

INFLUENCE OF DENTAL MATERIALS ON MRI

Abstract

The promising advantage of magnetic resonance imaging (MRI) is limited by artifacts due to the presence of metallic materials such as dental crowns, dental implants and metallic orthodontic appliances. Artifacts results in degraded image quality which compromises evaluation of images impossible in some cases. This article analyses the influence of different dental materials on MRI.

Introduction

Tooth is one of the hardest substance of human body which comprises mainly of three components such as Enamel, Dentin and Pulp. Dentistry has witnessed tremendous advances in all its branches over the past four decades in diagnosis and treatment planning but dentistry has relied substantially on technological aids. The technological aids such as Computed Tomography (CT), Cone Beam Computed Tomography (CBCT), Magnetic Resonance Imaging (MRI) and Ultrasonography have an important place in modern dentistry.

Recently, new approaches to the application of MRI in various branches of dentistry have been proposed in endodontics, prosthodontics, orthodontics and diagnosis of dental caries.⁽¹⁾ However, dental materials present in the subject's mouth pose a major concern for dental applications of MRI.

Magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) is one of the most powerful diagnostic tools in radiology and diagnostic sciences. 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. MRI is based on the signal of nuclear magnetic resonance (NMR) emitted by the interaction of atomic nuclei that possess spin with incident radiofrequency within a static magnetic field⁽²⁾. The principle behind 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. MRI technique has evolved through the years. The first nuclear magnetic resonance image was produced by Lauterbur in 1973.

Applications of MRI in Dentistry

The advantages of MRI include its ability to provide sectional images of anatomic regions in any arbitrary plane and its excellent soft-tissue contrast resolution⁽³⁾. MRI is used in diagnosis of TMJ disorders which may lead to a degeneration of the discs, inflammatory conditions of the facial skeleton soft tissue pathologies⁽⁴⁾. MRI helps to analyze bone topography for the placement of the dental implants. It provides more precise information regarding the bone height, bone density and contour⁽⁵⁾. The growth of the facial skeleton can also be monitored by MRI with the help of control points. MRI gives excellent images of anatomical structures differing in proton density and other tissue characteristics.

Drawbacks of MRI

Despite these imaging characteristics, MRI has the shortcoming of being prone to magnetic susceptibility difference artifacts caused by the presence of metallic materials such as dental or orthopedic implants, dental cast restorations, and aneurysm clips⁽³⁾. Magnetic susceptibility is an instinctive property of matter, emerging from its electron structure and is the tendency of a substance to attract magnetic lines of force. Artifacts in MR images can be defined as the pixels that do not faithfully represent the tissue components being studied.⁽⁶⁾

Magnetic susceptibility artifacts occur at interfaces between substances with different magnetic susceptibilities (air-tissue, bone-tissue, and metal-tissue); such strong susceptibility gradients result in signal loss due to spin dephasing and mismapping artifacts associated with frequency shifts⁽⁷⁾. 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.⁽¹⁾

Influence of dental materials on MRI

The substances are characterized based on their magnetic susceptibility as paramagnetic, diamagnetic, and ferromagnetic. Ferromagnetic substances are strongly attracted by a magnetic field and thus have a high potential for causing MRI artifacts. Diamagnetic substances have a very weak and negative susceptibility to magnetic field and paramagnetic materials have positive susceptibility and augment the external field⁽⁸⁾, but both are far less likely to cause artifact.

Magnetic susceptibility information is not readily available for many materials used in dentistry, especially those containing several components. Partly contradictory results have been reported regarding the severity of image artefacts caused by different dental materials⁹. For example, in some studies, high gold-content alloys were reported not to show any disturbance in phantoms and porcine jaw ex vivo but produced significant artefacts in other studies.⁽¹⁾ Similar contradictory results have been reported for titanium, dental amalgam and other materials.

Influence of MRI on restorative materials

The type of dental crowns used during a dental procedure will depend on unique needs and goals, as well as the recommendation. Only gold, palladium, nickel and chromium are important since they are the most common metals used in dental crowns and in the oral area, dental crowns generated little distortion of the image, only visible in the sagittal plane. Gold, a diamagnetic substance. However, gold alloys contain traces of others ferromagnetic metals. Even small amounts of a ferromagnetic substance lead to the most severe artifacts.

Hindshaw et al found that amalgam and gold are the most used materials in dentistry. Dental amalgam alloy has been shown to have little influence in dental MRI, while gold crowns have shown significant distortion. Amalgam is composed of several

metals, but silver is the metal commonly used in clinical practice. The absence of artifact caused by amalgam could be explained by the presence of silver, a non ferromagnetic metal.⁽⁸⁾

Influence of MRI on Dental implants

Dental implants are made of non-ferromagnetic materials (titanium) and contained traces of ferromagnetic iron which causes a drop-out of signal near the metallic surface. Andre et al found that implant generated artifacts in all planes, but its score was smaller than orthodontic appliances. They found that titanium implants can cause important artifact, resulting in a severe blooming and leading to problems in clinical practice.

Influence of MRI on orthodontic metallic appliance

Study by Leite et al showed that 78% of artifacts were caused by orthodontic metallic appliance as previously suggested. The orthodontic appliances are employed in large regions in upper and lower jaws and are comprised of stainless steel composed of nickel (8-12%), chromium (17-22%) and amounts of others metals⁽⁹⁾. Nickel and chromium are ferromagnetic metals; consequently, there are chances of distortion on local magnetic field, causing large artifacts which make image interpretation impossible.

A study by Andre et al demonstrated that the most likely origin of dental artifacts is metallic orthodontic appliances. They lead to large areas of artifacts, making imaging interpretation difficult.

A study by Abraham Mathew et al⁽¹⁰⁾ gave the following interpretation regarding artifacts caused by various dental materials is given below

No artifact	Minimal to moderate artifacts	Significant artifact
Amalgam	Titanium	Cobalt-chromium crowns
Titanium	Vitallium	Nickel chromium crowns
Cobalt-chromium crowns	Zinc phosphate	Stainless steel crowns
Nickel chromium crowns	Stainless steel crown	Metallic dentures
Light cured resin fillings	Bur fragments	Magnetic keepers
Acrylic resins	Metal ceramic	Orthodontic appliances
Gold fillings	Pins for amalgam restoration	Orthopedic metal plates
Gold crowns	Ceramic brackets	Gold
Galvano ceramic	Aluminum bronzes	Endodontic post
All ceramic restorations	Orthodontic bands	
Carbon-fiber reinforced Polymers		
Magnesium		
Zirconia		
Aluminium crown		
Microfilled resin		

Conclusion

Ferromagnetic substances are known to cause artefacts in MRI imaging. Even small amounts of ferromagnetic substance in an investigated region can cause extensive blanking of the image. In contrast, paramagnetic and diamagnetic substances are far less likely to cause artefacts. However, this also depends on the MRI sequence used ⁽¹¹⁾. In conclusion, dental restorations made from

titanium, gold or amalgam did not reduce the image quality of the MRI sequence used in imaging of the oral and maxillofacial region for dental implant planning.

The radiologist should be aware of the effects of orthodontic appliances and dental implants on head and neck MRI scans and how the diagnostic quality of these scans can be affected. Patients with metallic orthodontic appliances should remove them before scan.

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8 Artifacts in brain magnetic resonance imaging due to metallic dental objects Andre L. F. Costa, Simone Appenzeller , Clarissa-Lin Yasuda , Fabrício R. Pereira , Verônica A. Zanardi , Fernando Cendes

9 The effects of a common stainless steel orthodontic bracket on the diagnostic quality of cranial and cervical 3T- MR images: a prospective, case-control study

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