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Orthodontic appliances and MR image artefacts: An exploratory in vitro and in vivo study using 1.5-T and 3-T scanners

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ABSTRACT

Purpose: The aim of this study was to assess the artefacts of 12 fixed orthodontic appliances in magnetic resonance images obtained using 1.5-T and 3-T scanners, and to evaluate different imaging sequences designed to suppress metal artefacts.

Materials and Methods: In vitro, study casts of 1 adult with normal occlusion were used. Twelve orthodontic appliances were attached to the study casts and scanned. Turbo spin echo (TSE), TSE with high readout bandwidth, and TSE with view angle tilting and slice encoding for metal artefact correction were used to suppress metal artefacts. Artefacts were measured. In vivo, 6 appliances were scanned: 1) conventional stainless-steel brackets; 2) nickel-free brackets; 3) titanium brackets; 4) a Herbst appliance; 5) a fixed retainer; and 6) a rapid maxillary expander. The maxilla, mandible, nasopharynx, tongue, temporomandibular joints, and cranial base/eye globes were assessed. Scores of 0, 1, 2, and 3 indicated no artefacts and minor, moderate, and major artefacts, respectively.

Results: In vitro, titanium brackets and the fixed retainer created minor artefacts. In vivo, titanium brackets caused minor artefacts. Conventional stainless-steel and nickel free brackets, the fixed retainer, and the rapid maxillary expander caused major artefacts in the maxilla and mandible. Conventional stainless-steel and nickel-free brackets caused major artefacts in the eye globe (3-T). TSE with high readout bandwidth reduced image artefacts in both scanners.

Conclusion: Titanium brackets, the Herbst appliance, and the fixed retainer caused minor artefacts in images of neurocranial structures (1.5-T and 3-T) when using TSE with high readout bandwidth. ***(Imaging Sci Dent 2021; 51: 63-71)***

KEY WORDS: Artifacts; Magnetic Resonance Imaging; Orthodontic Appliances; Skull

Introduction

Magnetic resonance (MR) imaging of the head is a non-invasive technology that produces 3-dimensional anatomical images without involving the use of ionizing radiation. MR imaging is widely used in medicine, especially for soft-tissue imaging. In dentistry, MR imaging is applied when questions arise about soft tissue changes, such as in cases of disc displacement in the temporomandibular joints, development of odontogenic tumors, and pathology of the salivary glands.[1-5]

An MR scanner creates a strong magnetic field, which exerts powerful forces on objects made of metals and alloys with ferromagnetic properties.[6] Several metallic implants create inhomogeneity of the magnetic field, thereby generating artefacts in MR images.[7] These artefacts appear as geometric distortions and as black voids or bright spots of signal pile-up in the images.[8] The severity and size of the artefacts depend on the magnetic properties, spatial orientation, and size of the implants.[9,10]

In orthodontics, approximately 30% to 35% of adoles-

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cents need to be treated with a fixed orthodontic appliance.[11,12] These appliances are mostly made of stainless steel, but appliances of titanium, ceramic, or composite materials are also used. After treatment, a fixed retainer of stainless steel is commonly bonded to the anterior teeth to maintain the treatment result.

It has been shown that in patients who underwent MR imaging for treatment planning under circumstances not related to dental or orthodontic care, the size and shape of artefacts seemed to be dependent on the orthodontic appliances.[13-15] If it is suspected that an appliance might create artefacts, thus jeopardizing the possibility to detect normal anatomy or pathological changes in the area of interest, the appliance or retainer must be removed before the MR scan. Removal of the appliance increases the risk for hard-tissue injuries, and increases the cost of treatment.[16,17]

To reduce the size of the artefacts, several techniques have been developed for 1.5-T and 3-T scanners. The basic technique is to increase the receiver bandwidth of a standard imaging sequence. More advanced techniques, requiring customized pulse sequences, include view angle tilting (VAT) and slice encoding for metal artefact correction (SEMAC). VAT can correct in-plane distortions, while the SEMAC technique combines VAT with the correction of artefacts perpendicular through the imaging plane.[18-20] In comparison to conventional MR sequences, these techniques have been shown to reduce artefacts and to improve diagnostic image quality.[21]

Although 1.5-T scanners are routinely used, 3-T scanners have become a common alternative because they provide higher image resolution and improved image quality. However, 3-T scanners may also have disadvantages with regard to metal artefacts. The extent of artefacts increases with the strength of the magnetic field, which has stimulated discussions on whether an orthodontic appliance compatible with a 1.5-T scanner is also necessarily compatible with a 3-T MR scanner.[17,22]

Previous investigations of orthodontic appliances and artefacts on MR images of the head and neck have primarily been performed using 1.5-T or 3-T scanners. However, no study seems to have compared artefacts caused by orthodontic appliances between these 2 types of scanners. Thus, the impact of different orthodontic appliances on MR images and techniques to reduce artefacts in images obtained using 1.5-T and 3-T scanners remains a topic of discussion, and clinical guidelines or consensus seems not to be available.

The primary aim of the present study was to assess the propagation of artefacts created by commonly used fixed orthodontic appliances scanned in 1.5-T and 3-T scanners, respectively. The secondary aim was to evaluate 2 types of imaging sequences designed for the suppression of metal artefacts in the 1.5-T and 3-T scanners to determine whether these sequences yield improvements in image quality.

Materials and Methods

Twelve commonly used appliances were selected (Table 1). The appliances were prepared for scanning in a 1.5-T scanner and a 3-T scanner, respectively. The 5 appliances that created the largest spread of artefacts in vitro, as well as 1 commonly used retention appliance, were further investigated in vivo.

All evaluations were performed at the Department of Radiology, Malmö University, Sweden from February to April 2017. The Regional Ethical Research Board in Lund, Sweden approved the study, which was conducted in accordance with the Declaration of Helsinki (Dnr. 2016/831).

In vitro study

Twelve duplicates of a study cast of 1 healthy 28-year-old volunteer male subject with 28 permanent teeth were used. The casts were made of calcium sulfate hemihydrate (COECAL dental stone type III; GC America Inc., Alsip, IL, USA). The orthodontic appliances, in translucent plastic boxes, were attached to the study casts with methyl acetate glue. The boxes were filled with water, and to increase the signal from the water and to mimic soft tissue properties, 6 mL of a 0.5 M gadolinium (Gd) contrast agent was added to 10 L of water (Dotarem®, Guerbet, Roissy, France), corresponding to a Gd concentration of 0.3 mM. To control for potential safety hazards, the included appliances were checked with a conventional bar magnet for ferromagnetism before placement in the MR scanner.

The translucent plastic boxes containing the orthodontic appliances were scanned in the 1.5-T scanner with spine matrix and body matrix coils (1.5 T: MAGNETOM Avanto-Fit, Siemens Healthineers, Erlangen, Germany). Three imaging sequences designed for suppression of metal artefacts were tested: A: standard turbo spin echo (TSE), B: TSE with high readout bandwidth, and C: TSE with VAT and SEMAC. A standard TSE sequence with moderate readout bandwidth was performed as a reference.

The orthodontic appliances scanned in the 1.5-T scanner were further examined in the 3-T scanner (3 T: MAGNETOM Trio, Siemens Healthcare, Erlangen, Germany). For the 3-T scanner, 2 imaging sequences designed for suppression of metal artefacts were tested: 1) TSE and 2) TSE with high readout bandwidth. Coronal multi-slice, images

Table 1. Fixed orthodontic appliances examined in vitro in a 1.5-T scanner

Additional appliance	Production company	Type of material, composition of weight %
Casted rapid maxillary expander	Unitek Lab	C ≤ 0.10, Si ≤ 1.0, Mn ≤ 2.0, Cr 17.0-19.0, Mo -, Ni 8.0-10.0, P ≤ 0.045, S ≤ 0.015-0.35, others N ≤ 0.11
Nickel free bracket	Orto-Pro.	Cu 0.0-5.0, Co 0.0-37.0, Mo 0.0-12.0, Mn 0.0-23.0, Cr 13.0-23.0, Al 0.0-5.0, Fe 0.0-80.0,
Casted Herbst appliance	Hyrax screw, see below	C ≤ 0.07, Si ≤ 1.0, Mn ≤ 2.0, Cr 17.0-19.5, Mo -, Ni 8.0-10.5, P ≤ 0.045, S ≤ 0.03, others N ≤ 0.11
Conventional stainless-steel brackets	3M Unitek	C ≤ 0.03, Si ≤ 1.0, Mn ≤ 2.0, Cr 17.0-19.0, Mo ≤ 2.5-3.0, Ni 12.5-15.0, P ≤ 0.045, S ≤ 0.025, others N ≤ 0.11
Titanium brackets	Sweorto	Titanium
Gold chain	Sweorto	Gold 18K
Banded rapid maxillary expander	3M, Unitek	C ≤ 0.08, Si ≤ 2.0, Mn ≤ 2.0, P ≤ 0.04, S ≤ 0.02, Ni 6.0-9.5, Cr ≤ 16-19, Mo ≤ 0.8
Ceramic brackets	3M	Monocrystalline aluminum oxide
Palatal mini-screws	Ortho-easy Forestadent	Titanium
Fixed retainer	Ortopro AB MASEL	C ≤ 0.08, Si ≤ 1.0, Mn ≤ 2.0, P ≤ 0.04, S ≤ 0.03, Ni 8.0-10.5, Cr ≤ 18-20%
Buccal mini-screws	Orthod, Promedia	Titanium
Molar bands	3M Unitek	C ≤ 0.08, Si ≤ 1.0, Mn ≤ 2.0, P ≤ 0.05, S ≤ 0.03, Ni 8.0-10.5, Cr ≤ 18.0-20.0

Table 2. Magnetic resonance imaging sequence parameters for the in vitro scans

	TSE reference	TSE high bandwidth (VAT)	TSE VAT + SEMAC
TR	950 ms	950 ms	950 ms
TE	9 ms	5 ms	6 ms
Turbo factor	7	7	7
SEMAC factor	−	−	12
Slice thickness	3 mm, no gap	3 mm, no gap	3 mm, no gap
Number of slices	15	15	15
Slice orientation	Coronal	Coronal	Coronal
Field of view	$23 \times 17.2\ cm^2$	$23 \times 17.2\ cm^2$	$23 \times 17.2\ cm^2$
Matrix	320 × 240	320 × 240	320 × 240
Image resolution	$0.7 \times 0.7\ mm^2$	$0.7 \times 0.7\ mm^2$	$0.7 \times 0.7\ mm^2$
Phase-encoding direction	R-L	R-L	R-L
Averages	3	6	1
Receiver bandwidth	170 Hz/pixel	1.5 T: 977 Hz/pixel, 3 T: 781 Hz/pixel	977 Hz/pixel
Scan time	3:23 min	3:22 min	3:39 min

TSE: turbo spin echo, VAT: view angle tilting, SEMAC: slice encoding for metal artifact correction, R-L: right-left

were acquired, which covered the full volume of the casts. The details of the 3 different imaging sequences are given in Table 2.

The images were exported in Digital Imaging and Communications in Medicine format and the artefacts in the MR images were assessed using the ImageJ software (National Institute of Health, Bethesda, MD, USA). The extent of the artefacts was measured in centimeters perpendicular and parallel to the appliances. One rater assessed the artefacts.

In vivo study

One 28-year-old male volunteer was recruited. The height

Table 3. Magnetic resonance imaging sequence parameters for the in vivo scans

	TSE SAG	TSE COR	TSE VAT + SEMAC SAG	TSE VAT + SEMAC COR
TR	592 ms	404 ms	592 ms	404 ms
TE	5-8 ms*	5-8 ms*	6 ms	6 ms
Turbo factor	3	3	3	3
SEMAC factor	–	–	10	10
Slice thickness	4 mm, 0.4 mm gap	4 mm, 0.8 mm gap	4.5 mm, no gap	5 mm, no gap
Number of slices	13	15	13	15
Field of view	21×21 cm^2	21×21 cm^2	21×21 cm^2	21×21 cm^2
Matrix	320×256	320×256	320×256	320×256
Image resolution	0.7×0.8 mm^2	0.7×0.8 mm^2	0.7×0.8 mm^2	0.7×0.8 mm^2
Phase-encoding direction	A-P	R-L	A-P	R-L
Averages	2	2	1	1
Receiver bandwidth	Reference: 284 Hz/pixel, high bandwidth: 781 Hz/pixel	Reference: 284 Hz/pixel, high bandwidth: 781 Hz/pixel	781 Hz/pixel	781 Hz/pixel
Scan time	2:14 min	1.5T: 1:32 min 3T: 3:02 min	4:17 min	2:56 min

TSE: turbo spin echo, SAG: sagittal orientation, COR: coronal orientation, VAT: view angle tilting, SEMAC: slice encoding for metal artefact correction, *: TE varied depending on bandwidth and between 1.5 T and 3 T, A-P: anterior-posterior, R-L: right-left

of the volunteer was 180 cm, and his weight was 75 kilograms. The volunteer had normal facial skeletal and dental relationships. All 28 permanent teeth were erupted and no restorative, prosthodontic, or endodontic treatment had been performed. The following appliances were examined in vivo: 1) nickel-free brackets; 2) conventional stainless-steel brackets; 3) titanium brackets; 4) a banded Rapid Maxillary Expansion appliance; 5) a fixed retainer, and 6) a casted Herbst appliance. The comprehensive appliances were bonded to maxillary and mandibular acrylic aligners (A + plastic, .040 × 120 mm Circle 100, Dentsply, York, PA, USA) inserted orally. The banded rapid maxillary expansion appliance was bonded just to a maxillary acrylic aligner.

The same 1.5-T and 3-T scanners, and the TSE and the TSE with high readout bandwidth for artefact suppression sequences, were used as in the vitro examinations. To evaluate the extent of the metal-induced artefacts, images were acquired in sagittal and coronal orientations. The imaging sequences used in vitro were also used in vivo, but with slightly different parameters, as shown in Table 3.

The MR images were assessed by an experienced specialist in oral and maxillofacial radiology. The following specific anatomical structures were assessed: 1) maxilla, 2) mandible, 3) nasopharynx, 4) tongue, 5) temporomandibular joints, 6) cranial base, and 7) eye globes. The size of the artefacts in relation to the specific anatomical structures was evaluated using a 4-point scale, according to a modified index proposed by Zhylich et al.[23] 0: no artefact; 1: minor artefact, no impact on the possibility to evaluate the anatomical structures; 2: moderate artefact, the anatomical structure is just visible; 3: major artefact, the anatomical structure is not visible. When in doubt regarding the size of the artefact in relation to the specific structure, the issue was discussed with another experienced specialist in craniofacial radiology until a consensus was reached.

Statistical analysis

In this study, intra-observer agreement was determined by a single re-evaluation of the first sequence for all the appliances 1 month after the first evaluation. The Cohen kappa was used to measure the level of intra-examiner agreement.[24] The intra-rater reliability was 0.62, which was interpreted as good agreement.

Results

In vitro study

In both the 1.5-T and the 3-T scanners, only minor artefacts were created by the titanium brackets (1.0 cm and 0.6 cm, respectively) when measuring perpendicular and parallel to the magnetic field in the images (Fig. 1). The largest artefacts were observed for the nickel-free brackets

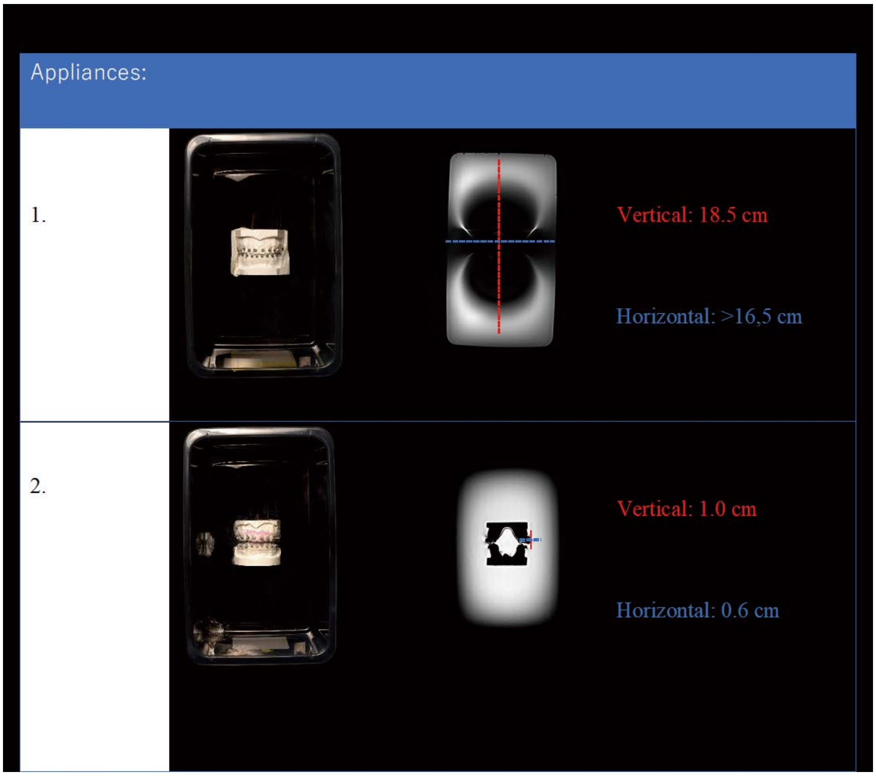

Fig. 1. Magnetic resonance imaging obtained using a 3-T scanner of study casts with brackets (in vitro). The large artefact is created by an Orto-Pro nickel-free bracket (1) and the small artefact is created by a titanium bracket (2).

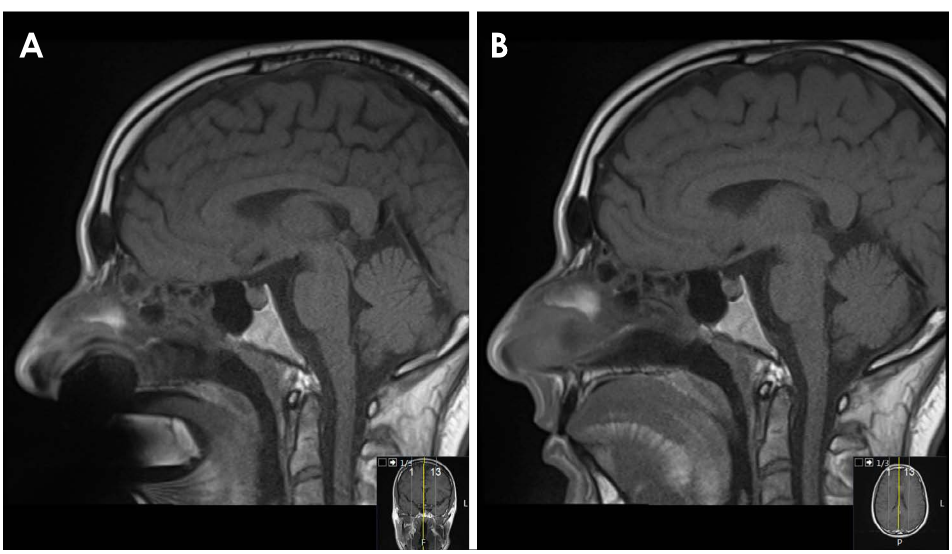

Fig. 2. A. Magnetic resonance image (MRI) obtained in a 3-T scanner of an object with a conventional stainless-steel bracket (in vivo). B. MRI obtained in a 3-T scanner of an object without brackets (in vivo).

(18.5 cm and >16.5 cm, respectively) followed by the stainless-steel brackets (16.0 cm and 16.5 cm, respectively), the banded rapid maxillary expansion appliance (15.0 cm and 15.0 cm, respectively), and the casted rapid maxillary expansion appliance (13.5 cm and 10.0 cm, respectively). Using the imaging sequences for suppression of metal artefacts during the 1.5-T and the 3-T scans resulted in a reduction of the artefacts in the images of both MR scanners.

In vivo study

Thirty MR scans, 18 using the 1.5-T scanner and 12 using the 3-T scanner, were performed. None of the appliances created major artefacts (score 3) in the area of the TMJ or anterior part of the cranial base when using TSE with high readout bandwidth in either scanner. Instead, it was more common for the appliances to create major artefacts (score 3) in the structures of the pituitary gland in the images obtained using the 3-T scanner (Figs. 2A and B) than in the images obtained using the 1.5-T scanner (Tables 4 and 5).

In the 1.5-T images, the titanium brackets caused moderate artefacts (score 2) in the maxilla and mandible when only standard TSE was used. The artefacts decreased in extent (score 1) when TSE with VAT and SEMAC was used (Table 4).

In the images of the 3-T scanner, the titanium brackets created major artefacts (score 3) in the structures of sella turcica/pituitary gland when standard TSE was used and moderate artefacts (score 2) when TSE with high readout bandwidth was used (Table 5).

In the 1.5-T images, the conventional stainless-steel brackets and the nickel-free brackets caused major artefacts (score 3) in the structures of the maxilla when all 3 imaging sequences for suppression of metal artefacts were used. In addition, the nickel-free brackets also caused major artefacts (score 3) in the structure of the tongue (Table 4).

In the 3-T images, the conventional stainless-steel brackets and the nickel-free brackets caused major artefacts (score 3) in the structures of the maxilla and the mandible when standard TSE and TSE with high readout bandwidth were used. The conventional stainless-steel brackets also caused major artefacts (score 3) on the structures of the nasopharynx, tongue, sella turcica, and the eye globe when the 2 imaging sequences for suppression were used (Table 5).

In the 1.5-T images, the casted rapid maxillary expansion appliance and the fixed retainer caused major artefacts (score 3) in the structures of the maxilla when all 3 imaging sequences for artefact suppression were used. In addition, the casted rapid maxillary expansion appliance also caused major artefacts (score 3) in the structure of the tongue. The fixed retainer and the casted Herbst appliance caused major artefacts (score 3) on the structures of the maxilla when standard TSE was used. The fixed retainer caused major artefacts (score 3) when TSE with VAT was used. When SEMAC was added, the fixed retainer caused moderate artefacts (score 2) (Table 4).

In the 3-T images, the casted rapid maxillary expansion appliance and the fixed retainer caused major artefacts (score 3) in the structures of the maxilla and the mandible when standard TSE and TSE with high readout were used.

Discussion

This study showed that titanium brackets created artefacts in MR images of the anatomical structures of the head, but to a lesser degree than conventional and nickel-free brackets, the casted Herbst appliance, fixed retainers, and the casted rapid maxillary expansion appliance.

Table 4. Assessment of artefacts in relation to appliances obtained in the 1.5 T scanner (in vivo)

Anatomical structurers	Nickel-free brackets			Conventional stainless-steel brackets			Titanium brackets			Casted rapid maxillary expander			Fixed retainers			Casted Herbst		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Maxilla	3	3	3	3	3	3	2	2	1	3	3	3	3	3	2	3	2	2
Mandible	3	3	3	3	3	3	2	2	1	3	3	3	2	2	2	2	1	2
Nasopharynx	2	1	1	1	1	1	1	1	0	2	1	1	0	0	0	1	0	0
Tongue	3	3	3	2	2	2	2	1	1	3	3	3	1	1	3	1	1	3
TMJ	1	1	1	2	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Cranial base, clivus	2	1	1	1	1	1	2	1	1	1	1	1	0	0	0	0	0	0
Sella turcica/ pituitary gland	2	1	1	2	1	1	2	1	1	1	1	1	0	0	0	0	0	0
Eye globe	2	1	1	2	2	2	2	1	1	0	0	0	0	0	0	0	0	0

0: no artefact, 1: minor artefact, no impact on the diagnostic performance, 2: moderate artefact, the structure is just visible, 3: major artefact, the structure is not visible, A: turbo spin echo (TSE) with moderate readout bandwidth, B: TSE with high readout bandwidth, C: TSE with view angle tilting (VAT) and slice encoding for metal artefact correction (SEMAC). TMJ: temporomandibular joint.

Table 5. Assessment of artefacts in relation to appliances obtained in the 3-T scanner (in vivo)

Anatomical structurers	Nickel-free brackets		Conventional stainless-steel brackets		Titanium brackets		Casted rapid maxillary expander		Fixed retainers		Casted Herbst	
	A	B	A	B	A	B	A	B	A	B	A	B
Maxilla	3	3	3	3	2	1	3	3	3	3	3	2
Mandible	3	3	3	3	2	2	3	3	3	3	2	2
Nasopharynx	2	2	3	3	2	2	2	1	2	1	2	1
Tongue	3	3	3	3	1	1	3	3	2	1	3	1
TMJ	1	1	2	2	1	1	2	1	0	0	0	0
Cranial base, clivus	2	2	2	2	2	2	2	2	2	2	2	1
Sella turcica/pituitary gland	2	2	3	3	3	2	3	2	3	1	3	1
Eye globe	3	3	3	3	2	1	1	1	2	1	2	1

0: no artefact, 1: minor artefact, no impact on the diagnostic performance, 2: moderate artefact, the structurer is just visible, 3: major artefact, the structure is not visible, A: turbo spin echo (TSE) with moderate readout bandwidth, B: TSE with high readout bandwidth. TMJ: temporomandibular joint

To our knowledge, this study is the first to investigate the degree of artefacts caused by commonly used orthodontic fixed appliances in images obtained using 1.5-T and 3-T scanners with different combinations of imaging sequences for suppression of metal artefacts. Currently, 1.5-T scanners are most commonly used. However, due to the higher image resolution and signal-to-noise ratio at 3-T, 3-T scanners have advantages that have contributed to their increasingly frequent use.

In both scanners, the titanium brackets created less extensive image artefacts than were caused by the conventional stainless-steel and nickel-free brackets and the casted rapid maxillary expansion appliance. This is in accordance with previous studies on titanium brackets and artefacts.[15,19,25] Interestingly, the Herbst appliance also created less extensive artefacts in the MR images of the 1.5-T and the 3-T scanners than several of the other appliances. The metal composition of the Herbst appliance is not particularly different from that of the rapid maxillary expansion appliance, conventional stainless-steel brackets, and nickel free brackets. Thus, the shape and position of the appliance might have been favorable for the limitation of artefacts in these images, as has been reported for other types of dental implants.[26]

The MR scanners used in the present study were produced by Siemens. General Electrics is another vendor that manufactures scanners with other suppression sequences, such as multi-acquisition with variable resonance image combination selective (MAVRIC SL). In a previous study on artefacts in MR images generated by metal hip implants, the MAVRIC SL technique led to smaller artefacts than were observed using VAT and SEMAC.[27] A potential refinement of this study would be to evaluate the MAVRIC-SL technique and its capacity to reduce artefacts created by orthodontic appliances. The suppression technique was examined in a previous study of patients with other types of metal implants, and the results seem promising.[28] However, it was shown in the present study on orthodontic appliances that the different imaging sequences designed for suppression of metal artefacts had the capacity to reduce image artefacts in several craniofacial structures.

The impact of the acrylic aligners on development of artefacts was not assessed, which might be a shortcoming of this study. However, aligners with the same dimensions were used in all the investigations, and it has been previously shown that an Essix appliance created minimal artefacts in MR images obtained using a 1.5-T or a 3-T scanner. Moreover, additional investigations of acrylic aligners would have increased the burden placed on the volunteer subject.

Treatment with fixed orthodontic appliances is common, and the demand for treatment will certainly increase worldwide in the future.[29] These treatments often take 18 months or more, and after removal of the orthodontic appliance, patients commonly wear fixed retainers to maintain the treatment results for several years. Thus, clinicians will likely encounter increasingly frequent occasions when it is necessary to consider the impact of metals and the risk that artefacts on MR images may impair diagnostic accuracy.

The common guidelines that say all stainless-steel orthodontic appliances must be removed before MR scans using a 1.5-T or 3-T scanner, as the appliances might produce large image artefacts, can be partly rejected, since the artefacts from the titanium brackets, the casted Herbst appliance, the casted rapid maxillary expansion appliance, and the fixed retainers showed relatively limited artefacts, especially in the 1.5-T scanner with TSE with VAT and SEMAC. In addition, the impact on the diagnostic performance on structures beyond the maxilla and the mandible seems to be less crucial for images performed in a 1.5-T scanner. However, it is important to discuss the impact of the artefacts created by the orthodontic appliance on the MR image with the patient's physician, since artefacts may result in under-diagnosis or difficulties in diagnosis, thereby posing a risk for delayed treatment.

All 6 orthodontic appliances in the in vivo examinations were investigated in a single healthy young adult man, which might be a limitation of this study. Nonetheless, the artefacts created by the different orthodontic appliances in the 1.5-T and 3-T scanners are easier to compare when the scanning is performed in just 1 subject. The 1.5-T and 3-T MR scanners and the orthodontic appliances examined in the present study are routinely used worldwide.

In conclusion, this study showed that fixed orthodontic appliances made of titanium, the casted Herbst appliance, and fixed retainers created less extensive image artefacts on the craniofacial structures than nickel-free and conventional stainless-steel brackets when standard TSE with VAT and SEMAC was used (in the 1.5-T scanner). This study also showed that the casted Herbst appliance and the fixed retainers caused no artefacts in 1.5-T images in the cranial structures superior to the maxilla when using TSE with high readout bandwidth. Images of appliances obtained using the 3-T scanner had, in general, a higher number of major artefacts (score 3) than images obtained using the 1.5-T scanner. These results indicate that titanium brackets, the Herbst appliance, and fixed retainers do not need to be removed before MR scanning of the neuro-cranial structures when using a 1.5-T scanner or a 3-T scanner and applying TSE with high readout bandwidth for artefact suppression.

Conflicts of Interest: None

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