Form 3

Abstract of Thesis

Name (Maziahtul Zawani Binti Munshi)	
Title	Magnetic susceptibility artifacts caused by dental materials in 3.0 tesla MRI (3テスラMRIにおける歯科材料による磁化率アーチファクト)

Background:

In the oral and maxillofacial field, magnetic resonance imaging (MRI) has become an important imaging modality to provide information on head and neck conditions for diagnosis. MRI uses a strong static magnetic field and radio-frequency electromagnetic waves to interact with biological tissues. The advantages of MRI include non-ionizing radiation, superior soft tissue contrast, and the ability to image in any desired tomographic plane.

Magnetic susceptibility artifacts may arise due to the presence of prostheses or dental implants that cannot be easily removed from the teeth and jawbones. In areas where two materials with different magnetic susceptibility are adjacent to each other, the magnetic flux density changes, and appears as a “magnetic susceptibility artifact” in MRI images. When MRI began to be applied to areas where metals exist, such as artificial joints and dental prostheses, research on magnetic susceptibility artifacts began to flourish. However, in those studies, each researcher defined magnetic susceptibility artifacts themselves, so it was not possible to compare the results of imaging under different conditions or for other metals. In 2013 and updated in 2024, ASTM proposed a standard imaging method for defining and comparing magnetic susceptibility artifacts in ASTM F2119-24.

Objectives:

This research was initially aimed at objectively comparing the volume of magnetic susceptibility artifacts caused by titanium on MRI images using 1.5 T and 3.0 T MRI devices.

Second, this research aimed to objectively compare the volume of magnetic susceptibility artifacts caused by various dental materials in a 3.0 T MRI device.

Main study 1: Comparison of artifacts between 1.5 T and 3.0 T

Materials and method:

Two scanners were used for comparison of the magnetic susceptibility artifact volumes in each scanner. One scanner used was a Signa® Premier 3.0 T superconducting MRI system (GE Healthcare, Milwaukee, WI, USA). To receive the signal, a 48-channel head coil was used (GE Healthcare, Milwaukee, WI, USA). The other scanner used was a Signa® HDxT 1.5 T superconducting MRI System (GE, Milwaukee, WI, USA). To receive the signal, an 8-channel head & neck coil was used (GE, Milwaukee, WI, USA).

A phantom was created using an acrylic container with a side of 15 cm. Half of the lower part of the acrylic container was filled with agar dissolved with gadolinium contrast agent at an optimal concentration (0.2%) to fix the material in the center of the phantom. The upper part of the phantom was filled with an aqueous solution containing the optimal concentration of the same gadolinium contrast agent

Six cubes of pure titanium with sides of one cm were made to produce the magnetic susceptibility artifact in an MRI scan.

The two pulse sequences used were FSE and GRE following ASTM F2119-24. FSE with TR at 500 ms, TE at 20 ms, and ETL at 8. GRE sequence with TR at 100 ms, TE at 15 ms, and FA at 30°. Other common conditions followed according to ASTM F2119-24. The TG, CF, and RG were set manually to constant values before and after the metal was installed, before imaging the sample. The axial and coronal planes were imaged. The magnetic susceptibility volume was measured pixel by pixel using Image J (version 1.54g). The definition of the magnetic susceptibility artifact followed the ASTM F2119-24.

Student’s t-test was performed to compare the volumes of magnetic susceptibility artifact using SPSS® version 30 (IBM Corp, Armonk, NY, USA) with a significance level of 1%.

Summary:

Statistically significant difference was found between FSE in 1.5 T and 3.0 T axial and coronal planes. There was also a statistically significant difference found between GRE in 1.5 T and 3.0 T axial and coronal planes. In the FSE axial plane, the total volume of magnetic susceptibility artifact for 3.0 T was 1.37 times larger than that of 1.5 T. In the FSE coronal plane, the total volume of magnetic susceptibility artifact for 3.0 T was 1.58 times larger than the 1.5 T.

In the GRE axial plane, the total volume of magnetic susceptibility artifact for 3.0 T was 1.97 times larger than that of 1.5 T. In the GRE coronal plane, the total volume of magnetic susceptibility artifact for 3.0 T was 1.46 times larger than that of 1.5 T.

Main study 2: Comparison of artifacts of dental materials at 3.0 T

Materials and method:

The MRI scanner used was a Signa® Premier 3.0 T superconducting MRI system (GE Healthcare, Milwaukee, WI, USA). To receive the signal, a 48-channel head coil was used (GE Healthcare, Milwaukee, WI, USA). A phantom was created using an acrylic container with a side of 15 cm. Half of the lower part of the acrylic container was filled with agar dissolved with gadolinium contrast agent and at an optimal concentration (0.2%) to fix the material in the center of the phantom. The upper part of the phantom was filled with an aqueous solution containing the optimal concentration of the same gadolinium contrast agent.

Eight types of material samples of 1 cm^3 cube, cobalt-chromium alloy (Co-Cr), pure titanium (Ti), zirconium dioxide (ZrO_2) (IPS e.max® ZirCAD LT, Ivoclar Vivadent AG, Schaan, Liechtenstein), lithium dioxide ($LiSi_2$) (IPS e.max® CAD, Ivoclar Vivadent AG, Schaan, Liechtenstein), pure silver (Ag), Type IV gold alloy (Au), silver-palladium-gold alloy (APA) and hybrid resin composite (RC) (Katana Avencia® P Block, Kuraray Noritake Dental Co., Ltd. Niigata, Japan). Six samples of each material were made. The two pulse sequences used were FSE and GRE following ASTM F2119-24. FSE with TR at 500 ms, TE at 20 ms, and ETL at 8. GRE sequence with TR at 100 ms, TE at 15 ms, and FA at 30°. Other common conditions followed according to ASTM F2119-24. The TG, CF, and RG were set manually to constant values before and after the metal was installed, before imaging the sample. The axial and coronal planes were imaged. The magnetic susceptibility volume was measured pixel by pixel using Image J (version 1.54g). The definition of the magnetic susceptibility artifact followed the ASTM F2119-24.

Tukey and Bonferroni tests were performed to compare the volumes of the magnetic susceptibility artifacts using SPSS® version 30 (IBM Corp, Armonk, NY, USA) with a significance level of 1%.

Summary:

At the FSE axial plane and coronal plane, there was statistically significant difference at black, white, and total artifact volume, between Co-Cr with other seven materials, and Ti with other seven materials.

At the GRE axial and coronal plane, there was also statistically significant difference at total artifact volume, between Co-Cr with other seven materials, Ti with other seven materials and RC with other seven materials.

Conclusion:

As a result, on the image by the fast spin echo sequence the volume of artifacts in the 3.0 tesla device was 1.4 times that of the 1.5 tesla device. In the gradient echo imaging, the volume of artifacts in the 3.0 tesla device was 2.0 times that of the 1.5 tesla device.

The volume of magnetic susceptibility artifacts caused by various dental materials was compared in a 3.0 tesla MRI device. It can be said that in both the fast spin echo imaging and the gradient echo imaging sequence, aesthetic materials depending on its component would be a better choice to prevent a large magnetic susceptibility artifact which may interfere an MR image.

In a clinical situation, whenever possible, the choice of dental prosthesis material or MRI strength for diagnosis should always prioritize situations where the benefit clearly outweigh the risk.

様式 7

論文審査の結果の要旨及び担当者

氏　名	（Maziahtul Zawani Binti Munshi）	
	（職）	氏　名
論文審査担当者	主査　教授	村上秀明
	副査　教授	今里　聡
	副査　准教授	峯　篤史
	副査　講師	谷川千尋

論文審査の結果の要旨

本研究は、MRI 画像における各種歯科材料による磁化率アーチファクトについて検討したものである。その結果、コバルトクロム合金を設置しグラジエントエコー法で撮像した場合、磁化率アーチファクトの体積は最大であった。一方、硬質レジンを設置しスピンエコー法で撮影した場合、磁化率アーチファクトの体積は最小であった

また、チタンを設置し 1.5 テスラと 3.0 テスラの機器で磁化率アーチファクトの体積を比較した。その結果、3.0 テスラの機器で撮像した場合、1.5 テスラの機器のものに比べて、グラジエントエコー法で 2.0 倍、スピンエコー法で 1.4 倍大きくなった。

本研究によって、一辺が 1 cm の立方体の各種歯科材料による磁化率アーチファクトの体積と MRI 画像に影響を及ぼす範囲が明らかになり、それらが口腔内に存在する場合の MRI による画像診断の際に有益となると結論づけられた。

よって、博士（歯学）の学位論文として価値のあるものと認める。