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Association between second mesiobuccal canal and apical periodontitis in retrospective cone-beam computed tomographic images

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Abstract

This retrospective cone-beam computed tomography study aimed to investigate the possible associations of apical periodontitis (AP) with missed/unmissed second mesiobuccal (MB2) canals. MB2 canals and AP were investigated in 257 endodontically treated and 673 untreated maxillary molars, and the former were analyzed regarding missed/unmissed MB2 canals. The chi-squared test and odds ratio (OR) were used for statistics. The prevalence of MB2 canals in maxillary first molars was higher than that in second molars ($p = 0.001$). MB2 canals were 1.751 times more common in males than in females (OR: 1.751; 95% CI: 1.334–2.297), with a significant difference in the 18–39 age groups ($p = 0.005$). The risk for AP was 5.5 times greater in endodontically treated maxillary molars with missed MB2 canals than in those with unmissed MB2 canals ($p = 0.012$) (OR: 5.5, 95% CI: 1.549–19.527). The findings of this study reveal that the likelihood of the MB2 canal is higher in the maxillary first molars of young adult males.

KEYWORDS

apical periodontitis, cone-beam computed tomography, maxillary molars, second mesiobuccal canal

INTRODUCTION

The success of endodontic treatment depends on various interrelated factors, including the biological features of teeth and the chemomechanical processes performed by dentists. Additionally, knowledge about the normal internal anatomy and possible anatomical variations, and the identification of complex anatomical root variations before treatment, has the potential to positively influence the treatment outcome [1–3].

Maxillary molars, especially first molars, have the greatest complexity and variation in the root canal system [1]. The second mesiobuccal (MB2) canal is the most challenging variation of these teeth, with a worldwide global prevalence of 73.8% [2]. It has been reported that failure to find and treat existing MB2 canals negatively affects the long-term outcomes of endodontic treatment [3]. Untreated missed canals are vulnerable to primary or secondary infection and harbour bacteria in sufficient numbers to cause or maintain apical periodontitis (AP) [4, 5].

All authors have contributed significantly and are in agreement with the manuscript.

In a previous study on endodontically treated teeth with missed canals, periapical lesions were found to be 4.38 times more common in these teeth than in other teeth [4].

Although there might be some clinical indicators that could help to predict the presence of an MB2 canal, radiographic imaging is the most useful method for identifying the exact internal anatomy of a tooth. Recently, the joint position of the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) stated that limited field of view (FOV) cone-beam computed tomography (CBCT) should be considered the imaging modality of choice for the initial treatment of teeth with the potential for extra canals and suspected of having a complex morphology [6]. Additionally, there have been several studies demonstrating the superiority of CBCT over intraoral radiography in detecting MB2 canals and AP [7–12]. Intraoral radiography may not be able to show MB2 canals in the buccolingual direction because of its two-dimensional nature and the superimposition of roots, the overlying cortical plate and the zygomatic buttress (anatomical noise) [9]. Variations in the apical tooth morphology, surrounding bone density, X-ray angulation and radiographic contrast may lead to radiographic misinterpretation [13]. Moreover, approximately 30–50% mineral bone loss is required for periapical lesions to be detectable on intraoral radiography [8]. CBCT enables the evaluation of a specific root by multiplanar reconstruction and reveals the true status of periapical tissues without overlying anatomical noise [9].

Previous studies in the literature have predominantly focused on the prevalence of MB2 canals based on population, sex, age group, tooth type and side. The anatomical and morphological characteristics of MB2 canals and their relationship with mesiobuccal (MB) and palatal (P) roots have also been investigated. However, the number of studies indicating the prevalence of missed MB2 canals and their association with AP is limited [4, 7, 12, 14]. Therefore, the aims of this retrospective CBCT study were as follows:

1. To determine the prevalence of MB2 canals in endodontically treated and untreated maxillary molars and the possible correlations with sex and age,
2. To identify the treatment rate of MB2 canals in endodontically treated teeth, to investigate the association of AP with missed or unmissed MB2 canals and to further radiologically observe the effect of MB2 canals on endodontic treatment outcomes.

MATERIALS AND METHODS

The protocol of the retrospective study was approved by the Local Ethics Committee of Istanbul Aydın University, Faculty of Dentistry (Protocol no: B.30.2.AYD.0.00.00–480.2/138).

A total of 2126 CBCT images of patients who were referred to the Department of Oral and Maxillofacial Radiology between January 2016 and December 2019 and required tomographic examination due to different indications were evaluated retrospectively. The inclusion criteria were available CBCT images of patients over 18 years of age with at least one endodontically treated or untreated maxillary first molar and maxillary second molar on any side of the jaw with fully developed roots and mature apices. The exclusion criteria were teeth with open apices, extensive coronal destruction and CBCT images with poor image quality and artefacts. Finally, a total of 357 CBCT images were deemed suitable for inclusion in the study.

Evaluation of CBCT images

CBCT images were obtained using a 3D Accuitomo 170 system (J. Morita, Kyoto, Japan). The scanning parameters were 90 kV, 5 mA and 30.8 sec, with a voxel size of 250 μm and FOV of 140x100 cm. Coronal, axial, sagittal and cross-sectional images obtained with a slice thickness and interval of 1 mm were reconstructed using i-Dixel 2.0 software (J. Morita, Kyoto, Japan) and evaluated on a 30-inch flat panel screen (DELL Ultrasharp, USA) with a resolution of 2560 × 600 pixels by adjusting the contrast and brightness of the images for best visualisation in a dark room. Two trained and designated examiners (one radiologist and one endodontist) analyzed the CBCT images concurrently, and a consensus was reached by discussing the radiological findings to minimise possible errors. When the results were inconsistent, the images were re-evaluated until a consensus was reached among examiners.

Initially, each root of the maxillary molars was aligned to the vertical and horizontal marking lines parallel to the long axes of each canal on all three planes. The evaluation was performed first on the axial plane and then on the coronal and sagittal planes to confirm the findings by scrolling downward continuously through the images from the pulp chamber to the apex. Each MB root of the maxillary molars was investigated in the apical 3 mm of the pulp chamber according to the presence of an MB2 canal. In endodontically treated maxillary molars with an MB2 canal, the MB2 canal was determined to be missed if the filling material did not appear from the coronal orifice of the canal to the apex, including canals splitting from the main MB (MB1) canal. AP was diagnosed when a low-density area at the radiographic apex at least twice the thickness of periodontal ligament space with disruption of the lamina dura was detected [4]. AP in all roots of maxillary molars was recorded.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 22; Armonk, NY: IBM Corp.). The chi-square test, Fisher's exact chi-squared test and Yate's continuity of correction were performed to verify differences between the groups. Odds ratios (ORs) were calculated with 95% confidence intervals (CIs) to assess the relative risk. The level of significance was set to $p < 0.05$.

RESULTS

The study group consisted of 257 (27.6%) endodontically treated maxillary molars (157 first, 100 second molars) and 673 (72.4%) endodontically untreated maxillary molars (264 first, 409 second molars) of 170 male (47.6%) and 187 female (52.4%) patients aged 18–74 years (40.53 ± 12.99). The examined images were classified into three age groups: 18–39 ($n = 166$, 46.5%), 40–59 ($n = 167$, 46.8%) and > 60 years ($n = 24$, 6.7%).

Of the maxillary molars, 35.3% (n: 328) showed an MB2 canal. The prevalence of MB2 canals was significantly higher in maxillary first molars (46.7%) than in maxillary second molars (25.9%) ($p = 0.001$; $p < 0.05$). However, the presence of bilateral MB2 canals was almost equal in maxillary first and second molars ($p > 0.05$) (Table 1).

The 18-39-year age group presented a significantly higher prevalence of MB2 canals than the 40-59-year and > 60-year age groups ($p = 0.005$; $p < 0.05$) (Table 2). Male patients were found to be 1.751 times more likely to have MB2 canals than females (OR: 1.751; 95% CI: 1.334–2.297).

AP was detected in 77.1% of endodontically treated teeth ($n = 198$), whereas it was 9.4% ($n = 63$) in endodontically untreated teeth. MB root presented statistically higher AP (70.8%) than the other roots of endodontically treated teeth ($p = 0.001$; $p < 0.05$). It was 61.5% for distobuccal (DB) and 54.5% for P roots. MB, DB and P (MB + DB + P) roots had the highest incidence of AP at the same time (n: 115, 68.9%), followed by MB + DB (n: 36, 21.6%), MB + P (n: 12, 7.1%) and DB + P (n: 4, 2.4%). Additionally, the incidence of AP was higher in endodontically treated teeth with MB2 canals (83.1%) than in those without MB2 canals (73.8%) ($p > 0.05$).

Of the MB2 canals, only 14 MB2 canals were identified and treated properly by dentists (Figure 1). The treatment rate of MB2 canals in maxillary first and second molars was 14.3% and 21.1%, respectively. The incidence of AP was significantly higher in endodontically treated teeth with missed MB2 canals (88%) than those with unmissed MB2 canals (57.1%) ($p = 0.012$; $p < 0.05$) (Table 3). The risk of AP was 5.5 times higher in endodontically treated maxillary molars with missed MB2 canals than in those with unmissed MB2 canals (OR: 5.5, 95% CI: 1.549–19.527).

DISCUSSION

The complex anatomy of root canals plays a challenging role and contributes to the failure of endodontic treatment in cases where the anatomy is not correctly identified or treated [3]. When teeth have multiple roots and additional canals, each root and canal may have a different outcome. The MB2 canal is an extra canal that is usually curved, very small and located palatally or mesiopalatally to the MB1 canal of maxillary molars. Its orifice is often covered by deposits of secondary dentin or pulpal calcification, and there may be an isthmus between the MB2 and MB1 canals. These characteristics of the MB2 canal may complicate both the diagnosis of its presence and the process of gaining access to the apex of the MB root [2, 11, 15].

Numerous studies have investigated the prevalence of MB2 canals in maxillary molars, particularly first molars. Their findings vary according to differences in the methodology of the study and the race, sex and age of the population [16]. In a comprehensive CBCT study conducted in twenty-one countries, the prevalence of MB2 canals in maxillary first molars was documented as varying from 48 to 97.6% [2]. The prevalence in maxillary second molars also widely ranged from 17.7 to 84.3% [11, 15, 17–21]. In agreement with the findings reported by Fernandes et al. and Nikoloudaki et al., the MB2 canal was found to be significantly more common in maxillary first molars (46.7%)

TABLE 1 Presence of MB2 canals in maxillary molars

	Maxillary molars	First molars (*n*, %)	Second molars (*n*, %)	Total (*n*, %)	*p*
Presence of an MB2 canal	Present	196 (46.7)	132 (25.9)	328 (35.3)	**+0.001***
	Absent	224 (53.3)	378 (74.1)	602 (64.7)	
	Unilateral	96 (65.8)	68 (68)	164 (66.7)	0.714
	Bilateral	50 (34.2)	32 (32)	82 (33.3)	

Note: Chi-squared test. **$p < 0.05$.

than in maxillary second molars (25.9%) in the present study [19, 20].

Compared with the data of previous Turkish studies, the present findings for maxillary second molars are similar to those reported by Usta and Eymirli [18]. However, the prevalence rates of MB2 canals in maxillary molars in the present study are higher than those reported by Magat and Hakbilen [17]. Contrary to their study, in which the MB2 canal in the apical 1 mm of the pulp chamber was examined, in the present study, we analyzed the MB2 canal in the apical 3 mm of the pulp chamber, which yielded MB2 canal prevalence rates consistent with those in previous ex vivo Turkish report [17, 22].

To date, conflicting results regarding the correlation between sex and the presence of an MB2 canal have been reported. A few studies reported no statistically significant difference between sexes [20, 21], whereas some studies showed a male predominance regarding the MB2 canal [2, 11, 17, 18, 23]. This fact could be explained by the threefold greater demineralization and loss of bone mass occurring in females, which would result in a lack of contrast on tomography and prevent accurate MB2 canal identification [24]. In addition, it has been proposed that the size

TABLE 2 Presence of MB2 canals in participants categorised by age group and sex

Presence of an MB2 canal		Present (*n*, %)	Absent (*n*, %)	*p*
Age group (years)	18–39	195 (39.8)	295 (60.2)	0.005*
	40–59	120 (31.3)	264 (68.8)	
	>60	13 (23.2)	43 (76.8)	
Sex	Male	184 (42)	254 (58)	0.001*
	Female	144 (29.3)	348 (70.7)	

Note: Chi-squared test. *$p < 0.05$.

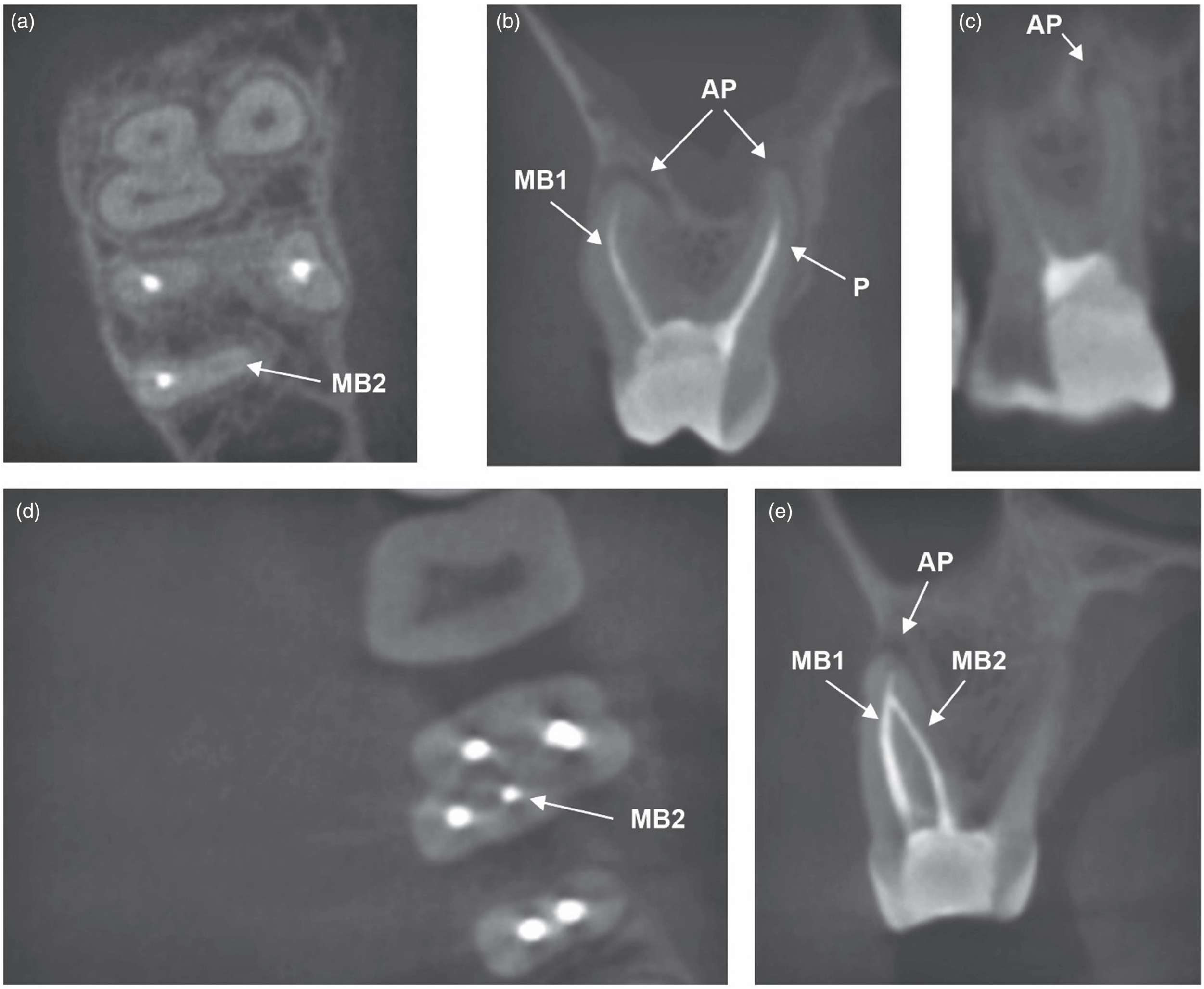

FIGURE 1 CBCT images of two endodontically treated right maxillary first molars with missed (a–c) and unmissed (d–e) MB2 canals. (a) Missed MB2 canal and treated MB1, DB and P canals on the axial plane. (b) Treated MB1 and P canals with AP on the sagittal plane. (c) Missed MB2 canal with AP on the coronal plane. (d) Unmissed and properly treated MB2 canal on the axial plane. (e) MB1 canal and MB2 canal with AP on the sagittal plane

TABLE 3 Presence of AP in endodontically treated maxillary molars with MB2 canals

Number of teeth	Presence of an MB2 canal (*n*, %)	Unmissed MB2 canal (*n*, %)		Missed MB2 canal (*n*, %)		*p*
		With AP	Without AP	With AP	Without AP	
#16	36 (40.5)	3 (60)	2 (40)	25 (80.6)	6 (19.4)	**0.012***
#26	34 (38.2)	2 (40)	3 (60)	26 (89.6)	3 (10.4)	
#17	9 (10.1)	3 (100)	0 (0)	6 (100)	0 (0)	
#27	10 (11.2)	0 (0)	1 (100)	9 (100)	0 (0)	
Total	89 (100)	8 (57.1)	6 (42.9)	66 (88)	9 (12)	

Note: Chi-squared test. $^{*}p < 0.05$.

of molars, which is generally larger in males due to sexual dimorphism, may lead to an increase in the number of root canals [16]. Since the relative risk of an MB2 canal was 1.751 times greater for males than females, the present study supports the aforementioned statement.

As age increases, tertiary dentin formation due to external factors may occur at certain sites of the pulp-dentin interface, which leads to greater root canal calcification in elderly patients. In addition, the narrow diameter of the MB2 canal, which is less than that of the main root canals, makes it difficult to detect it on CBCT images [15]. Additionally, the porosity of cortical bone increases over 50 years of age, and bone mass decreases, which results in a lack of contrast on CBCT [25]. Consequently, many researchers have indicated that both the presence of MB2 canals and the accuracy of CBCT for detecting MB2 canals decrease with age, which is also supported by the present findings [2, 17, 23]. This study shows a significant relationship between the presence of MB2 canals and younger age and emphasises the need to search for MB2 canals in those aged 18–39 years.

Previous studies have investigated the location and side differences and shown that the tooth location does not affect the prevalence of MB2 canals. Thus, information on the bilateral presence of MB2 canals is still much more important than information on side differences for clinicians [2, 11, 15, 17, 18, 21, 23]. The prevalence of bilateral MB2 canals has been reported to be very high for both maxillary first and second molars in previous studies [2, 17, 23]. Contrary to those findings, the prevalence of bilateral MB2 canals was relatively low in the present study. Nevertheless, this finding shows that consideration of the possibility of MB2 canals in the contralateral teeth of individual patients is essential.

Many researchers have reported that maxillary molars have the highest prevalence of missed canals (MB2 canals) and apical lesions when compared to other teeth [4, 7, 12, 26]. The higher frequency of missed MB2 canals observed in maxillary first molars than in maxillary second molars in the present study is consistent with that in earlier reports [12, 14]. Regarding the individual roots of maxillary molars, the MB root was the major root showing AP in endodontically treated teeth of the present study group. When more than one root had AP, involvement of the MB root was detected in the majority of the cases. The determination of additional canals is of great importance in endodontic treatment, and the above findings suggest the complexity of MB roots compared with other roots of maxillary molars. Previous studies have shown that more than 40% of MB roots have additional canals ending with two separated apical foramina (Vertucci types IV, V, VI and VII) [22, 27]. When the MB2 canal merges with the MB1 canal (Vertucci type II) and if the MB1 canal is filled successfully to the apical constriction, the possibility of AP decreases due to the adequate apical seal [28]. In cases of missed MB2 canals, the existence of an additional canal is still one of the main causes of endodontic treatment failure [5].

Nascimento et al. [26] reported an increase in the frequency of endodontic technical errors when additional canals, i.e. MB2 canals, were present. do Carmo et al. [14] emphasised that for a one-unit increase in the number of canals, the probability of missed canals increased by 4.22%. Previous studies have shown positive correlations between missed MB2 canals and AP, and the relative risk for AP has been reported to range from 2.57 to 3.1 [12, 14]. Similarly, this study found that the probability of AP was 5.5 times higher in endodontically treated maxillary molars with missed MB2 canals than in those with unmissed MB2 canals. However, this value is relatively higher than that in the aforementioned studies [12, 14].

The differences between the findings may depend on variable factors of the methodology employed in the studies. The design of the present study was similar to that of the study by do Carmo et al. regarding the criteria for evaluating MB2 canals and AP applied using a standardised CBCT device with the same voxel size (250 μm). However, the rate of AP with missed MB2 canals in the present study was almost twice the rate in their study. This may be related to the older age of the participants in their study group (>50 years) [14]. It should also be noted that since the methodology reported by Baruwa et al. varied in terms of observers and devices, the results were difficult to standardise. Additionally, their study did not focus solely on maxillary molars. As another factor, interpretation of the images by a higher number of observers might interfere with the subjective assessment results. Furthermore, the use of five different CBCT devices with varying resolutions and different voxel sizes (80–200 μm) might affect the homogeneity of the results [12]. Earlier studies have suggested that decreasing the voxel size increases the accuracy of diagnosing MB2 canals [10, 29]. However, Vizzotto et al. [30] noted that root canal filling material had a greater effect than the voxel size on the detection of MB2 canals. Scatter and beam hardening artefacts caused by the high density of neighbouring structures (root canal fillings, metallic posts, etc.) may affect the diagnostic accuracy of CBCT by reducing the image quality [8]. In contrast, Mirrmahommadi et al. [10] indicated that the presence of root canal filling material did not affect the diagnostic accuracy of CBCT. Although the aim of the present study was not to observe the outcome of artefacts in terms of the assessment of MB2 canals, we observed that the presence of root canal filling material did not seem to influence the image quality or the detection of MB2 canals. Additionally, the voxel size in the present study was 250 μm, which is acceptable for the detection of MB2 canals. Vizzotto et al. [30] stated that the experience of observers may play an important role in the detection of MB2 canals. In the present study, one radiologist and one endodontist with at least 10 years of experience evaluated the CBCT images concurrently.

CBCT imaging is considered to be the gold standard for in vivo studies of MB2 canals [11, 12]. However, no acceptable CBCT imaging protocol for endodontic purposes has been reported, except for the recommendation of a high resolution and small FOV [6]. In the present study, despite not being the most suitable setting, a FOV of 140x100 cm was used due to the retrospective design of the study.

This study highlights a significant correlation between untreated MB2 canals and AP and shows that the presence and treatability of MB2 canals have an impact on the treatment outcomes. However, it should be noted that the results only show an association between MB2 canals and AP and do not represent a causal relationship with endodontic treatment failure, which is regarded as multifactorial. One important limitation of this study is the retrospective cross-sectional design due to the evaluation of CBCT images at a given point in time. The clinical data related to the steps of the endodontic treatment of teeth with and without MB2 canals are not available. Additionally, the exclusion criteria of this study restricted the size of the study group to 357 out of 2126 patients.

CONCLUSION

As the detection rate of MB2 canals in maxillary molars has increased due to sophisticated clinical instruments and radiologic imaging modalities, clinicians should take into account the possibility of additional canals and variations of teeth in endodontic procedures. The treatment rate of MB2 canals in this study was remarkably low and missed MB2 canals increased the risk of AP by 5.5 times. When there is AP related to the MB root of maxillary molars, the possibility of a missed MB2 canal should be considered and further investigated three-dimensionally. Based on our findings, the maxillary first molars of young adult male patients require a closer look due to the higher probability of the presence of MB2 canals. These results also indicate the need for future clinical prospective studies to assess the exact interaction.

AUTHOR CONTRIBUTIONS

G.C. and I.K.B. involved in the methodology and investigation. I.K.B. and Y.G.B. involved in conceptualization. M.A.E. involved in resources. I.K.B., M.A.E. and S.E.Y. involved in formal analysis. Y.G.B. and S.E.Y. involved in supervision. G.C. and S.E.Y. involved in writing—review and editing. All authors have contributed significantly, and all authors have read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no financial support or relationships that may pose conflicts of interest.

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