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Vplyv vlastností drôtov ortodontických retainerov na veľkosť artefaktov na obraze MR in vitro

Abstrakt

Pôvodná vedecká práca skúma vplyv vlastností drôtov ortodontických retainerov, ako je hrúbka drôtu a spôsob vinutia, na veľkosť artefaktov na MR obraze in vitro.

In the original scientific article, the impact of retainer orthodontic wire properties, such as size and method of fabrication, on the size of MRI artifacts in vitro is examined.

Abstract

Objective. Magnetic resonance imaging (MRI) artifacts occur due to interactions of metallic fixed retainers with the magnetic field. Given the clinical impact of artifacts on MRI images, it is essential to examine the influence of the properties of fixed retainers on their formation. The purpose of this study is to evaluate in vitro, if the formation of the artifacts in MRI images is influenced not only by material of the fixed retainer, but also its other characteristics, such as wire size and fabrication method.

Methods. The subject of the study were nine orthodontic wires placed in a phantom. They were made of stainless steel, golden and titanium alloy. All specimens were scanned by MRI tomograph (1,5T). Three radiologists were to choose the slice with the largest artifact and measure its dimensions. We assessed whether the type of metal affects the size of the artefact. Likewise, whether the size is also influenced by the size of the retainer and the method of wire fabrication (twisted, coaxial and braided retainer wire).

Results. The type of alloy of the wire affects the size of artifacts. Among coaxial and twisted stainless steel wires, we identified positive relationship between the increase in wire thickness and the size of the artifacts. When comparing twisted and coaxial wires, it is not clear which type of winding has a greater impact on the size of artifacts. On the other hand, representative of stainless steel round wires created significantly larger artifacts than braided wire.

Conclusions. We concluded that the size of the stainless steel retainer wire and its fabrication method affect the size of artifacts in MRI, under in vitro conditions.

Keywords: magnetic resonance imaging, orthodontic retainer wire, susceptibility artifact

Abstrakt

Cieľ práce. Artefakty na snímkach magnetickej rezonancie (MR) vznikajú v dôsledku interakcií kovových fixných retainerov s magnetickým poľom. Vzhľadom na klinický vplyv artefaktov na obraz MR je nevyhnutné skúmať vplyv vlastností fixných retainerov na ich tvorbu. Cieľom tejto štúdie je hodnotiť in vitro, či je tvorba artefaktov na obrazoch MR ovplyvnená nielen materiálom fixného retainera, ale aj jeho ďalšími charakteristikami, ako sú hrúbka drôtu a spôsob vinutia.

Materiál a metodika. Predmetom štúdie bolo deväť ortodontických drôtov umiestnených do fantómu. Boli vyrobené z nehrdzavejúcej ocele, zlata a titánovej zliatiny. Všetky vzorky boli skenované pomocou tomografu o sile 1,5T. Trojica radiológov mala za úlohu vybrať rez s najväčším artefaktom a zmerať jeho rozmery. Posudzovali sme, či typ kovu ovplyvňuje veľkosť artefaktu. Rovnako, či je veľkosť tiež ovplyvnená hrúbkou a spôsobom zhotovenia drôtu (twistový, koaxiálny a splietaný retainerový drôt).

Výsledky. Typ zliatiny drôtu ovplyvňuje veľkosť artefaktov. Medzi koaxiálnymi a twistovými drôtmi z nehrdzavejúcej ocele sme identifikovali pozitívny vzťah medzi zvýšením hrúbky drôtu a veľkosťou artefaktov. Pri porovnávaní twistových a koaxiálnych drôtov nie je jasné, ktorý typ vinutia má väčší vplyv na veľkosť artefaktov. Na druhej strane zástupca oceľových guľatých drôtov vytvoril výrazne väčšie artefakty než splietaný drôt.

Záver. Dospeli sme k záveru, že hrúbka drôtu retainera z nerezovej ocele a jeho spôsob výroby ovplyvňujú veľkosť artefaktov MR, za in vitro podmienok.

Kľúčové slová: magnetická rezonancia, ortodontický retainerový drôt, artefakt magnetickej susceptability

Introduction

Magnetic resonance imaging (MRI) is an essential diagnostic tool in medicine. Due to its significant advantages over conventional imaging techniques, it is becoming increasingly common in everyday practice (13). Despite its undeniable benefits, the potential of MRI can only be fully

utilized if the output data are readable and interpretable. As in all imaging modalities, artifacts can occur, potentially compromising the evaluation of images. Dental metallic materials and specifically orthodontic appliances are commonly known for creating susceptibility artifacts in head and neck scans (Image 1) (3,5,12).

Fixed retainers serve as a stabilization aid for the final position of anterior teeth after completion of active orthodontic treatment. Unlike brackets and orthodontic wires, fixed retainers remain in the mouth for many years after the end of active treatment (Image 2). This area of components has become clinically relevant (9,12) as orthodontists are asked to remove all orthodontic devices prior to MRI examination. Therefore, detailed knowledge of artifacts caused by different retainer materials and other characteristics creates basis for rational clinical routines for both orthodontists and radiologists.

Several articles have described the effects of fixed orthodontic retainers on formation of the artifacts (4,6,8), but none of them have been looking for relationships between wire size or its fabrication method and the size of MRI artifact.

The purpose of this study is to serve as a pilot work for research in this field.

Material and methods

Retainer samples

Nine common retainer wires were included. The relevant information on alloy type, retainer size and winding method is given in Table 1. Dimensions of the wires are given in inches.

As the reference wire, a fixed retainer for lower dentition (total 6 teeth) was chosen. The wire length was determined according to the tooth dimension data of 105 patients from the Clinic of Dentistry and Maxillofacial Surgery of the Faculty of Medicine, Comenius University. The sum of the mesiodistal widths of the lower incisors and half the width of the lower canine teeth were considered. The median was 29.18 mm, hence a dimension of 29.2 mm was

chosen for all samples used in the study. The wires were gently bent to simulate the curvature of the dental arch.

The phantom used for imaging the retainers consisted of a plastic cylindrical container with a volume of 0.6 liters (diameter 10 cm, height 9 cm). The wire samples were embedded in purified laboratory PCR agarose (Top-Bio) in the middle of the container. One phantom with no wire sample was used as control.

MRI examinations

In vitro MRI scans were performed on 1,5 Tesla MRI system (Phillips Ingenia). In all phantoms, a standard Turbo-Spin-Echo T2-weighted sequence was used. Sequence parameters were echo time: 16ms, repetition time: 4873.9 ms, voxel size: 0.32 mm x 0.32 mm x 0.32 mm, slice thickness 5mm. The phantoms were placed at the magnet's isocenter. We aimed to simulate conditions similar to head imaging, so the phantoms were positioned in a head holder and oriented such that the course of the wire would be the same as in a patient with a fixed retainer. Slices were made in the sagittal plane, perpendicular to the course of the retainer.

In vitro assessment of artifacts

All datasets were assessed by three independent radiologists. From the measured slices, they were to choose the image with the largest artifact. An artifact was considered to be an enhancement, loss, or deformation of the MR signal (compared to the reference phantom without a retainer). The largest size of the artifact in cranio-caudal orientation was recorded (Image 3).

If the scanned phantom was evaluated as a control, i.e., without a wire or artifact, the size was marked as 0 mm. If any phantom was evaluated as containing only a wire creating no artifact, the size recorded was set to 0.5mm (which is the maximum size of the wire used in the study). The order of the evaluated phantoms was random, but each was measured four times by each examiners.

For the evaluation of artifact size regarding alloy type, all wires were taken into consideration.

Table 1 Wire samples used for the study

Sample	Material	Dimensions (inch)	Fabrication method	Strands	Manufacturer
1	Au-alloy	0.0383x0.0158	Links of a chain	0	Reliance
2	Ti-alloy	0.017	Coaxial	3	Dentaurum
3	Ti-alloy	0.020	Coaxial	3	Dentaurum
4	Stainless steel alloy	0.015	Twist	3	Dentaurum
5	Stainless steel alloy	0.018	Twist	3	Dentaurum
6	Stainless steel alloy	0.020	Twist	3	Dentaurum
7	Stainless steel alloy	0.015	Coaxial	5	Dentaurum
8	Stainless steel alloy	0.018	Coaxial	5	Dentaurum
9	Stainless steel alloy	0.011x0.027	Braided	8	Reliance

With the aim of comparing the influence of wire size, we distinguished three groups of wires.

Group A: stainless steel – coaxial wire – sizes 0.015i and 0.018i

Group B: stainless steel – twisted wire – sizes 0.015i and 0.020i

Group C: Ti-alloy - coaxial wire – sizes 0.017i and 0.020i

In order to evaluate the effect of coiling of stainless steel wire on artifact formation, we compared coaxial and twist wires of the same size – 0.015i and 0.018i. Subsequently, one sample from the group of round wires was compared with a rectangular braided retainer wire. As a representative sample for the round ones, a twisted stainless steel wire with a size of 0.020i was selected. The thickness was intentionally chosen that the wire's cross-sectional area would be as close as possible to the cross-sectional area of the rectangular wire.

Statistical analysis

The measurement system used in this study (including people, their blinding and errors and the method of measurement) was assessed according to Measurement System Analysis (MSA) standards. The results were processed using statistical tests T-test and ANOVA in SPSS Version 20. All tests were conducted at a significance level of $\alpha = 0.05$.

Results

Measurement System Analysis (MSA) that we used includes the assessment of Repeatability – equipment variation (EV), and Reproducibility – appraiser variation (AV). The criterion for unconditional capability is that the value of the combined parameter – Repeatability and Reproducibility (R&R) must be below 10%. Our measurement system achieved 8.55%, which means it is suitable for assessing the size of artifacts on MRI images.

Comparison by type of alloy

The mean size of artifact among Au-alloy was 0.5 mm, for Ti-alloy 4.43 ± 0.68 mm and for stainless steel wires 31.81 ± 9.47 mm. The differences between the sizes of artifacts among different alloys are statistically significant ($p = 0.001$). Therefore, type of metal used in the retainer wire affects the size of artifacts. Chart 1 illustrates the difference in their sizes.

Comparison by wire size

In Group A, we can describe an increase in artifact size for stainless steel coaxial wires. For the 0.015 inch wire, the mean was 30.53 ± 1.69 mm and increased to 38.23 ± 2.05 mm for the 0.018 inch wire. In Group B, among stainless steel twist wires we can also identify an increase in artifact size. For the 0.015 inch wire, the mean was 35.61 ± 2.61 mm and increased to 38.28 ± 3.55 mm for the 0.020 inch wire. In Group C, in Ti-alloy coaxial retainers, the size

of the wire did not significantly affect the size of the artifact (4.45 ± 0.81 mm in 0.017i and 4.41 ± 0.56 mm in 0.020i).

Comparison by fabrication method

In the group of 0.015i wires, the twisted wires had a larger artifact size compared to the coaxial ones, with a mean difference of 5.07 mm. Paradoxically, in the group of 0.018i retainer wires, the average size of the artifact was higher for the coaxial wires compared to the twisted ones, with an average difference of 2.19 mm. Despite statistically significant results, from the available data it is not clear whether a coaxial- or twist- winding of the wire contributes more to the artifact formation. For thinner wires, the results favor the twisted type, while for thicker ones, the coaxial type of coiling created larger artifacts. In the next phase, the reference wire from the group of round stainless steel wires (twisted wire of 0.020i), was compared with a rectangular braided steel wire of dimensions 0.011x0.027i. The artifacts created by the rectangular wire had a mean size of 12.19 ± 1.17 mm. Compared to the round wire, the artifacts are significantly smaller. The twisted wire created artifacts of size 38.28 ± 3.55 mm (Image 4).

Discussion

In the scientific literature, there are some studies on the issue of orthodontic materials and MRI imaging. When authors have chosen this area of research, they mainly examined brackets, with retainer wires being studied only sporadically. They (1,4) found that steel brackets cause significant artifacts. Costa et al. (3) went even further, recommending the removal of fixed orthodontic appliances before MRI examination when confirming the diagnosis of epilepsy. This is because significant changes occur in the MR slices of the temporal and frontal brain lobes, preventing accurate diagnosis. In his retrospective study, he further revealed artifacts in 6% of head scans and found that orthodontic appliances were responsible for 78% of them. The materials of fixed retainers were rarely evaluated in studies. Therefore, with our study we attempted to contribute our own findings to this area of research.

The wire made of gold alloy was only evaluated by Shalish et al. (12) and Juerchott et al. (7), who, in agreement with our results, found that this material produces only limited artifacts.

Some authors claim that titanium alloys generally do not create artifacts (1,10). On the other hand, other studies proved that alloys of this metal are capable of creating certain distortions in the MRI (3,11). Costa explains the difference in study conclusions by the use of different types and amounts of alloy in individual experiments (3). Titanium itself has low magnetic susceptibility and is paramagnetic, therefore it augments external magnetic field. Even small interactions creating inhomogeneities in the magnetic field may result in artifact formation. Anyway, traces of other

metals in the alloy can affect interaction with MRI (1). It depends on the individual composition of the component how it specifically manifests in the MRI image. Regarding the formation of artifacts, the literature agrees that anatomically they are limited to the immediate vicinity of the component (2).

Our measurement results of phantoms with steel wires confirmed in agreement with others that stainless steel creates significant artifacts on MRI (1,4,12).

Like the thickness of the wire, the coiling method and its impact on MRI artifacts have not been specifically studied to date.

The impact of the increase in size of the wire seems to depend on the evaluated metal. An increase in artifact size was confirmed for round stainless steel wires. On the other hand, increase in size of Ti-alloy wires did not significantly affect the size of the artifact. This may be due to the fact that Ti-alloys generally create only minimal artifacts.

The difference in fabrication methods for twisted and coaxial wires could reveal different magnetic properties, which stainless steel itself does not possess. Our results are not conclusive in this matter. With the two evaluated wire thicknesses, the outcome favors the coaxial coiling in one set of the samples and the twisted coiling in another one. For the future, we recommend measurements with a greater number of compared wire thicknesses.

In the next part, we focused on comparing twisted and braided rectangular wires. Despite the same material and comparable cross section area, the size of artifacts in the studied samples varied significantly. A possible explanation is that the twisted wire is wound like a coil. In a strong magnetic field, it may cause greater disruption of its homogeneity compared to a braided wire. Given that the difference in artifact size between twisted and coaxial wire is minimal, we assume that this argument can also be applied to coaxial wire. However, these hypotheses should be verified by further research.

Conclusion

The results of this study demonstrate, that under in vitro conditions, the type of alloy used for retainer wires affects the artifact size in MRI scans. We also conclude the positive relationship between the increase in size of the wire and the artifacts in stainless steel wires. Finally, we found significant difference in the artifact size between twisted and braided stainless steel wires.

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Obrazová príloha

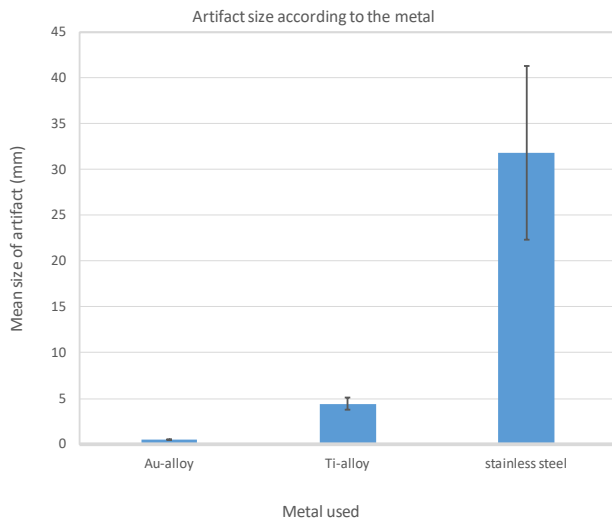


Image 1. Signal loss (artifact) due to presence of fixed orthodontic appliance (source: archive of 2nd department of Radiology, Faculty of medicine, Comenius University)



Image 2. Fixed orthodontic retainer (source: author's archive)

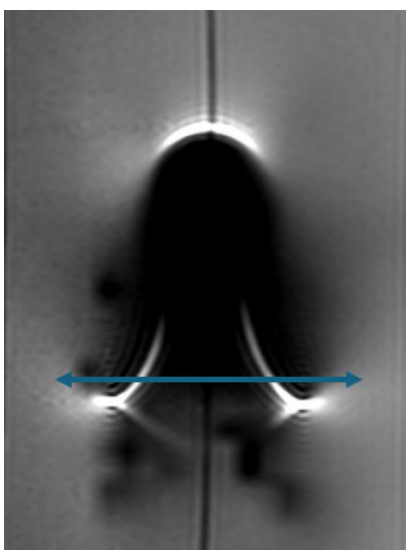


Image 3. Artifact measurement

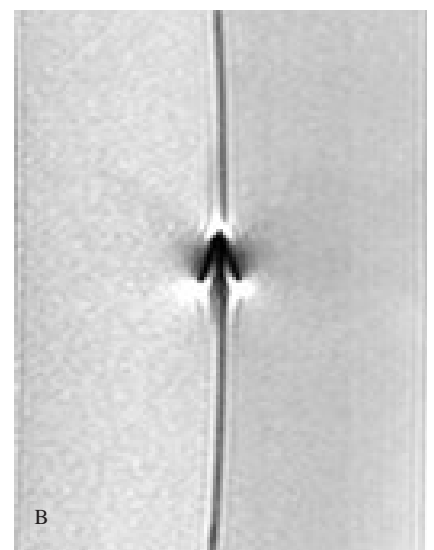
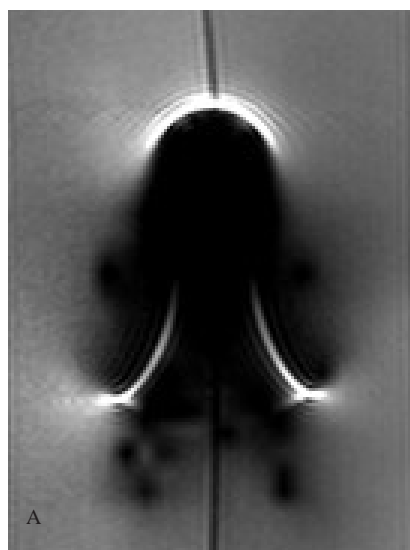


Image 4. Comparison of artifact size in twisted (A) and braided (B) stainless steel wire