green square: MR safe, yellow triangle: MR conditional, red circle: MR unsafe.**

When dental materials are used which create MR image degradations, diagnosis in the cranio-cervical region is rendered impossible. On occasion immediate MRI projections might be required for the prompt diagnosis and treatment of serious cases. In such instances as a medical emergency, there is no available time, for referral of the patient to a dentist for the removal of the metal fitments. Those metals which create MR image degradation must not be used for fixed prosthesis or orthodontic devices both of which could easily be made from other metals. If the MR image degrading metals are to be used in dentistry, their application should be restricted to removable prosthesis [18].

There would be no difficulty in the diagnostic interpretation of MRIs from the head and neck regions in patients with dental casting alloys that do not disturb the magnetic field. Therefore, materials for prosthetic restoration should be selected based not only on their biologic compatibility and functional and

esthetic qualities, but also on whether they generate minimum artefacts in MRI [15]. Precious alloys are superior not only in terms of biocompatibility, but also as they produce fewer artefacts on the MRI scan [30].

### Conclusions

With regard to improving image quality, removable dentures and orthodontic wires should be removed where possible prior to scanning particularly when the head and neck region is being imaged [4]. Metallic orthodontic appliances can distort MRI images reducing their diagnostic value. Aesthetic brackets including molars (with no metal components and with arch wires removed) do not appear to distort MRI scans. Alternatively, fixed appliance placement should be delayed until after all investigations are carried out, especially in those cases likely to require “one-off” scans [14]. Titanium implants are still considered the ‘gold standard’ in dental implantology. Similarly, the use of Co-Cr based single crowns is established in clinical

practice; however, the introduction of computer-aided design/ computer-aided manufacturing (CAD/CAM) has promoted the use of all ceramic crowns. Furthermore, from an imaging point of view, zirconia implants outperform their titanium counterparts in terms of artefact volume. However, more research is necessary to assess other materials (e.g. lithium disilicate or zirconia-reinforced lithium silicate), different abutment types (e.g. titanium implants with zirconia abutments) or other implant types (two-piece zirconia implants) [21].

Ideally, ferromagnetic keepers are removed from the oral cavity before MRI; however, it is not always in the best interest of the patient. From a safety perspective, the fixation of such devices should be inspected before and after the MRI [9].

While the responsibility to assess these risks and problems lies mainly with the radiologist, they do not normally have the knowledge regarding the composition of the dental materials present in the patient's mouth. Consultation with the treating dentist often remains inconclusive because relevant specifications are unknown even by them. Attempts to obtain information from the manufacturer are routinely denied due to fear of competition, leading manufacturers to disclose only relevant information such as safety datasheets or alloy components, as they are currently not legally obliged to specify the MRI compatibility of the medical grade materials. The only remaining option is to search the scientific literature. Yet those relevant studies that are available on the subject have invariably dealt with individual products and frequently contain incomplete descriptions of materials. Thus, their findings cannot be generalized and are rarely helpful in dealing with specific situations. [7]. MRI technicians must conduct a careful evaluation of each patient and may alter the field strength to ensure the safety of the procedure [30].

Dentists should consider whether an alloy can be magnetized when selecting their materials. As ever more adults are seeking dental treatment these days, the number of patients requiring MRI examinations during treatment will grow. The key to solving the problem of susceptibility artifacts currently rests with the manufacturers of dental materials. They should be required to disclose the magnetic properties of their products. The incentive for innovation arising from such a disclosure obligation might well eliminate the problem of MRI compatibility for a while.

## References

1. Tymofiyeva O, Vaegler S, Rottner K, Boldt J, Hofgartner AJ, Proff PC, et al. Influence of dental materials on dental MRI. *Dentomaxillofac Radiol* 2013; 42:20120271.
2. Starcukova J, Starcuk Z Jr, Hubalkova H, Linetskiy I. Magnetic susceptibility and electrical conductivity of metallic dental materials and their impact on MR imaging artifacts. *Dent Mater* 2008;24:715-23. doi: <https://doi.org/10.1016/j.dental.2007.07.002>
3. P. Allisy-Robert and J Williams, "Magnetic resonance imaging," in *Farr's Physics for Medical Imaging 2<sup>nd</sup> Edition*, pp. 169-195, Edinburgh, vol 43, no. 4, 2018.
4. Wilson BJ, O'Hare PE, Zacariah J. Implications and considerations of dental materials in MRI: A case report and literature review. *Hindawi : Case reports in Dentistry* 2020; Article ID 8891302:1-3. doi: <https://doi.org/10.1155/2020/8891302>
5. Murukami S, Verdonschot RG, Kataoka M, Kakimoto N, Shimamoto H, Kreiborg S. A standardized evaluation of artefacts from metallic compounds during fast MR imaging. *Dentomaxillofac Radiol* 2016;45:20160094.
6. Agarwal B, Mishra SK. Awareness among dentist about interactions between metallic dental prosthesis and magnetic resonance

- imaging - a questionnaire-based survey. *Guident* 2018 (July);22-24.
7. Blankenstein F, Truong BT, Thomas A, Thieme N, Zachriat C. Predictability of magnetic susceptibility artifacts from metallic orthodontic appliances in magnetic resonance imaging. *J Orofac Orthop* 2015;76:14-29. doi: 10.1007/s00056-014-0258-0
  8. Hasegawa M, Miyata K, Abe Y, Ishigami T. Radiofrequency heating of metallic dental devices during 3.0T MRI. *Dentomaxillofac Radiol* 2013;42:20120234.
  9. Hasegawa M, Miyata K, Abe Y, Ishii T, Ishigami T., Ohtani K, et al. 3-T MRI safety assessments of magnetic dental attachments and castable magnetic alloys. *Dentomaxillofac Radiol* 2015;44:20150011.
  10. Green BG. Heat pain thresholds in oral-facial region. *Percept Psychophys* 1985;38:110-14. doi: 10.3758/bf03168847
  11. Kenta O, Jun Y, Kyoko T, Hidemichi K, Hisatomo K. Safety of dental implants materials and effects of artifact in 7 Tesla ultra-high field MRI. *Clin Oral Impl Res* 2017;28(Suppl. 14):133.
  12. Chockattu SJ, Suryakant DB, Thakur S. Unwanted effects due to interactions between dental materials and magnetic resonance imaging: a review of literature. *Restorative Dentistry & Endodontics* 2018;43:no. 4.
  13. Hubalkova H, Hora K, Seidi Z, Krasensky J. Dental materials and magnetic resonance imaging. *Eu J Prosthodont Restr Dent* 2002;10:125-30.
  14. Harris TMJ, Faridrad MR, Dickson JAS. The benefits of aesthetic orthodontic brackets in patients requiring multiple MRI scanning. *J Orthodont* 2006;33:90-94.
  15. Shafiei F, Honda E, Takahashi H, Sasaki T. Artefacts from dental casting alloys in magnetic resonance imaging. *J Dent Res* 2003;82(8):602-06.
  16. Bohner L, Meier N, Gremse F, Tortamano P, Kleinheinz J, Hanisch M. Magnetic resonance imaging artifacts produced by dental implants with different geometries. *Dentomaxillofac Radiol* 2020;49:20200121.
  17. Schenck JF. The role of magnetic susceptibility in magnetic resonance imaging: MRI magnetic compatibility of the first and second kinds. *Med Phys* 1996; 23: 815-50.
  18. Masumi S, Arita M, Morikawa M, Toyoda S. Effects of dental metals on magnetic resonance imaging (MRI). *J Oral Rehab* 1993;20:97-106.
  19. Vandevenne JE, Vanhoenacker FM, Parizel PM, Butts Pauly K, Lang RK. Reduction of metal artefacts in musculoskeletal MR imaging. *JBR-BTR* 2007; 90:345-9.
  20. Fakhar HB, Sharifian H, Niknami M, Iranmanesh M. Artifacts of titanium, zirconium and binary titanium-zirconium abutments in computed tomography, cone beam computed tomography and magnetic resonance imaging. *JDMT* Jan 2020;Vol 9,No.1:10-14.
  21. Hilgenfeld T, Prager M, Schwindling FS, Heil A, Kuchenbecker S, Rammelsberg P, Bendszus M., Heiland S. Artefacts of implant-supported single crowns – impact of material composition on artefact volume on dental MRI.301-8
  22. Ferracane JL. Materials in dentistry: principles and applications. Philadelphia, PA: Lippincott Williams & Wilkins;2001.
  23. Katti G, Ara SA, Shireen A. Magnetic resonance imaging (MRI) – a review. *Int J Dent Clinics*. 2011;3(1):65-70
  24. Blickman JG, Parker BR, Barnes PD. Pediatric Radiology: The Requisites. 3<sup>rd</sup> ed; Mosby Elsevier, 2009;297-338.
  25. Niraj LK, Patthi B, Singla A, Gupta R, Ali I, Dhama K, Kumar JK, Prasad M. MRI in dentistry – A future towards radiation free

- imaging – systematic review. [www.jcdr.net](http://www.jcdr.net)  
. doi:10.7860/JCDR/2016/19435.8658
26. Scherzinger AL, Hendee WR. Basic principles of magnetic resonance imaging – an update, In High-tech medicine [Special Issue]. *West J Med* 1985;143:782-92
  27. Shellock FG, Curtis JS, MR imaging and biomedical implants, materials and devices - an updated review. *Radiol* 1991;180:541-50.
  28. Shellock FG. MR imaging of metallic implants and materials: a compilation of the literature. *AJR Am J Roentgenol* 1988;151:811-14.
  29. El-Bediwi AB, El-Fallal A, Saker S, Ozcan M. Effects of non-ionizing radio frequency signals of magnetic resonance imaging on physical properties of dental alloys and metal ceramic adhesion. *J Adhes Dent* 2014;16:407-13. doi: 10.3290/j.jad.a32664
  30. Peterborough DS. MRI scan hazard. *BDJ* 2007;205:293.doi:10.1038/sj.bdj.2013.389