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Artifacts in brain magnetic resonance imaging due to metallic dental objects

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Abstract
Objective: Artifacts caused by metallic objects, such as dental crowns, dental implants and metallic orthodontic appliances, are a common problem in head and neck MRI. The aim of this retrospective study was to identify the main metal dental objects that produce artifacts on brain MRIs.
Study design: Imaged metallic artifacts and their sources were identified. Artifact image plane was rated on a score of 0 or 1 (0 - distinguishable for diagnosis and 1 - not distinguishable for diagnosis).
Results: Seventy-eight percent of the artifacts appearing in images were caused by orthodontic appliances, followed by dental titanium implants (18%) and metallic crowns (4%). Orthodontic appliances obtained the highest scores in all planes.
Conclusions: We concluded that is difficult to avoid the effect of metallic artifacts in the maxillofacial regions on brain scan. Removing metallic parts of the orthodontic appliance should ensure diagnostically useful quality scans.

Key words: *Artifact, magnetic resonance imaging, dental material.*

Introduction
Magnetic resonance imaging (MRI) is considered a powerful diagnostic method which enables the visualization of soft tissue contrast without the use of ionizing radiation (1). As in all imaging modality, artifacts can occur, resulting in degraded image quality which can compromise imaging evaluation and in some cases render it impossible.
MRI creates images using a strong uniform static magnetic field and switching magnetic field gradients with radiofrequency magnetic field pulses (2). All substances when placed in a magnetic field are magnetized to a degree that varies according to their magnetic susceptibility (2-5). Dentists usually use precious (Au, Ag, Pt) and non-precious alloys (Cr, Co, Mo, Ni), pure gold, titanium and titanium alloys (6).
The presence of metallic sources, such as dental implants, dental braces and metallic dental crowns may reduced image quality in the maxillofacial region of MRI (7), causing large magnetic field distortion and signal

loss. In general, the magnitude of an imaging artifact during MRI correlates with the magnetism of the metal. The damage in image depends on their shape, position, orientation and the number of objects (5,8).

Although several articles have described the effects of metallic objects on MRI interpretation, few have addressed these problems in clinical situations.

The purpose of the present study was to overview the artifacts caused by metallic objects in the orofacial region of the brain MRI which were acquired for investigation of epilepsy.

Material and Method

This retrospective study took place at the Magnetic Resonance Imaging Service of the University Hospital at the University of Campinas. The medical records of 1200 subjects with epilepsy who underwent MRI for epilepsy investigation were gathered to cover a 4 year period regarding possible artifacts from dental materials. We identified 70 MRIs with artifacts. The images were then retrieved and reviewed.

The imaging planes affected were identified and sources of artifacts were described (as stated on files), and divided into three generic categories:

a) Gold crowns.

b) Dental titanium implants.

c) Metallic orthodontic appliances (bands, brackets and archwire).

The MRI acquisition parameters were: (1) Sagittal T1 spin echo, 6mm thick, flip angle= 180o; repetition time (TR)=430, echo time (TE)=12, matrix 200 x 350, field of view (FOV)=25 x 25cm; (2) Coronal images, perpendicular to long axis of hippocampus, defined on the sagittal images: T1-weighted inversion recovery (IR), 3mm thick, flip angle=200o; TR=2800, TE=14, inversion time (TI)=840, matrix 130 x 256, FOV=16 x 18cm; (3) Axial images parallel to the long axis of the hippocampi: (a) T1-weighted gradient echo, 3mm thick, flip angle=70o, TR=200, TE=5, matrix 180 x 232, FOV=22 x 22 cm; b) fluid attenuated inversion recovery (FLAIR), 4 mm thick, flip angle=110o, TR=10099, TE=90, matrix 252 x 328, FOV=21 x 23cm.

A simplified scoring system was used to facilitate ranking the MRI scans in anatomic planes (axial, coronal and sagittal). The extent of the damage and its impact on image in diagnosis was evaluated by one investigator, with experience in MRI, following these parameters:

- 0, Image plane distinguishable for diagnostic evaluation in the brain area.
- 1, Image plane not distinguishable for diagnostic evaluation in the brain area.

When the dental object caused an artifact in the MRI plane, it scored. Each plane seen could achieve a maximum score of one point. A total score of 100% was equivalent that all objects ranking in that considered plane; 0% indicated that no significant artifact was produced (Table 1).The validation of the scoring system across all images was tested for statistical significance using a t test. The final imaging quality of the MRI scans was scored and the scores were, as a percentage, compared to each other by Q-square test. P value <0.05 was considered significant.

After the each MRI was ranked for each plane, we evaluated the total of unusable scans caused by dental metallic objects (Table 2).

Table 1. Evaluation of images in MRI planes

Dental Procedure	**Affected Image plane displayed**					
	Axial		Sagittal		Coronal	
	score	%	score	%	score	%
Dental crowns	0	0	2	100	0	0
Dental implants	1	7,6	13*	100	10*	77%
Orthodontic braces	52*	94,5	55*	100	53*	96,3

*P< 0.05

Table 2. Number of unusable scans per artifact.

Scans	**Objects**
0	Gold Crowns
9	Dental Implants
55	Orthodontic Appliances

Results

During the study period, 1200 MRI scans for investigation in epilepsy were performed. We visually assessed the images. Artifacts were observed in 6% of scans. We identified dental gold crowns in 2 scans (Fig.1A), implants in 13 scans (Fig.1B, C, D) and metallic orthodontic appliances in 55 scans (Fig.2A, B, C). Metallic orthodontic appliances produced 78% of the imaging artifacts (55 images), dental implants 18% (13 images) and dental gold crowns 4% (2 images).

Orthodontic appliances achieved an elevated imaging score in all planes, with the highest points, reaching statistical significance in two planes (axial and coronal). Susceptibility artifacts of dental implants showed the second highest imaging score, scoring in axial (1), coronal (10) and sagittal (13) planes. Dental crowns produced the least artifacts, and achieved an imaging score of 2 with two objects only in the sagittal plane (Table 1). The results of the validation of the scoring system were:

- Mean score value: 20.6;
- P< value: 0.05

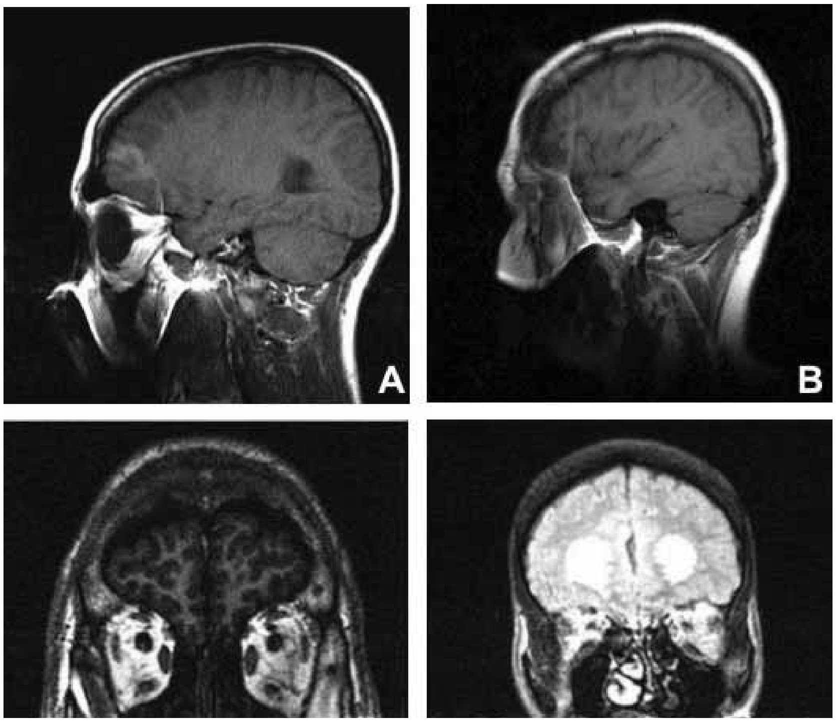

Fig. 1. A. Sagittal T1-weighted MR image clearly showing distortion around jaw from gold crown;

B. Sagittal T1-weighted MR image shows severe artifact from dental implant;

C. Coronal T1-weighted MR image shows area distortion, with rims due to dental implant;

D. Coronal MR image shows artifact from dental implant on left mandible.

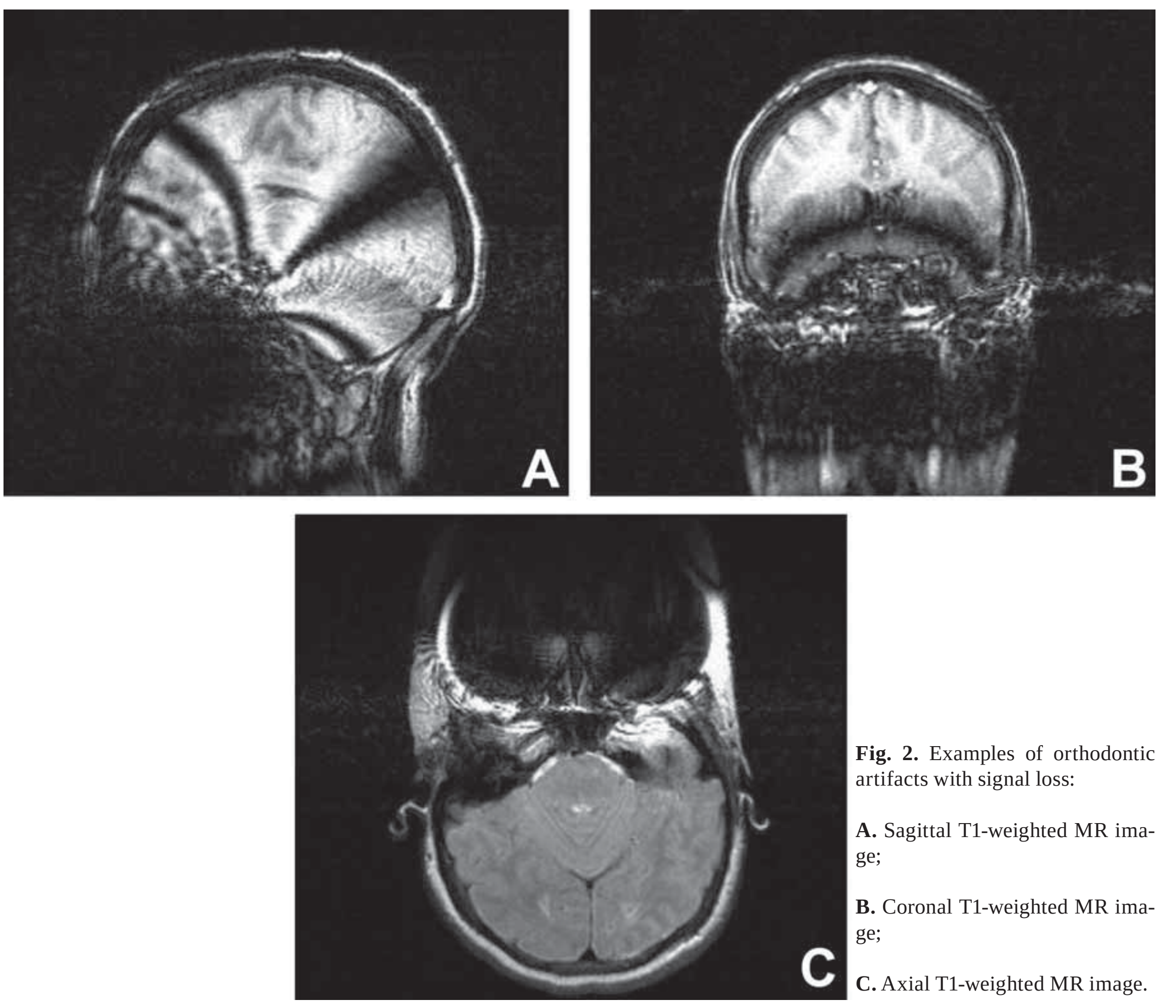

Fig. 2. Examples of orthodontic artifacts with signal loss:

A. Sagittal T1-weighted MR image;

B. Coronal T1-weighted MR image;

C. Axial T1-weighted MR image.

The unusable scans are displayed in Table 2. From the data, it can be seem that orthodontic appliances reached the largest number of misinterpretation of the MRI results, followed by dental implants (9 scans). All scans with some artifact caused by dental crown were distinguishable for diagnostic evaluation.

Discussion

Magnetic susceptibility is an inherent property of matter, originating from its electron structure and is the tendency of a substance to attract magnetic lines of force (1). 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 (9).

Since the development of MRI, the artifacts caused by metallic objects are a common problem in MRI scans. Artifacts due to metals are well documented, and usually lead to areas of signal blackout, with rims of high signal strength around the offending object (10).

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 (1). Diamagnetic substances have a very weak and negative susceptibility to magnetic field and paramagnetic materials have positive susceptibility and augment the external field (11), but both are far less likely to cause artifact (12).

The present study evaluated the dental metallic artifacts on MRI records from Magnetic Resonance Imaging Service of a University Hospital, during a 4-year period. In our study, we found that dental amalgam alloys were not mentioned, according to the hospital records, as a source of artifact generation. Amalgam and gold are the most used materials in dentistry. Dental amalgam alloy has been shown to have little influence in dental MRI (13), while gold crowns have shown significant distortion (1). Amalgam is composed of several metals, but silver is the metal commonly used in clinical practice (14). The absence of artifact caused by amalgam could be explained by the presence of silver, a nonferromagnetic metal.

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 (15) and in the oral area, however in our data, dental crowns generated little distortion of the image, only visible in the sagittal plane. The crowns mentioned in our work were identified from gold, a diamagnetic substance. However, gold alloys contain traces of others ferromagnetic metals. According to Eggers et al. (7), even small amounts of a ferromagnetic substance can cause an extensive blank in the image.

Although ferromagnetic objects lead to the most severe artifacts, the second source of artifacts was implants. Dental implants are made of non-ferromagnetic materials (titanium) and contained traces of ferromagnetic iron (7) which causes a drop-out of signal near the metallic surface (10). We found that it generated artifacts in all planes, but its score was smaller than orthodontic appliances. Some authors reported that titanium causes only minor artifacts and allows good visualization (8,12), while others disagree (13). We found that titanium implants can cause important artifact, resulting in a severe blooming and leading to a problems in clinical practice.

Our study showed that 78% of artifacts were caused by orthodontic metallic appliance as previously suggested (11,15). 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 (16). Nickel and cromium are ferromagnetic metals; consequently, we can expect distortion on local magnetic field, causing large artifacts which make image interpretation impossible.

The MRIs in our research were used for assessment of epilepsy investigation. Orthodontic appliances are known to have a significant influence on the frontal and temporal lobes (17); for epilepsy diagnosics, the MR interpretation in these lobes is of fundamental importance (18). This could explain our results.

The magnitude of susceptibility artifact is also related to the type of imaging sequence used; some sequences are more sensitive to susceptibility artifact (19). A more severe artifact is produced in images with a long echo time (TE) because small differences in precession frequency have more time to increase a large phase error. Artifacts are most severe in gradient echo sequences owing to the absence of the 1800 refocusing pulse (20). Therefore, the best sequence to reduce the severity of the susceptibility artifact would be a spin echo sequence with a short TE (21,22). However, in our sequence protocol, the short TE was not sufficient to reduce susceptibility artifact.

It is important to address the issue of bias in our study. The images were only evaluated by one investigator which may have introduced a selection bias in our sample.

Conclusions

The results of this study demonstrate that the most likely origin of dental artifacts is metallic orthodontic appliances. They lead to large areas of artifacts, making imaging interpretation difficult. The frequency of these findings has not been described before. Although the presence of dental gold crows is also a possible cause of artifacts, this study did not show an important influence on brain MRI when compared to dental implants and orthodontic appliances. 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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