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Artifacts Caused by Orthodontic Appliances on Magnetic Resonance Imaging: Awareness and Knowledge Level of Maxillofacial Radiologists and Orthodontists

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ABSTRACT

Objective: Artifacts caused by orthodontic appliances on Magnetic Resonance Imaging (MRI) can affect the image quality and make diagnosis difficult. The debate is ongoing on whether orthodontic appliances should be removed to eliminate these problems. This study aimed to evaluate the awareness and knowledge level of dentists working in maxillofacial radiology and orthodontics about this subject through a questionnaire.

Methods: The questionnaire consisted of 20 items and four parts: A) Personal information, B) Awareness level about the artifacts and complications caused by orthodontic appliances on MRI, C) Knowledge level about the factors related to artifacts and complications caused by orthodontic appliances on MRI, and D) Preventive approaches. The questionnaire was prepared on Google Forms and sent to potential participants via e-mail. The Chi-square ($\chi 2$) test was used for the statistical analysis of the variables.

Results: Most participants were aware of the artifacts caused by orthodontic appliances on MRI (90.8%) (93.5% of maxillofacial radiologists and 88.5% of orthodontists) and thought that material type influenced the artifact formation (98.1%) (100% of maxillofacial radiologists and 96.3% of orthodontists). The percentage of participants with 1-5 years of experience who were aware of artifacts was less than those with more experience ($p = .033$). The percentage of orthodontists who referred patients for orthodontic appliance removal was higher than maxillofacial radiologists who requested the orthodontic appliance removal (93.5%>15%).

Conclusion: Simultaneously increasing demands for both orthodontic treatment and MRI in the society cause concerns about the MRI image quality due to artifacts on images of the head and neck region. The main output of this study is that dentists working in orthodontics and maxillofacial radiology have a high awareness and knowledge about the artifacts and complications caused by orthodontic appliances on MRI.

Keywords: Magnetic resonance imaging, artifacts, orthodontic appliances

1. INTRODUCTION

Magnetic Resonance Imaging (MRI) is a radiological diagnostic technique that uses radiofrequency energy instead of ionizing radiation, particularly in the evaluation of soft tissue lesions (1). On MRI, the artifact is defined as the distortion of signal intensity or voids unrelated to any identifiable anatomical basis in the resultant image (2). MRI artifacts include motion, saturation, chemical, and metal artifacts (2). Metallic objects in the patient's body can produce local inhomogeneities into the main magnetic field that cause artifacts on MRI (3). The factors affecting the severity of the artifact depend on the object's magnetic susceptibility (paramagnetic, diamagnetic, and ferromagnetic), spatial orientation, size (length and diameter), homogeneity, amount (number), and shape. Besides these, the distance between the Region of Interest (ROI) and the object, echo time, pulse sequence, magnetic field strength, imaging plane, and image resolution also have effects (3-7). Additionally, metallic objects can cause complications such as heating and movement during the Magnetic Resonance (MR) scan (8-11). Various strategies have offered to reduce the metal artifacts and complications, but it is impossible to completely overcome them (12).

MRI of the head and neck region is becoming commonly used for investigating oral and maxillofacial pathological lesions, temporomandibular joint disorders, in addition to other conditions (13). Dental implants, prostheses, and orthodontic appliances (e.g., fixed or removable orthodontic and maxillofacial orthopedic appliances) located in the oral cavity can cause artifacts on the MRI of these regions (14). The poor-quality images may lead to misdiagnosis or mismanagement of an ongoing treatment process (2). In conventional orthodontic treatment, two different types of archwires [Stainless Steel (SS) and Nickel-Titanium (Ni-Ti)] are usually attached to the SS brackets which are bonded to the teeth. Therefore, these metallic orthodontic appliances have a high potential to cause

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complications such as heating and movement during the MR scanning and artifacts on images (11). In recent years, among the general population, MRI referrals (15) and orthodontic treatments (16) have increased independently of each other. As a result, radiologists frequently request orthodontists to remove fixed metal orthodontic appliances, particularly before the head and neck region MRI (17). Although the responsibility for evaluating these risks lies primarily with the radiologist, they often do not have comprehensive knowledge about the magnetic susceptibility of the material of the orthodontic appliances. Consulting an orthodontist may often remain unsatisfactory due to similar lack of awareness and knowledge (18). In the past, although several studies have investigated the effects of the artifacts and complications caused by orthodontic appliances on MRI, the results are unclear because of the variety of materials of devices and examined regions (1,9,10,18-28). However, today, increasing data on the orthodontic appliance and MRI relationship leads to more precise judgments on the subject (13).

Removing and rebonding the orthodontic appliance during the ongoing orthodontic treatment process is time-consuming, costly, and laborious for the patient and orthodontist; also, it can damage the tooth enamel and affect the course of the treatment negatively (29). In studies examining the effect of orthodontic appliances that cause artifacts on image quality, the fact that the orthodontic appliance is close to the ROI and contains steel was shown as the reason for its removal (17,30). In contrast, according to the study that focused on the size of the artifact, it was related to the magnetic properties of the MRI device and the material type of orthodontic appliance (18). The decision to remove fixed orthodontic appliances before MRI creates a process that is affected by many factors and can cause many disadvantages, depending on the case. Orthodontists must decide between avoiding image artifacts and not affect the prognosis of ongoing orthodontic treatment. Maxillofacial and medical radiologists also experience the same difficulty in deciding which orthodontic appliance to request removal according to the ROI and its material type.

This study aimed to evaluate the level of awareness and knowledge of dentists working in orthodontics and maxillofacial radiology about artifacts and complications that orthodontic appliances may cause on MRI. The hypothesis of this study was "there was no difference between the awareness and knowledge level of dentists working in maxillofacial radiology and orthodontics about the artifacts caused by orthodontic appliances on MRI."

2. METHODS

This study was approved by the Gazi University Ethics Committee (date: 10/07/2020, number: 06), and all stages of the study were conducted in accordance with the Declaration of Helsinki. For this study, a special questionnaire was set up to investigate the level of awareness and knowledge about the MRI artifacts caused by orthodontic appliances. The questionnaire was designed to be responded to by dentists who were specialists or continuing their specialty training in orthodontics or maxillofacial radiology. Initially, the questionnaire was set up by an orthodontist and two maxillofacial radiologists with at least 15 years of professional experience, and the first version included 21 questions. It was then evaluated by an orthodontist and a medical radiologist who were blind to previous procedures, and a question was removed in line with their recommendations. Additionally, a face-to-face pre-test was conducted with five maxillofacial radiologists and five orthodontists; incomprehensible, misunderstood, or guiding questions were determined, and then the questionnaire was rearranged in line with these criticisms. After these stages, the questionnaire was carefully checked by the authors to ensure it did not contain any questions that contradicted each other or misdirected the participants.

The last version of the questionnaire consisted of 20 items and four parts: A) Personal information, B) Awareness level of dentists about the artifacts and complications caused by orthodontic appliances on MRI, C) Knowledge level of dentists about the factors related to artifacts and complications caused by orthodontic appliances on MRI, and D) Preventive approaches (Table 1). The questionnaire was prepared on Google Forms (Alphabet, Mountain View, California). It was sent via e-mail to the members of the Turkish Association of Orthodontists and the Turkish Society of Oral Diagnosis and Maxillofacial Radiology with permission. The members of these associations consist of specialists and those who continue their specialization training in dentistry faculties cross Turkey. The questionnaire was prepared in Turkish, then translated into English during the writing process. It was applied to 229 participants between August 08 and September 29, 2020.

2.1. Data Analysis

While determining the study's sample size, the G-Power analysis 3.1.0 package program was used. In the analysis, the power of the test was 0.80, $\alpha = 0.05$, and the effect size was 0.3. For the participant groups, a total of at least 204 volunteers, including 102 maxillofacial radiologists and 102 orthodontists, were planned to participate in the questionnaire.

The IBM SPSS package program (version 25) (SPSS Inc., Chicago, IL) was used for summarizing and analyzing the data. First, the numbers and percentages of the participants were listed according to their answers to the questionnaire. Then the necessary statistical analysis was made using the Chi-square (χ^2) test for the relationship between the two variables. Less than 0.05 as the *p*-value was taken as statistically significant.

3. RESULTS

A total of 229 dentists, 107 (46.7%) working in maxillofacial radiology and 122 (53.3%) in orthodontics, participated in this study. Table 1 shows the distribution of the responses given by the participants in numbers and percentages on the original questionnaire used in the study.

The relationship between the participants' awareness of the artifacts caused by orthodontic appliances on MRI

and their personal information is presented in Table 2. Regarding the awareness of artifacts, although the percentage of maxillofacial radiologists is higher than that of orthodontists and lecturers have a higher percentage than those in other titles, the differences were not statistically significant (p = 0.197, p = 0.637). However, regarding professional experience, the percentage of participants who were aware of the artifacts with 1-5 years of experience was less than the more experienced participants, and the difference was statistically significant (p = 0.033).

The relationship between the participant's awareness of the effect of orthodontic appliance material type on the artifact formation on MRI and the personal information of the participants is shown in Table 3. There was no statistically significant difference between being aware of the effect of the orthodontic appliance material type on the artifact formation on MRI and the specialty area (p = 0.052), title (p = 0.157), and professional experience (p = 0.188).

Table 4 shows the distribution of the participants from two different specialty areas who can encounter MRI artifacts caused by orthodontic appliances in clinical practice according to title and professional experience. In the orthodontic area, the percentage of research assistants with 1-5 years of experience referred patients for orthodontic appliance removal before MRI was lower than the more experienced specialists and lecturers, and the difference was statistically significant (p = 0.000, p = 0.001). Whereas, in maxillofacial radiology, the percentage of the requests for the removal of the orthodontic appliance from a patient under an orthodontic treatment before MRI did not make a statistically significant difference according to the title (p = 0.152) and professional experience (p = 0.109).

Table 1. *Distribution of the participants according to the questionnaire form and their responses, N (%) (N = 229)*

A) Personal information				
1. Age	Min; 25 Max; 64 Mean ± standard deviation; 34.6 ± 8.3			
				N (%)
2. Gender	Female			161 (70.3)
	Male			68 (29.7)
3. Specialty area	Maxillofacial radiology			107 (46.7)
	Orthodontics			122 (53.3)
4. Title	Research assistant			69 (30.1)
	Specialist dentist			76 (33.2)
	Lecturer			84 (36.7)
5. Professional experience	1-5 years			102 (44.5)
	6-10 years			54 (23.6)
	10+ years			73 (31.9)
B) Awareness level about the artifacts and complications caused by orthodontic appliances on MRI		**Specialty area**		**Total**
		Maxillofacial radiology	**Orthodontics**	
		N (%)	**N (%)**	
6. Are you aware of the artifacts that can be caused by fixed/removable orthodontic appliances on MRI?	Yes	100 (93.5)	108 (88.5)	208 (90.8)
	No	7 (6.5)	14 (11.5)	21 (9.2)
7. What complications do you know about orthodontic appliances other than artifacts on MRI? [Φ]	Soft and hard tissue injury due to the movement of the appliances (projectile effect)	72 (72.0)	75 (69.4)	147 (70.7)
	Soft and hard tissues thermal injury due to heating of appliances	82 (82.0)	73 (67.6)	155 (74.5)
	Orthodontic treatment failure due to bending of the archwire or unwanted tooth movements	61 (61.0)	46 (42.6)	107 (51.4)
8. Does the material type of the orthodontic appliance influence the artifact on MRI?	Yes	100 (100.0)	104 (96.3)	204 (98.1)
	No	0 (0.0)	4 (3.7)	4 (1.9)
9. Can the material selection of the orthodontic appliances be determined according to the patient's medical history and potential MRI needs?	Yes	85 (85.0)	94 (87.6)	179 (86.1)
	No	15 (15.0)	14 (13.0)	29 (13.9)
10. As a dentist working in orthodontics, have you had a patient who was referred for the removal of the brackets or any orthodontic appliance before MRI?	Yes	-	101 (93.5)	101 (93.5)
	No	-	7 (6.5)	7 (6.5)
11. As a dentist working in maxillofacial radiology, have you requested that a patient's bracket or any orthodontic appliance be removed before MRI?	Yes	15 (15.0)	-	15 (15)
	No	85 (85.0)	-	85 (85)

12. Who should make the final decision whether to remove any orthodontic appliance before MRI? Φ	Orthodontist	70 (70.0)	71 (65.7)	141 (67.8)
	Maxillofacial radiologist	86 (86.0)	67 (62.0)	153 (73.6)
	Medical radiologist	74 (74.0)	93 (86.1)	167 (80.3)
C) Knowledge level about the factors related to artifacts and complications caused by orthodontic appliances on MRI				
13. What are the effects of the artifact of orthodontic appliances on MRI? Φ	Only image quality is affected (minimal distortion)	67 (67.0)	74 (68.5)	141 (67.8)
	Diagnosis is also affected	96 (96.0)	92 (85.2)	188 (90.4)
14. In which region or regions do orthodontic appliances cause artifacts mostly on MRI? Φ	Brain	40 (40.0)	62 (57.4)	102 (49)
	TMJ	69 (69.0)	76 (70.4)	145 (69.7)
	Neck	45 (45.0)	71 (65.7)	116 (55.8)
	Maxillofacial	95 (95.0)	100 (92.6)	195 (93.8)
	Whole body	1 (1.0)	2 (1.9)	3 (1.4)
	In similar severity in every part of the body	1 (1.0)	0 (0.0)	1 (0.5)
15. Which of them influences the occurrence of artifacts or complications on MRI? Φ	Magnetic main field strength (1.5T, 3T, etc.)	94 (94.0)	70 (64.8)	164 (78.8)
	MR pulse sequence (Spin echo, Gradient echo, etc.)	59 (59.0)	26 (24.1)	85 (40.9)
	Weight of the MR images (T1, T2, etc.)	49 (49.0)	17 (15.7)	66 (31.7)
	Size of the FOV	46 (46.0)	28 (25.9)	74 (35.6)
	Thickness of the section	29 (29.0)	20 (18.5)	49 (23.6)
	Section plane	36 (36.0)	24 (22.2)	60 (28.8)
	Orthodontic appliance size	83 (83.0)	70 (64.8)	153 (73.6)
	Orthodontic appliance shape	53 (53.0)	29 (26.9)	82 (39.4)
	Material composition of the orthodontic appliance	92 (92.0)	84 (77.8)	176 (84.6)
	Magnetic susceptibility of the orthodontic appliance material	91 (91.0)	75 (69.4)	166 (79.8)
	Orientation of the orthodontic appliance	43 (43.0)	18 (16.7)	61 (29.3)
	Distance of the orthodontic appliance to the ROI	80 (80.0)	87 (80.6)	167 (80.3)
16. If you believe the material effect, what do you think is the least effective in artifact formation? Φ	Stainless steel	7 (7.0)	6 (5.6)	13 (6.3)
	Titanium	32 (32.0)	24 (22.2)	56 (26.9)
	Ceramic	50 (50.0)	81 (75.0)	131 (63.0)
	Stainless steel + Ceramic	5 (5.0)	2 (1.9)	7 (3.4)
	Nickel free stainless steel	4 (4.0)	6 (5.6)	10 (4.8)
	Nickel-titanium	11 (11.0)	16 (14.8)	27 (13.0)
	Chromium-cobalt	6 (6.0)	6 (5.6)	12 (5.8)
	Plastic	82 (82.0)	88 (81.5)	170 (81.7)
D) Preventive approaches				
17. What should be done to avoid artifacts and complications arising on MRI associated with orthodontic appliances? Φ	Removal of archwires	69 (69.0)	83 (76.9)	152 (73.1)
	Removal of retainers	38 (38.0)	41 (38.0)	79 (38)
	Removal of removable appliances	93 (93.0)	98 (90.7)	191 (91.8)
	Removal all types of brackets	9 (9.0)	25 (23.1)	34 (16.3)
	Removal stainless steel brackets only	59 (59.0)	68 (63.0)	127 (61.1)
	Checking the fixation of the fixed appliances attachments	56 (56.0)	38 (35.2)	94 (45.2)
18. What is your approach to your patients who will apply for the removal fixed orthodontic appliance or for consultation? Φ	Confirm the removal	15 (15.0)	32 (29.6)	47 (22.6)
	Tell the removal is unnecessary	12 (12.0)	9 (8.3)	21 (10.1)
	Decide according to the closeness of the ROI to the orthodontic appliance	74 (74.0)	89 (82.4)	163 (78.4)
	Confirm the MRI after necessary security measures have been taken for the orthodontic aspect	72 (72.0)	57 (52.8)	129 (62)
	Reconsider the MRI indication	25 (25.0)	36 (33.3)	61 (29.3)
19. What is the most important disadvantage of the bracket removal process to avoid artifact on MRI? Φ	Waste of time both for patient and dentist	77 (77.0)	104 (96.3)	181 (87)
	Financial loss	54 (54.0)	99 (91.7)	153 (73.6)
	Effect the prognosis of orthodontic treatment	62 (62.0)	80 (74.1)	142 (68.3)
	Damage of the dental tissues	73 (73.0)	60 (55.6)	133 (63.9)

20. What could be the forward-looking strategies to avoid MRI artifacts caused by orthodontic appliances? Φ	Using small-sized brackets with less magnetic susceptibility material (MR-safe)	89 (89.0)	90 (83.3)	179 (86.1)
	Shortening the scan time	32 (32.0)	28 (25.9)	60 (28.8)
	Scanning in lower magnetic strength	37 (37.0)	44 (40.7)	81 (38.9)
	Making the material selection of the orthodontic appliance according to the MRI potential in the light of the patient's medical history	81 (81.0)	91 (84.3)	172 (82.7)
	Using an artifact reduction software	81 (81.0)	74 (68.5)	155 (74.5)

Φ; Multiple-choice question

Abbreviations: MRI; Magnetic Resonance Imaging, TMJ; Temporomandibular Joint, MR; Magnetic Resonance FOV; Field of View, ROI; Region of Interest

Table 2. *Statistical analysis of the relationship between the participants' awareness of the artifacts that orthodontic appliances may cause on MRI and their personal information, N (%) (N = 229) (6th Question)*

Variables		Are you aware of the artifacts that can be caused by fixed/removable orthodontic appliances on MRI?				
		Yes	No	Total	x^2	*p*-value
		N (%)	N (%)	N (%)		
Specialty area	Maxillofacial radiology	100 (93.5)	7 (6.5)	107 (100)	1.666	0.197
	Orthodontics	108 (88.5)	14 (11.5)	122 (100)		
Title	Research assistant	61 (88.4)	8 (11.6)	69 (100)	0.901	0.637
	Specialist dentist	69 (90.8)	7 (9.2)	76 (100)		
	Lecturer	78 (92.9)	6 (7.1)	84 (100)		
Professional experience	1-5 years	87 (85.3)	15 (14.7)	102 (100)	6.844	0.033*
	6-10 years	51 (94.4)	3 (5.6)	54 (100)		
	10+ years	70 (95.9)	3 (4.1)	73 (100)		

**; The Chi-square statistic is significant at the 0.05 level*

Abbreviation: MRI; Magnetic Resonance Imaging

Table 3. *Statistical analysis of the relationship between the participants' awareness about the effect of the orthodontic appliance material type on artifact formation and their personal information, N (%) (N = 208) (8th Question)*

Variables		Does the material type of the orthodontic appliance influence the artifact on MRI				
		Yes	No	Total	x^2	*p*-value
		N (%)	N (%)	N (%)		
Specialty area	Maxillofacial radiology	100 (100)	0 (0)	100 (100)	3.776	0.052
	Orthodontics	104 (96.3)	4 (3.7)	108 (100)		
Title	Research assistant	60 (98.4)	1 (1.6)	61 (100)	3.706	0.157
	Specialist dentist	66 (95.7)	3 (4.3)	69 (100)		
	Lecturer	78 (100)	0 (0)	78 (100)		
Professional experience	1-5 years	86 (98.9)	1 (1.1)	87 (100)	3.348	0.188
	6-10 years	51 (100)	0 (0)	51 (100)		
	10+ years	67 (95.7)	3 (4.3)	70 (100)		

The Chi-square statistic is significant at the 0.05 level

Abbreviation: MRI; Magnetic Resonance Imaging

Table 4. *Statistical analysis of the clinical approaches of dentists from two different specialties to the orthodontic appliance-MRI artifact relationship according to title and professional experience, N (%) (N = 208) (10th and 11th Questions)*

Variables			Title			Professional experience		
			Research assistant	Specialist dentist	Lecturer	1-5 years	6-10 years	10+ years
As a dentist working in orthodontics, have you had a patient who was referred for the removal of the brackets or any orthodontic appliance before MRI?	**Yes**	**N (%)**	19 (73.1)	56 (100)	26 (100)	32 (82.1)	24 (100)	45 (100)
	No	**N (%)**	7 (26.9)	0 (0)	0 (0)	7 (17.9)	0 (0)	0 (0)
	Total	**N (%)**	26 (100)	56 (100)	26 (100)	39 (100)	24 (100)	45 (100)
	x^2		23.607			13.243		
	***p*-value**		0.000*			0.001*		

As a dentist working in maxillofacial radiology, have you requested that a patient's brackets or any orthodontic appliance be removed before MRI?	Yes	N (%)	2 (5.7)	3 (23.1)	10 (19.2)	5 (10.4)	3 (11.1)	7 (28)
	No	N (%)	33 (94.3)	10 (76.9)	42 (80.8)	43 (89.6)	24 (88.9)	18 (72)
	Total	N (%)	35 (100)	13 (100)	52 (100)	48 (100)	27 (100)	25 (100)
	x^2		3.762			4.425		
	p-value		0.152			0.109		

**; The Chi-square statistic is significant at the 0.05 level*
Abbreviation: MRI; Magnetic Resonance Imaging

4. DISCUSSION

In the literature, the artifacts and complications caused by orthodontic appliances on MRI were investigated in many studies (1,9,10,18-28). To the best of our knowledge, there is no published article evaluating the level of awareness and/or knowledge about factors that caused artifacts of dentists who had to decide whether to remove these appliances. This study was conducted to reflect the approach of dentists working in maxillofacial radiology and orthodontics to the artifacts and complications that orthodontic appliances may cause on MRI and the difficulties in deciding on the removal. The hypothesis of this study was supported as there was no difference between the awareness and knowledge level of dentists working in maxillofacial radiology and orthodontics about the artifacts caused by orthodontic appliances on MRI.

4.1. Level of Awareness About the Artifacts and Complications

Metal objects in the body, including the orthodontic appliances, cause artifacts on MRI (18). In this study, most participants were aware of the orthodontic appliance-related artifacts on MRI (90.8%). When it was scoped in more detailed regarding specialty area, title, and professional experience, the maxillofacial radiologists, lecturers, and 10+ years of experience participants' awareness level was higher. However, only for professional experience, the difference was statistically significant. If participants were unaware of metal artifacts on MRI (6th question), they were forced to stop answering the questionnaire.

In addition to artifacts, there are other complications that metallic objects may cause during the MR scanning. The strong magnetic field of the MR system causes the sudden movement of ferromagnetic objects with great force (known as the projectile effect) (31). Even though it is claimed otherwise (31-33), the generated force cannot exceed the 60 N threshold required to deboned the fixed orthodontic appliances (9-11,34), but this may pose a risk, especially in patients with an insufficient bracket-tooth attachment (30). Another complication is the possible thermal damage of the oral cavity tissues caused by orthodontic appliances exposed to radiofrequency (8,21,35,36). However, depending on the manufacturer, the increase in temperature is between 0.2 and 3.04°C, which has a negligible effect (11,25). Despite reports of previous studies and manufacturers' assurances on these issues, most participants believed that the risk of thermal injury and motion injury was high. However, just half of the participants believed that orthodontic treatment could fail because of the bending of the archwire or unwanted tooth movements.

It has been stated that the material type influences the artifact (14). In this study, in line with this previous finding, most participants (98.1%) thought that the material type influenced artifact formation. Participants' specialty area, title, and professional experience did not change their approach to this subject.

Orthodontists may prefer non-metal appliances like ceramic brackets to SS brackets for patients who require periodic MRI evaluations (18). Since the patient's health history cannot always guide to possible MRI requirements, it would be reasonable to choose the type of SS that causes less artifact on MRI (37). In this study, most participants stated that it would be a reasonable method to make the material selection of orthodontic appliances according to the medical history and potential MRI needs of the patient.

Since this study interested the orthodontic appliances that cause artifacts on MRI, the addressees of the subjects as dentists would naturally be those working in maxillofacial radiology and orthodontics. However, responses to the 10th and 11th questions showed that the percentage of encountering this subject in orthodontics (referred patients for removal) was higher than in maxillofacial radiology (requested for removal) (93.5% >15%). Because of the relatively limited use of MRI in maxillofacial radiology, dental radiological examination of patients with orthodontic appliances is usually completed without problems such as artifacts or complications. According to the participant's responses to the 12th question, the final decision on removing the appliance should be made by medical radiologists rather than orthodontists and maxillofacial radiologists. This result showed that those who referred patients to orthodontists for removing the appliances might have be mostly medical radiologists.

4.2. Level of Knowledge About the Factors Caused Artifacts and Complications

According to the orthodontic appliance type, material type, or ROI, the artifacts could affect the image quality, which makes the diagnosis difficult or impossible (2,17,22,28,30,37-39). The images of regions close to orthodontic appliances are more affected (30). Depending on the appliance and material type, the artifacts could be observed in the oral cavity, Temporomandibular Joint (TMJ), brain, posterior cerebral

fossa, cervical vertebrae, cervical region, and paranasal sinuses. However, since the artifacts caused by orthodontic appliances are localized in the oral cavity, the diagnostic quality of other head and neck regions with more routine MRI indications is not affected much (17,27,30). In another study, the regions with severe artifacts caused by SS appliances were reported as the hard palate, tongue base, mandible body, globes, frontal lobes, and nasopharynx (37). In this study, the percentage of participants who thought the diagnosis would be affected was higher than those who believed only the image quality would be affected (90.4%>67.8%). The participants stated that orthodontic appliance artifacts could be observed mainly in the maxillofacial region, in line with the studies in the literature (93.8%) (17,27,30,37).

The factors influencing metal-related artifact's production on MRI can be classified as object-related, parameter-related, and sequence-related (5). If the orthodontic appliance material composition is rich in ferromagnetic metal, which has high magnetic susceptibilities, the artifact size will be larger than paramagnetic and diamagnetic substances (14). The severity of the artifact increases in the presence of larger-sized and round-shaped metal objects (3,7,18). The T2-weighted images are more susceptible than the T1-weighted images due to longer echo times (19,30). The faster gradient-echo sequence leads to larger artifacts than the spin-echo sequence (40). It has been reported that the low magnetic field strength (e.g., 1.5 T vs. 3 T), small Field of View (FOV), thin slice, to locate the long axis of the object parallel to the axis of the main magnetic field, and more distance to the ROI will decrease the metal artifacts (18,30,37,41). Furthermore, while metallic object-induced artifacts can completely obscure the region of interest in one section plane, they may cause fewer effects on another plane (20). In this study, the participants thought that the material composition of the orthodontic appliance (84.6%), the distance of the orthodontic appliance to the region to be examined (80.3%), and the magnetic susceptibility of the orthodontic appliance material (79.8%), respectively, were the most influential factors on artifacts formation. The thickness of the section (23.6%), the section plane (28.8%), and the orientation of the orthodontic appliance (29.3%) were thought to be the least influential factors on artifacts formation.

The orthodontic appliances may contain ferromagnetic metals such as Chromium (Cr)-Cobalt (Co), and Ni-Cr that interfere with magnetic fields and cause artifacts on MRI (14,20,42). In fixed orthodontic treatment, Ni-Ti and SS archwires are used with SS brackets (SS composed of Ni (8%-12%), Cr (17%-22%), and variable amounts of other metals) (43). Some researchers stated that the material proportions in the metals used are also effective in forming of artifacts (37). Several studies revealed that SS brackets cause greater artifacts than plastic, ceramic, and titanium brackets with a metal slot leading to MRI non-interpretability (17,22,23,28,37). In addition to studies that reported that titanium, often considered MR compatible, produces artifacts (4,20,38), some studies also stated that titanium only causes minor artifacts (6,14,17). These different results can be explained by the different amounts of titanium used because it has been claimed that smaller amounts cause more minor artifacts (17,44). Therefore, unlike other materials, we cannot speak of a consensus on the effect of titanium artifact formation. Most of the participants considered plastic and ceramic as less effective materials in the construction of MRI artifacts. In line with the literature's confusion, there was no dominant opinion about titanium among the participants in this study.

4.3. Preventive Approaches

Because of possible artifacts and complications that orthodontic appliances may cause, the number of patients applying to dentists working in maxillofacial radiology and orthodontics is increasing day by day. Although many studies have investigated whether orthodontic appliances should be removed before MRI, the issue remains unclear (1,10,17,19,23,24,37). Before the removal or non-removal decision, the following three risky situations should be considered; high-frequency-induced heating of the appliance, movement of the appliance caused by the main field, and artifact formation, which might restrict the diagnosis (18). In the studies conducted, it was emphasized that the decision should generally be made according to the material type of the appliances (1,17,20,45), the region to be examined (1,20), and the type of the appliances (17,23,45). Especially in cases where oral cavity and brain examination will be performed, removal the appliances containing SS material has been recommended, which can be removed relatively easily. In contrast, studies indicated that all orthodontic appliances may remain in the mouth without materials discrimination during MRI (26) or that SS brackets do not always need to be removed if the brain and TMJ regions are to be examined (27). The stability of orthodontic instruments, such as ligament wires, archwires, brackets, bands, and tubes that are decided to remain in the patient's mouth, should be carefully checked (24). It was stated that loose orthodontic appliances pose a significant danger to the patient, so the attachment of all banded and bonded components should be checked or passively ligated with elastomeric chains for added safety (24,30). Additionally, all removable metallic appliances must be removed, as their removal will not cause any difficulties or additional costs (10,30). In this study, for preventing MRI artifacts and complications, the removal of removable appliances had the highest rate (91.8%), while the removal of archwires was also very popular (73.1%). In another question that inquired what should be considered when making the removal decision, most participants stated that the distance of the orthodontic appliance to the ROI was the most important factor (78.1%).

The removal of orthodontic appliances, especially SS brackets, before MRI is a problematic procedure in many aspects. In fact, it can be time-consuming, costly, and uncomfortable for both the patient and orthodontist (46). Moreover, this procedure could damage the enamel structure, prolong the treatment period and influence the prognosis of treatment (47). In line

with this information, the study participants also highlighted the waste of time for both patients and orthodontists, and financial loss is an important disadvantage.

Strategies to reduce metal artifacts on MRI can be listed as follows; 1) using small-sized brackets that have less magnetic susceptibility material, 2) using SE sequence instead of GE sequence, 3) shortening the scan time, 4) scanning in lower magnetic field strength, 5) making the material selection of the orthodontic appliance according to the MRI potential in light of the patient's medical history, and 6) using an artifact reduction software (5,18,26,48,49). The dentists who participated in this study thought the ideal way to reduce the artifacts was to use small-sized brackets with less magnetic susceptibility material.

Increasing demands for both orthodontic treatment and MR in society force orthodontists to be more conscious about the types of appliances they use. The difficulty of removing fixed orthodontic appliances necessitates orthodontists to choose them by considering the possible future medical needs of their patients as well as orthodontic treatment. The prominent solutions of the participants in this study to avoid artifacts and other complications of orthodontic appliances were to act with the consideration about the potential use of MRI for medically specific patients and to use MRI-safe materials. Future studies may provide more detailed data on the frequency of dentists' encounters with orthodontic cases of dentists and the problems they experience.

A limitation of this study was that the questionnaire was conducted in a single country and online with the participation of a limited number of orthodontists and maxillofacial radiologists. Different results may be obtained when applied to more participants in other countries. Another limitation is that medical radiologists request an MRI of the head and neck region more than maxillofacial radiologists. Similar questionnaires that medical radiologists will include can be applied in future studies.

5. CONCLUSIONS

The results of this study demonstrate that dentists working in orthodontics and maxillofacial radiology have a high level of awareness and knowledge about the artifacts and complications caused by orthodontic appliances on MRI. The levels of the participants with less professional experience in both specialty areas were lower. The number of referrals for the removal of the orthodontic appliances to orthodontics was higher compared with the number of requests for the removal from maxillofacial radiology. Using small-sized brackets with less magnetic susceptibility material was considered the ideal way to reduce the number of artifacts on MRI.

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REFERENCES

[1] Shalish M, Dykstein N, Friedlander-Barenboim S, Ben-David E, Gomori JM, Chaushu S. Influence of common fixed retainers on the diagnostic quality of cranial magnetic resonance images. Am J Orthod Dentofacial Orthop. 2015;147(5):604–609. DOI: 10.1016/j.ajodo.2014.11.022

[2] Hargreaves BA, Worters PW, Pauly KB, Pauly JM, Koch KM, Gold GE. Metal – induced artifacts in MRI. AJR Am J Roentgenol. 2011;197(3):547–555. DOI: 10.2214/AJR.11.7364

[3] Beuf O, Lissac M, Crémillieux Y, Briguet A. Correlation between magnetic resonance imaging disturbances and the magnetic susceptibility of dental materials. Dent Mater. 1994;10(4):265-268. DOI: 10.1016/0109-5641(94)90072-8

[4] Schenck JF. The role of magnetic susceptibility in magnetic resonance imaging: MRI magnetic compatibility of the first and second kinds. Med Phys. 1996;23(6):815-850. DOI: 10.1118/1.597854

[5] Lee MJ, Kim S, Lee SA, Song HT, Huh YM, Kim DH, Han SH, Suh JS. Overcoming artifacts from metallic orthopedic implants at high-field strength MR imaging and multi-detector CT. Radiographics 2007;27(3):791-803 DOI: 10.1148/rg.273065087

[6] Fache JS, Price C, Hawbolt EB, Li DK. MR imaging artifacts produced by dental materials. AJNR Am J Neuroradiol. 1987;8(5):837-840

[7] Shellock F, Kanal E. Aneurysm clips: Evaluation of MR imaging artifacts at 1.5 T. Radiology 1998;209(2):563-566. DOI: 10.1148/radiology.209.2.9807590

[8] Marincas C, Mada M, Rotaru D, Carpenter A, Ciupa R. Evaluation of radio frequency-ınduced heating near fixed orthodontic appliances during mrı examination at 3 tesla. Acta Electroteh. 2013;54(1):72-75.

[9] Klocke A, Kahl-Nieke B, Adam G, Kemper J. Magnetic forces on orthodontic wires in high field magnetic resonance imaging (MRI) at 3 tesla. J Orofac Orthop. 2006;67(6):424-429. DOI: 10.1007/s00056.006.0621-x

[10] Kemper J, Klocke A, Kahl-Nieke B, Adam G. Orthodontic brackets in high field MR imaging: experimental evaluation of magnetic field interactions at 3.0 Tesla. RoFo. 2005;177(12):1691-1698. DOI: 10.1055/s-2005-858762

[11] Sfondrini MF, Preda L, Calliada F, Carbone L, Lungarotti L, Bernardinelli L, Gandini P, Scribante A. Magnetic Resonance

Imaging and Its Effects on Metallic Brackets and Wires: Does It Alter the Temperature and Bonding Efficacy of Orthodontic Devices? Materials (Basel) 2019;12(23):3971. DOI: 10.3390/ma12233971

[12] Mir AP-B, Rahmati-Kamel M. Should the orthodontic brackets always be removed prior to magnetic resonance imaging (MRI)? J Oral Biol Craniofac Res. 2016;6(2):142-152. DOI: 10.1016/j.jobcr.2015.08.007

[13] Hasanin M, Kaplan S. E, Hohlen B, Lai C, Nagshabandi R, Zhu X, Al-Jewair T. Effects of orthodontic appliances on the diagnostic capability of magnetic resonance imaging in the head and neck region: A systematic review. Int Orthod. 2019;17(3):403-414. DOI: 10.1016/j.ortho.2019.06.001

[14] Eggers G, Rieker M, Kress B, Fiebach J, Dickhaus H, Hassfeld S. Artefacts in magnetic resonance imaging caused by dental material. MAGMA 2005;18(2):103-111. DOI: 10.1007/s10334.005.0101-0

[15] Smith-Bindman R, Miglioretti DL, Johnson E, Lee C, Feigelson HS, Flynn M, Greenlee RT, Kruger RL, Hornbrook MC, Roblin D, Solberg LI, Vanneman N, Weinmann S, Williams AE. Use of diagnostic ımaging studies andassociated radiation exposure for patients enrolled in large ıntegrated health care systems, 1996-2010. JAMA 2012;307(22):2400-2409. DOI: 10.1001/jama.2012.5960

[16] Proffit WR, Fields HW, Jr., Moray LJ. Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES III survey. Int J Adult Orthodon Orthognath Surg. 1998;13(2):97-106.

[17] Beau A, Bossard D, Gebeile-Chauty S. Magnetic resonance imaging artefacts and fixed orthodontic attachments. Eur J Orthod. 2015;37(1):105-110. DOI: 10.1093/ejo/cju020

[18] Blankenstein F, Truong BT, Thomas A, Thieme N, Zachriat C. Predictability of magnetic susceptibility artifacts from metallic orthodontic appliances in magnetic resonance imaging. J Orofac Orthop. 2015;76(1):14-29. DOI: 10.1007/s00056.014.0258-0

[19] Dalili Kajan Z, Khademi J, Alizadeh A, Babaei Hemmaty Y, Atrkar Roushan Z. A comparative study of metal artifacts from common metal orthodontic brackets in magnetic resonance imaging. Imaging Sci Dent. 2015;45(3):159-168. DOI: 10.5624/isd.2015.45.3.159

[20] Costa AL, Appenzeller S, Yasuda C-L, Pereira FR, Zanardi VA, Cendes F. Artifacts in brain magnetic resonance imaging due to metallic dental objects. Med Oral Patol Oral Cir Bucal. 2009;14(6):E278-82.

[21] Hasegawa M, Miyata K, Abe Y, Ishigami T. Radiofrequency heating of metallic dental devices during 3.0 T MRI. Dentomaxillofac Radiol. 2013;42(5):20120234. DOI: 10.1259/dmfr.20120234

[22] Harris TM, Faridrad MR, Dickson JA. The benefits of aesthetic orthodontic brackets in patients requiring multiple MRI scanning. J Orthod. 2006;33(2):90-94. DOI: 10.1179/146.531.205225021465

[23] Okano Y, Yamashiro M, Kaneda T, Kasai K. Magnetic resonance imaging diagnosis of the temporomandibular joint in patients with orthodontic appliances. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003;95(2):255-263. DOI: 10.1067/moe.2003.37

[24] Patel A, Bhavra GS, O'Neill JR. MRI scanning and orthodontics. J Orthod. 2006;33(4):246-249. DOI: 10.1179/146.531.205225021726

[25] Blankenstein F, Asbach P, Beuer F, Glienke J, Mayer S, Zachriat C. Magnetic permeability as a predictor of the artefact size caused by orthodontic appliances at 1.5 T magnetic resonance imaging. Clin Oral Investig. 2017;21(1):281-289. DOI: 10.1007/s00784.016.1788-1

[26] Zachriat C, Asbach P, Blankenstein K, Peroz I, Blankenstein F. MRI with intraoral orthodontic appliance—a comparative in vitro and in vivo study of image artefacts at 1.5 T. Dentomaxillofac Radiol. 2015;44(6):20140416. DOI: 10.1259/dmfr.20140416

[27] Cassetta M, Pranno N, Stasolla A, Orsogna N, Fierro D, Cavallini C, Cantisani V. 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. Dentomaxillofac Radiol. 2017;46(6):20170051. DOI: 10.1259/dmfr.20170051

[28] Zhylich D, Krishnan P, Muthusami P, Rayner T, Shroff M, Doria A, Tompson B, Lou W, Suri S. Effects of orthodontic appliances on the diagnostic quality of magnetic resonance images of the head. Am J Orthod Dentofacial Orthop. 2017;151(3):484-499. DOI: 10.1016/j.ajodo.2016.07.020

[29] Hosein I, Sherriff M, Ireland A. Enamel loss during bonding, debonding, and cleanup with use of a self-etching primer. Am J Orthod Dentofacial Orthop. 2004;126(6):717-724. DOI: 10.1016/j.ajodo.2003.10.032

[30] Sadowsky PL, Bernreuter W, Lakshminarayanan AV, Kenney P. Orthodontic appliances and magnetic resonance imaging of the brain and temporomandibular joint. Angle Orthod. 1988;58(1):9-20. DOI: 10.1043/0003-3219(1988)058<0009:OAAMRI>2.0.CO;2

[31] Huettel SA, Song AW, McCarthy G. Functional magnetic resonance imaging. 1th ed. Sunderland: MA: Sinauer Associates; 2004.

[32] Shellock FG. Biomedical implants and devices: assessment of magnetic field interactions with a 3.0-Tesla MR system. J Magn Reson Imaging. 2002;16(6):721-732. DOI: 10.1002/jmri.10207

[33] Sinkiewicz D. MRI scan hazard. Br Dent J. 2013;214(8):376. DOI: 10.1038/sj.bdj.2013.388

[34] Sung JW, Kwon TY, Kyung HM. Debonding forces of three different customized bases of a lingual bracket system. Korean J Orthod. 2013;43(5):235-241. DOI: 10.4041/kjod.2013.43.5.235

[35] Yassi K, Ziane F, Bardinet E, Moinard M, Veyret B, Chateil J. Evaluation of the risk of overheating and displacement of orthodontic devices in magnetic resonance imaging. J Radiol. 2007;88(2):263-268. DOI: 10.1016/s0221-0363(07)89813-1

[36] Gorgulu S, Ayyildiz S, Kamburoglu K, Gokce S, Ozen T. Effect of orthodontic brackets and different wires on radiofrequency heating and magnetic field interactions during 3-T MRI. Dentomaxillofac Radiol. 2014;43(2):20130356. DOI: 10.1259/dmfr.20130356

[37] Elison JM, Leggitt VL, Thomson M, Oyoyo U, Wycliffe ND. Influence of common orthodontic appliances on the diagnostic quality of cranial magnetic resonance images. Am J Orthod Dentofacial Orthop. 2008;134(4):563-572. DOI: 10.1016/j.ajodo.2006.10.038

[38] Hinshaw Jr D, Holshouser B, Engstrom H, Tjan A, Christiansen E, Catelli W. Dental material artifacts on MR images. Radiology. 1988;166(3):777-779. DOI: 10.1148/radiology.166.3.3340777

[39] Fellner C, Behr M, Fellner F, Held P, Handel G, Feuerbach S. Artifacts in MR imaging of the temporomandibular joint

caused by dental alloys: A phantom model study at T1.5. RoFo. 1997;166(5):421-428. DOI: 10.1055/s-2007.101.5452

[40] Herold T, Caro WC, Heers G, Perlick L, Grifka J, Feuerbach S, Nitz W, Lenhart M. Influence of sequence type on the extent of the susceptibility artifact in MRI–A shoulder specimen study after suture anchor repair. Rofo. 2004;176(9):1296-1301. DOI: 10.1055/s-2004-813404

[41] Guermazi A, Miaux Y, Zaim S, Peterfy CG, White D, Genant HK. Metallic artefacts in MR imaging: effects of main field orientation and strength. Clin Radiol. 2003;58(4):322-328. DOI: 10.1016/s0009-9260(02)00540-8

[42] Starcuk Z. Evaluation of MRI artifacts caused by metallic dental implants and classification of the dental materials in use. Meas Sci Rev. 2006;6(2):357-362.

[43] Leite LP, Bell RA. Adverse hypersensitivity reactions in orthodontics. Semin Orthod. 2004;10(4):240-243

[44] Shafiei F, Honda E, Takahashi H, Sasaki T. Artifacts from dental casting alloys in magnetic resonance imaging. J Dent Res. 2003;82(8):602-606. DOI: 10.1177/154.405.910308200806

[45] Asano S, Kaneda T, Fukuda T, Makiyama Y, Hirota H, Saitoh K, Negishi S, Kasai K. Influence of metal artifact by orthodontic appliances on brain MRI. Int J Oral-Med Sci. 2016;14(4):74-81.

[46] Degrazia FW, Genari B, Ferrazzo VA, Santos-Pinto AD, Grehs RA. Enamel Roughness Changes after Removal of Orthodontic Adhesive. Dent J (Basel). 2018;6(3):39. DOI: 10.3390/dj6030039

[47] Yassaei S, Aghili H, KhanPayeh E, Goldani Moghadam M. Comparison of shear bond strength of rebonded brackets with four methods of adhesive removal. Lasers Med Sci. 2014;29(5):1563-1568. DOI: 10.1007/s10103.013.1310-9

[48] Lee YH, Lim D, Kim E, Kim S, Song HT, Suh JS. Feasibility of fat-saturated T2-weighted magnetic resonance imaging with slice encoding for metal artifact correction (SEMAC) at 3T. Magn Reson Imaging. 2014;32(8):1001-1005. DOI: 10.1016/j.mri.2014.04.009

[49] Gunzinger JM, Delso G, Boss A, Porto M, Davison H, von Schulthess GK, Huellner M, Stolzmann P, Veit-Haibach P, Burger IA. Metal artifact reduction in patients with dental implants using multispectral three-dimensional data acquisition for hybrid PET/MRI. EJNMMI Phys. 2014;1(1):102. DOI: 10.1186/s40658.014.0102-z

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