

Effect of a metal artifact removal algorithm on visibility of the second mesiobuccal canal of maxillary molars on cone-beam computed tomography scans: multilevel mixed-effects ordered logistic regression

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Abstract

Objectives: This study aimed to assess the effect of a metal artifact removal (MAR) algorithm on the visibility of the second mesiobuccal canal (MB2) of maxillary molars on cone-beam computed tomography (CBCT) scans.

Materials and Methods: This cross-sectional study evaluated 41 CBCT scans of patients retrieved from the radiology clinic's archives. The CBCT scans were saved with and without the MAR algorithm applied. The images were coded and evaluated by two endodontists to assess MB2 detection in maxillary molars and its visibility level using a 5-point Likert scale. Of the 164 samples, 32 were excluded from the study, and 132 teeth were examined. The Wilcoxon test was used to compare images with and without MAR with respect to MB2 visibility ($\alpha=0.05$).

Results: No significant difference existed between images with and without MAR regarding the visibility of MB2 of maxillary first and second molars in apical (OR= 0.96, 95% CI; 0.58–1.59), middle (OR= 1.01, 95% CI; 0.65 – 1.59) and coronal (OR= 1.02, 95% CI; 0.63-1.64) thirds of the root by adjusting the effect of other variables. **Conclusion:** According to the present results, the application of the MAR algorithm did not significantly change the visibility of MB2 in the maxillary first and second molars on CBCT scans.

Keywords: Metal Artifacts; Cone-Beam Computed Tomography; Maxillary Molar; Root Canal.

Introduction

Radiographic examination is an integral part of patient management in dentistry and is often required as a supplement to a definitive clinical diagnosis involving the teeth and adjacent structures. (1)

The diagnostic accuracy of cone-beam computed tomography (CBCT) compared with panoramic and periapical radiographic modalities has been the subject of numerous investigations. (2) CBCT allows visualization of internal dental anatomy, facilitating more efficient and effective treatment. (3) CBCT images can aid in detecting additional canals,



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anatomical variations, root resorption defects, and possible pathologies. Also, CBCT enables evaluation of images in axial, sagittal, and coronal planes.(1, 4, 5) CBCT provides high-resolution 3D images with no distortion or superimposition of anatomical structures, which is a great advantage.(1)

However, high-density objects such as dental implants, amalgam restorations, or root-filling materials can cause artifacts on CBCT images, which can adversely affect image quality and diagnosis. (6, 7) X-ray beams have low-energy photons, which are absorbed when passing through a hard object. This phenomenon is known as beam hardening and may appear as cupping and streak-line artifacts, which can compromise overall image quality (6, 7).

Several strategies are available for metal artifact reduction, such as using wedge and bowtie filters, scatter correction algorithm, beam hardening software, and some degrees of anti-scatter. Although these methods may be helpful for artifact reduction, they may also omit valuable information (8).

Studies on the effects of metal artifact removal (MAR) algorithms on the diagnostic accuracy of CBCT across different tissues are limited, and the reported results have been controversial in some cases. One previous study reported a reduction in visibility and detection of small anatomical landmarks following the application of MAR (8, 9). In contrast, some studies found no significant difference in the visibility of anatomical structures or in the accuracy of CBCT scans with and without artifacts (10, 11).

Considering the existing controversy and absence of studies on the effects of the MAR algorithm of CBCT on the accuracy of evaluation of root canal anatomy, this study aimed to assess the effect of a MAR algorithm on the visibility of the second mesiobuccal canal (MB2) of maxillary molars on CBCT scans. The null hypothesis of the study was that the application of the MAR algorithm would have no significant effect on the visibility of the MB2 of the maxillary molars on CBCT scans.

Materials and methods

This cross-sectional study was conducted on CBCT scans of patients' maxillary first and second molars presenting to a radiology clinic in Qazvin, Iran, from March 2022 to April 2022. The study protocol was approved by the ethics committee of Qazvin University of Medical Sciences (IR.QUMS.REC.1402.079).

Eligibility criteria:

The inclusion criteria were good-quality CBCT scans of the first and second molar area (absence of motion blurring and optimal image resolution and clarity), presence of the maxillary first and second molars on the images, and availability of patients' demographic information.

Images of teeth without an MB2 were excluded. Teeth with severe coronal caries were also excluded.

The CBCT scans were collected by convenience sampling until the required sample size was reached.

Sample size:

The minimum sample size was calculated to be 124 maxillary first and second molars, based on previous

studies (10, 12), assuming $\alpha=0.05$, a study power of 0.80, and an effect size of 0.26, using G Power software and the Wilcoxon test.

Methodology

A total of 41 CBCT scans (132 maxillary first and second molars) were evaluated. All CBCT scans were obtained with the ProMax 3D CBCT scanner (Planmeca, Helsinki, Finland) using a voxel size of 0.15 x 0.15 mm, a tube potential of 84 kV, and a tube current of 9 mA. The images were saved, and the MAR algorithm with medium intensity was applied to them in Romexis version 3.8.0 software; this series of images was also saved. The images were then randomly coded, and two endodontists were asked to evaluate them for the presence/absence of MB2 in the maxillary first and second molars, based on the position of the first mesiobuccal canal (MB1). In the presence of MB1 at the center of the mesiobuccal root, the possibility of MB2 would be excluded, and the tooth would be excluded from the study (Campo (4) Figure 1).

The two endodontists also evaluated the visibility of MB2 in maxillary first and second molars on each CBCT image in the apical, middle, and coronal thirds according to the presence/absence of restoration or presence of an artifact-generating factor in the respective tooth or adjacent teeth, and also presence/absence of root filling in the respective tooth or adjacent teeth (Figure 2). The observers used all CBCT sections (axial, sagittal, and coronal) for their assessments. In the event of a disagreement between the two observers, a radiologist would be consulted. The observers reported the visibility of MB2 using a 5-point Likert scale as follows, (10):

1: Definitely absent; 2: Probably absent; 3: No opinion; 4: Probably present; 5: Definitely present.

Statistical analysis:

Data were analyzed by SPSS version 25 (IBM Co., Armonk, NY, USA). Frequency and percentage are used to describe qualitative variables. The Wilcoxon test was used to compare canal visibility on CBCT images with and without the MAR algorithm, at the 0.05 significance level.

In addition, we applied Mixed-effects ordered logistic regression to account for within-patient clustering and to adjust for the effects of other variables, including the presence/absence of coronal restoration and root filling in the respective teeth and their adjacent teeth.

Results

A total of 41 CBCT scans, visualizing 164 maxillary first and second molars, were evaluated, of which 132 eligible samples were included (73 maxillary first molars and 59 maxillary second molars). Of all, 32 teeth were excluded due to the absence of MB2, maxillary molar extraction, or severe caries (22 maxillary second molars and 2 maxillary first molars due to absence of MB2, 6 first molars and 1 second molar due to extraction, and 1 first molar due to severe caries) (Figure 3). Of all maxillary teeth evaluated in this study, 73 (55.3%) were first molars and 59 (44.7%) were second molars.

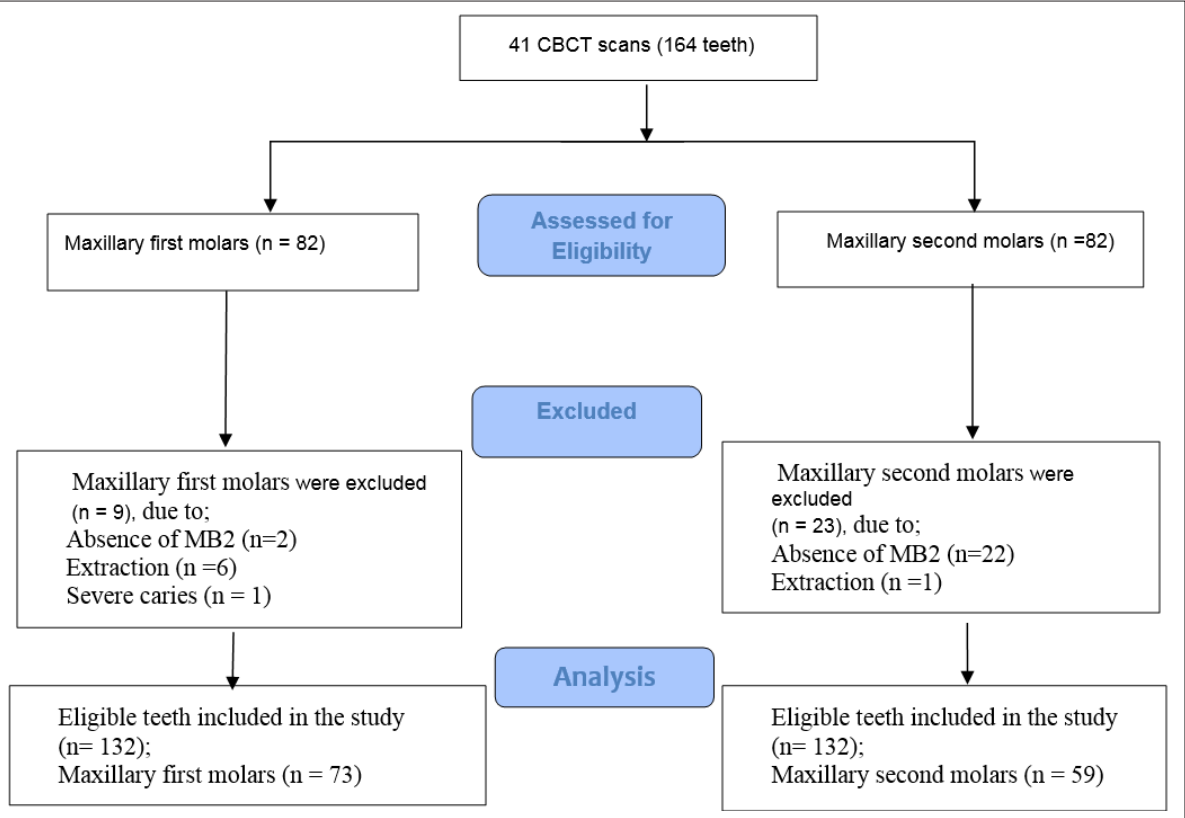


Figure 1. Inclusion criteria of samples into the study.



Figure 2. The maxillary first molar has an MB2, while the second molar does not have an MB2.

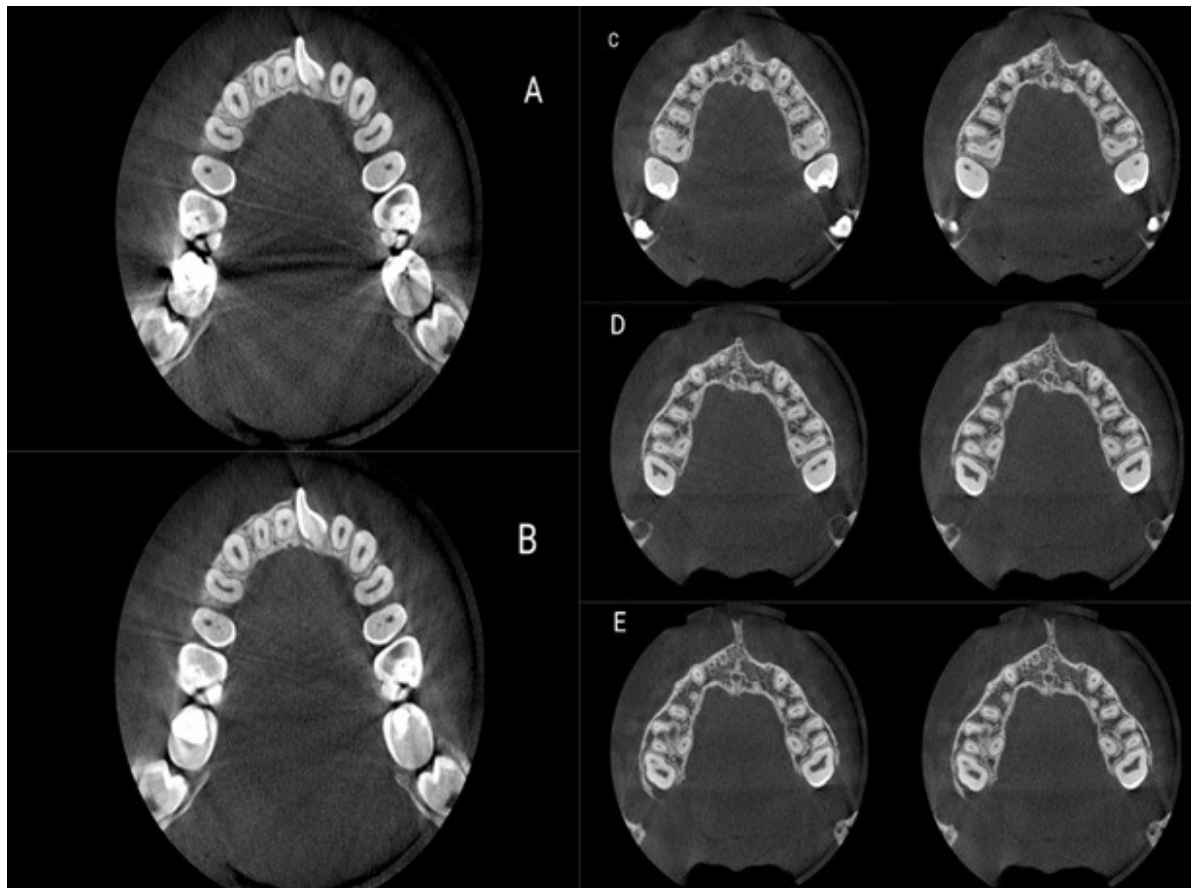


Figure 3. Coronal view in axial section (A) without MAR; (B) with MAR; Tooth view in Axial section without MAR and with MAR in the (C) coronal, (D) middle, and (E) apical third

Regarding coronal restoration, 62 (47%) had coronal restorations, and in 70 (53%) cases, the adjacent teeth had coronal restorations.

Regarding the presence/absence of root canal filling, 18 teeth (13%) had root fillings, and in 23 teeth (17.4%), the adjacent teeth had undergone root canal therapy.

Comparison of visibility of MB2 in the coronal third: Table 1 compares the visibility of MB2 in the coronal third of the root on CBCT scans with and without the application of MAR. The Wilcoxon test showed no significant difference between CBCT scans with and without the application of MAR in the detection of MB2 in the coronal third ($P=0.878$). Table 2 presents the agreement on MB2 visibility in the coronal third between images with and without MAR.

Comparison of visibility of MB2 in the middle third: As shown in Table 3, no significant difference was found between CBCT scans with and without the application of MAR in the detection of MB2 in the middle third ($P=0.756$). Table 4 presents the agreement on MB2 visibility in the middle third between images with and without MAR.

Table 5 compares the visibility of MB2 in the apical third of the root on CBCT scans with and without MAR. The difference in this regard was not significant between the two methods ($P=0.911$). Table 6 presents the agreement on MB2 visibility in the apical third between images with and without MAR.

It was applied that Mixed-effects ordered logistic regression was used to determine the effect of a MAR algorithm on the visibility of the apical, middle, and coronal thirds of the root, adjusting for the presence/absence of coronal restoration and root filling in the respective teeth and their adjacent teeth. As indicated in Table 7, no significant difference was found between images with and without MAR in the detection of MB2 in any part of the root when the above-mentioned scenarios were compared ($P>0.05$).

Discussion

This study assessed the effect of an MAR algorithm on the visibility of the MB2 of maxillary molars on CBCT scans. The null hypothesis of the study was that the application of the MAR algorithm would have no significant effect on the visibility of the MB2 of the maxillary molars on CBCT scans. In this study, the results showed that the application of MAR did not significantly change the visibility of MB2 on CBCT scans of the maxillary first and second molars, and the null hypothesis of the study was accepted. No significant difference was found between images with and without MAR regarding the visibility of MB2 in the apical, middle, or coronal third of maxillary first and second molars in the presence/absence of coronal restoration or root filling in the respective teeth or their adjacent teeth.

Table 1. Comparison of the visibility of MB2 in the coronal third of the root on CBCT scans with and without the application of MAR

	Without MAR		With MAR		Wilcoxon Signed Ranks Test P-value
	Number	Percentage	Number	Percentage	
Definitely absent	41	31.1	42	31.8	0.878
Probably absent	18	13.6	17	12.9	
No opinion	12	9.1	12	9.1	
Probably present	25	18.9	28	21.2	
Definitely present	36	27.3	33	25	
Total	132	100	132	100	

Table 2. Agreement in visibility of MB2 in the coronal third between images with and without MAR

Definitely absent		With MAR					Total
		Probably absent	No opinion	Probably present	Definitely present		
Without MAR	Definitely absent	19(14.4)	9(6.8)	3(2.3)	5(3.8)	5(3.8)	41(31.1)
	Probably absent	6(4.5)	4(3)	1(0.8)	7(5.3)	0(0)	18(13.6)
	No opinion	6(4.5)	0(0)	3(2.3)	0(0)	3(2.3)	12(9.1)
	Probably present	4(3)	2(1.5)	2(1.5)	8(6.1)	9(6.8)	25(18.9)
	Definitely present	7(5.3)	2(1.5)	3(2.3)	8(6.1)	16(12.1)	36(27.3)
Total		42(31.8)	17(12.9)	12(9.1)	28(21.2)	33(25)	132(100)

Table 3. Comparison of the visibility of MB2 in the middle third of the root on CBCT scans with and without the application of MAR

	Without MAR		With MAR		Wilcoxon Signed Ranks Test P-value
	Number	Percentage	Number	Percentage	
Definitely absent	27	20.5	29	22	0.756
Probably absent	30	22.7	22	16.7	
No opinion	9	6.8	11	8.3	
Probably present	31	23.5	39	29.5	
Definitely present	35	26.5	31	23.5	
Total	132	100	132	100	

Table 4. Agreement in visibility of MB2 in the middle third between images with and without MAR

Definitely absent		With MAR					Total
		Probably absent	No opinion	Probably present	Definitely present		
Without MAR	Definitely absent	13(9.8)	4(3)	3(2.3)	5(3.8)	2(1.5)	27(20.5)
	Probably absent	4(3)	8(6.1)	2(1.5)	13(9.8)	3(2.3)	30(22.7)
	No opinion	3(2.3)	3(2.3)	2(1.5)	1(0.8)	0(0)	9(6.8)
	Probably present	5(3.8)	4(3)	2(1.5)	13(9.8)	7(5.3)	31(23.5)
	Definitely present	4(3)	3(2.3)	2(1.5)	7(5.3)	19(14.4)	35(26.5)
Total		29(22)	22(16.7)	11(8.3)	39(29.5)	31(23.5)	132(100)

Table 5. Comparison of the visibility of MB2 in the apical third of the root on CBCT scans with and without the application of MAR

	Without MAR		With MAR		Wilcoxon Signed Ranks Test
	Number	Percentage	Number	Percentage	P-value
Definitely absent	31	23.5	25	18.9	0.911
Probably absent	18	13.6	23	17.4	
No opinion	10	7.6	15	11.4	
Probably present	28	21.2	27	20.5	
Definitely present	45	34.1	42	31.8	
Total	132	100	132	100	

Table 6. Agreement in visibility of MB2 in the apical third between images with and without MAR

Definitely absent		With MAR					Total
		Probably absent	No opinion	Probably present	Definitely present		
Without MAR	Definitely absent	12(9.1)	7(5.3)	4(3)	3(2.3)	5(3.8)	31(23.5)
	Probably absent	4(3)	5(3.8)	2(1.5)	5(3.8)	2(1.5)	18(13.6)
	No opinion	3(2.3)	1(0.8)	2(1.5)	3(2.3)	1(0.8)	10(7.6)
	Probably present	3(2.3)	5(3.8)	3(2.3)	6(4.5)	11(8.3)	28(21.2)
	Definitely present	3(2.3)	5(3.8)	4(3)	10(7.6)	23(17.4)	45(34.1)
Total		25(18.9)	23(17.4)	15(11.4)	27(20.5)	42(31.8)	132(100)

Table 7. Mixed-effects ordered logistic regression determining the effect of a MAR algorithm on visibility of the apical, middle, and coronal thirds of the root by adjusting presence/absence of coronal restoration and root filling in the respective teeth and their adjacent teeth.

	Coronal third			Middle third			Apical third		
Variable	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value
MAR	0.96	(0.58 – 1.59)	0.881	1.01	(0.65 – 1.59)	0.950	1.02	(0.63-1.64)	0.940
Coronal restoration of the tooth	0.99	(0.55 – 1.78)	0.975	0.73	(0.41 – 1.29)	0.275	0.44	(0.24-0.82)	0.009
Coronal restoration of adjacent tooth	1.39	(0.80 – 2.42)	0.236	1.42	(0.83 – 2.44)	0.206	1.39	(0.78-1.48)	0.263
Canal filling	0.999	(0.42 – 2.37)	1.000	1.59	(0.70 – 3.62)	0.266	0.79	(0.34-1.86)	0.602
Canal filling of adjacent tooth	1.06	(0.52 – 2.16)	0.874	0.67	(.034 – 1.33)	0.253	1.56	(0.74-3.29)	0.244

In this study, we applied MAR with moderate intensity. Perhaps a significant impact on the results would be achieved with a larger sample size or a higher MAR. The present results were in agreement with the findings of de-Azevedo-Vaz et al., who assessed the effect of MAR application on the detection of fenestration and dehiscence defects on CBCT scans. They concluded that it had no significant effect on defect detection (10). Fontenel et al. (11) showed that the application of MAR had no significant effect on the detection of vertical root fractures (VRFs) on CBCT scans, which was consistent with the present results; nonetheless, Fontenel et al. (11) demonstrated that the presence of an artifact-generating object (dental implant) complicated the detection of VRFs. In contrast, in the present study, the presence/absence of artifact-generating factors (restoration or root filling in the tooth or adjacent teeth) had no significant effect on the detection of MB2. This difference may be attributed to the type of artifact-generating object (dental implant versus coronal restoration or root filling), its location (dental implant is placed in bone and at the level of VRF, while coronal restoration is coronal to the canal), and the assessed parameter (detection of VRF is more difficult than MB2). Queiroz et al. (13) demonstrated that the application of MAR improved the quality of CBCT images in the presence of amalgam restorations, which served as the artifact-generating factor. In contrast, its application did not significantly change the image quality when gutta-percha served as the artifact-generating factor. The same can be applied to the comparison of dental implants (in the study by Fontenel et al. (11) and (11)) with gutta-percha (one of the artifact-generating parameters in the present study). In other words, although dental implants can cause greater artifacts and complicate the detection of VRFs, the application of MAR improves the image quality. However, gutta-percha causes fewer artifacts in the first place due to its lower density, and thus, no significant change in diagnostic accuracy was detected after the application

of MAR. The present results also contrast with the findings of Fakhar et al. (8). They evaluated the effect of applying MAR on the detection of anatomical landmarks on CBCT scans. They concluded that, in the detection of small anatomical landmarks such as lamina dura, increasing the application of MAR (medium level compared with low level) was associated with reduced diagnostic ability. At the same time, in the present study, it caused no significant change in the detection of MB2 as a small landmark. This difference may be attributed to different sample sizes (30 CBCT scans in their study versus 132 in the current study). Moreover, they evaluated dental implants and intra-canal posts as artifact-generating factors, whereas the present study evaluated coronal restorations and gutta-percha as artifact-generating objects.

This study had some limitations. Some teeth had to be excluded because MB2 was absent. Since this study was conducted on CBCT scans, a definitive conclusion regarding the presence/absence of MB2 could not be reached, and therefore, sensitivity and specificity values could not be calculated. Also, since all CBCT scans were taken with the ProMax 3D CBCT scanner, the results cannot be generalized to all CBCT scanners and their MAR features.

Future studies are required to assess the effect of MAR voxel size on the visibility of additional canals and diagnostic accuracy. Moreover, the effect of CBCT image artifact severity on object visibility and diagnostic accuracy after the application of the MAR algorithm should be assessed. The role of operators in assessing indices is another factor requiring further investigation.

Conclusion

According to the present results, the application of MAR did not significantly change the visibility of MB2 on CBCT scans of the maxillary first and second molars.

Acknowledgments

The authors deny any conflicts of interest.

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