Three-dimensional position of mandibular third molars and its association with distal caries in mandibular second molars: a cone beam computed tomographic study

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Abstract

Objective To analyze the prevalence of distal caries in mandibular second molars (M2Ms) and its correlation with the three-dimensional position of mandibular third molars (M3Ms) by cone beam computed tomography (CBCT) images.

Materials and methods CBCT scans involving 421 M3Ms were assessed. The presence of distal caries of M2Ms, patient age and gender, impaction depths and mesial angulation of M3Ms, the cemento-enamel junction (CEJ) distances and contact point localization, and the horizontal positions of M3Ms were assessed. Risk factors were identified by multivariate logistic regression analysis.

Results The overall prevalence of distal caries in M2Ms was 31.6%. Mesial angulation (16°–75°) of M3Ms, contact point localization at or below the CEJ of M2Ms, and a buccal or lingual position of M3Ms relative to the molar line were identified as risk factors for the prevalence of distal caries in M2Ms ($p < 0.05$). Distal caries was more severe when the mesial angulation of M3Ms was 16°–75° ($p < 0.05$).

Conclusions Buccal or lingual position of M3Ms may represent a new risk factor for the distal caries in M2Ms. Mesial angulation (16°–75°) of M3Ms is a predictive parameter for both the presence and severity of distal caries in M2Ms.

Clinical relevance As the presence of distal caries in M2Ms is significantly associated with the three-dimensional position of M3Ms, watchful monitoring or prophylactic removal of M3Ms should be deliberated when M3Ms are mesially angulated (16°–75°), buccally or lingually positioned, and with the contact point localization at or below the CEJ of M2Ms.

Keywords Dental caries · Mandibular third molar · Mandibular second molar · Distal caries · Cone beam computed tomography

Introduction

Third molars often fail to completely erupt into function due to either lack of space, development in an abnormal position, or aberrant eruption path and may bear pathological changes including periodontitis, pericoronitis [1], cystic lesions [2], and development of cysts or tumors [3]. They were also associated with caries in the distal surfaces of adjacent mandibular second

molars (M2Ms) [4–7]. M2Ms with distal caries associated mandibular third molars (M3Ms) may further develop pulpitis or apical periodontitis [8] and need endodontic therapy or even extraction. Early detection and evaluation of the caries risk of M2Ms associated with an adjacent M3M might be useful for the prevention of distal caries in M2Ms [2]. Although prophylactic removal of impacted M3Ms remains controversial, when the M2Ms are at a high risk of developing caries due to their proximity to the M3Ms, preventive extraction of the M3Ms may be recommended to reduce caries risk in M2Ms [8].

Many studies correlating the presence of distal caries in M2Ms and the eruption status of M3Ms have been performed using periapical or panoramic radiographs. The reported distal caries prevalence ranges from 13.4 to 25.4% [2, 5, 6, 9]. Using periapical or panoramic radiographs, the mesial angulation, the vertical position of M3M, and the distance between M2M and M3M have been found to be the risk factors for distal caries in M2Ms [2, 4–6, 9–11].

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To date, very few studies have explored the effect of eruption status of M3M on the presence of distal caries lesions of M2M by using cone beam computed tomography (CBCT). Compared with two-dimensional radiographs, CBCT images offers distinct advantages of three-dimension visualization free from overlaps and have been shown to improve the detection of proximal carious lesions for M2Ms [12–14]. It has been found that the bucco-lingual position of M3Ms cannot be visualized using panoramic and periapical techniques [15]. CBCT can supply the detailed information of the proximity relationship between M2M and M3M in three dimensions, making analysis of risk factors of distal caries of M2M more accurate. Considering that the unique interproximal region between the M2M and M3M might facilitate food impaction and plaque retention and consequently caries, the proximity relationship between M2M and M3M in three dimensions, including the horizontal plane, should be studied for its association with the presence of distal caries of M2Ms. Currently, as a potential risk factor for distal caries of M2M, the proximity relationship between M2M and M3M in the horizontal plane has not yet been analyzed and evaluated.

The aim of this retrospective study, based on CBCT images, was to analyze the prevalence of distal caries in M2Ms and correlate this with the eruption and position of M3Ms in three dimensions, including its bucco-lingual position on the horizontal plane. The severity of distal caries in M2Ms as it relates to these variables was also analyzed.

Materials and methods

Sample selection

The present study was approved by the ethics committee of the Affiliated Stomatological Hospital of Sun Yat-sen University, Guangzhou, China (ERC-2017-09). Seven hundred and ten CBCT images were randomly selected from 3500 images with a field of view (FOV) of 16 cm × 7 cm and a voxel size of 0.20 mm, which were just enough to display the complete upper and lower dentition and were of adequately high resolution. These CBCT scans had been taken for diagnostic purposes by several different departments, including oral surgery, endodontics, prosthetics, and orthodontics, in the Affiliated Stomatological Hospital of Sun Yat-sen University from 2010 to 2018.

The included CBCT images must distinctly display images of the M3Ms and the adjacent M2Ms. CBCT images were excluded from this study if (1) M3Ms or M2Ms were associated with root resorption, extensive carious lesions (more than one surface was affected), cysts, tumors, osteomyelitis, and trauma; (2) images with artifacts owing to the presence of high-density materials or other reasons that obscured the areas of interest; and (3) M3Ms with less than two thirds of the root developed [8]. Only one M3M from each patient was included

in this study to avoid the potential for selection bias. Thus, when both right and left M3Ms of the same patient met the inclusion criteria, only one M3M was randomly included.

CBCT images of 421 patients (208 men and 213 women), with a mean age of 34 years (range from 18 to 75 years), involving 421 M2Ms adjacent to M3Ms (191 at the left and 230 at the right) were collected and assessed.

Radiographic assessment

The images were obtained using a CBCT scanner (DCTPRO; VATECH, Yongin-Si, Republic of Korea). The operating parameters were set at 90.0 kV and 9 mA with a scanning time of 24 s. The measurements were evaluated by Ez3D 2009 software (Vatech Corporation, Hwaseong-si, Gyeonggi-do, Republic of Korea).

The impaction depths of the M3Ms were categorized according to the classification of Pell and Gregory [16] (Fig. 1a). The mesial angulation of the M3M was calculated by measuring the angle of the intersection made by the occlusal plane of the M2M and the occlusal plane of the M3M [17] (Fig. 1b). The occlusal plane was drawn along the tips of the cusps of the M2M or the M3M [17]. In our study, when the angulations were respectively < −15°, −15° to 15° (between −15° and 15°, including −15° and 15°), 16°–75°, and > 75°, the M3M was defined as distally, vertically, mesially, and horizontally impacted [18]. The distance between the mesial cemento-enamel junction (CEJ) of the M3M and the distal CEJ of the adjacent M2M, abbreviated as “CEJ distance” (Fig. 1c) [19]. The contact point between M3Ms and M2Ms was categorized according to the distal CEJ of the M2M. The categories were on the CEJ, above the CEJ, and below the CEJ (Fig. 1d) [5].

The horizontal position of the M3M was determined according to the median of the crown contour of the M3M in relation to the molar line, a line extending from the median of the lower first premolar (or canine in the case of an absent premolar) to the median of the M2M on the horizontal plane, modified from the method of Ishii et al. [20] (Fig. 2). The horizontal positions of M3Ms were categorized as follows: median position, in which the distance between the median of the crown of the M3M and the molar line was less than 0.5 mm; buccal position, in which the median of the crown of the M3M was buccal to the molar line and the distance to the molar line was more than 0.5 mm; and lingual position, in which the median of the crown of the M3M was lingual to the molar line and the distance to the molar line was more than 0.5 mm (Fig. 2).

Impaction depths, mesial angulations of M3Ms, CEJ distance, and contact point localization were evaluated in the sagittal planes of CBCT images. The horizontal position of M3Ms was measured in horizontal planes. M3M mesial angulation and CEJ distances were measured in three different sagittal planes. Using the Ez3D 2009 software, after a pulp chamber of the M2M appeared in the horizontal window, we rotated the sagittal line

Fig. 1 Impaction status of the mandibular third molar (M3M). **a** Impaction depth of the M3M according to the classification of Pell and Gregory [16]. **b** Mesial angulation of M3M [17]. **c** Distance between the mesial cementoenamel junction (CEJ) of the M3M and the distal CEJ of the mandibular second molar (M2M) [19]. **d** Localization of contact point between the M3M and the M2M [5]

until the width of the M3M crown reached the largest dimension in the sagittal window, which was the first sagittal plane for us to measure M3M mesial angulation and CEJ distances. Then, we turned the sagittal line clockwise and counterclockwise by 2° to get another 2 sagittal planes. And then, the average values were obtained. A carious lesion was determined to be present when radiolucency with irregular morphology and margins could be observed in the enamel and/or dentine in any of the sagittal or horizontal planes and a clear gap existed between the crown of the M3M and the distal aspect of M2M [8, 21].

We have adapted and modified the radiographic classification in the international caries detection and assessment system

(ICDAS) [22] and the International Caries Classification and Management System (ICCMS™) [23] for use in this study. According to the radiographic appearance, the severity of carious lesions was classified as (1) slight caries, involving less than half the dentin thickness; (2) moderate caries, involving at least half the dentin thickness and with the pulp cavity remaining unbroken; and (3) severe caries, involving the pulp cavity (Fig. 3).

The presence and severity of distal caries in the M2Ms, impaction depth, contact point localization, and horizontal position of M3M were evaluated independently by two observers. Disagreements were resolved by discussion to consensus. If a consensus could not be reached, a third observer was consulted

Fig. 2 M3M horizontal position was determined according to the relationship between the median of the crown of the MTM and the molar line (from the median of the lower first premolar (or canine in the

case of an absent premolar) to the median of the lower second molar), which is modified by the method of Ishii et al. [20]. The categories were **a** buccal position, **b** median position, and **c** lingual position

Fig. 3 The severity of caries on distal surface of the M2M was categorized as **a, b** slight caries, involving less than half the dentin thickness; **c, d** moderate caries, involving at least half the dentin thickness with the pulp lining being unbroken; and **e, f** severe caries, involving the pulp cavity [22, 23]

to come to agreement. To analyze the intra-observer agreement, 43 randomly selected cases (10% of the whole) were assessed and repeated after a month.

Statistical analysis

Data were processed using SPSS 24.0 for Windows (SPSS Inc., Chicago, IL, USA). The inter-observer and intra-observer agreement on the measurement of the radiographic characteristics was analyzed using Cohen's κ test (poor agreement, less than 0.40; moderate agreement, 0.40 to 0.59; good agreement, 0.60 to 0.74; excellent agreement, 0.75 to 1.00). The association between distal caries in the M2M and demographic/radiographic variables was analyzed using Pearson's chi-square independence tests. Then, a multivariate logistic regression model was built to further evaluate predictive values of the factors for the prevalence of distal caries in M2Ms. The severity of distal caries among different groups classified according to the radiographic characteristics was compared by the Kruskal-Wallis test or Mann-Whitney U test. The level of significance was set at a p value < 0.05 .

Results

The level of agreement between the two observers was excellent ($\kappa = 0.891\text{--}0.946$; $p < 0.001$). The intra-observer

reliability of both observers was excellent (κ of observer A = $0.873\text{--}0.962$; κ of observer B = $0.907\text{--}0.936$; $p < 0.001$).

The overall prevalence of distal caries in M2Ms adjacent to the M3Ms was 31.6% (133/421). Most M3Ms were vertically or mesially inclined (307/421) and class B impacted (278/421) in the sagittal plane, and buccally positioned to the molar line (244/421) in the horizontal plane. The presence of distal caries in M2Ms and its association with various demographic and radiographic characteristics are shown in Table 1. Pearson's chi-square independence tests indicated that mesial angulation and the buccal or lingual position of M3M, CEJ distance, and contact point localization were associated with the presence of distal caries in M2Ms ($p < 0.05$; Table 1). The prevalence of distal caries in M2Ms was not related to age, gender, and depth of impaction ($p > 0.05$; Table 1).

Among the different groups of mesial angulation of M3Ms, mesially inclined M3Ms (mesial angulation $16^\circ\text{--}75^\circ$) were related to the highest prevalence of distal caries in M2Ms (57.5%), followed by horizontally inclined M3Ms (mesial angulation $> 75^\circ$). Distal caries in M2Ms was more frequently found when the CEJ distance was of 6–9 mm (55.7%), compared to other groups with CEJ distance outside the range. Distal caries in M2Ms was less observed in the cases in which the contact points were above the distal CEJ of M2Ms (11.7%), compared to those cases in which the contact point was at and below the distal CEJ of M2Ms (77.5% and 52.5%, respectively). Buccally and lingually

Table 1 The prevalence of distal caries in mandibular second molars and its associations with the demographic/radiographic characteristics

Variables	Total <i>n</i> = 421	Presence of distal caries of M2M		<i>p</i> value
		Yes (%)	No (%)	
Age (years)				
18–27	158	54 (34.2)	104 (65.8)	0.237
28–37	125	43 (34.4)	82 (65.6)	
≥ 38	138	36 (31.6)	102 (68.4)	
Gender				
Male	208	64 (30.8)	144 (69.2)	0.400
Female	213	69 (32.4)	144 (67.6)	
Impaction depth				
A	97	22 (22.7)	75 (77.3)	0.090
B	278	94 (33.8)	184 (66.2)	
C	46	17 (37.0)	29 (63.0)	
M3M mesial angulation				
<− 15° (distally angulated)	72	10 (13.9)	62 (86.1)	< 0.001*
− 15° to 15° (vertically angulated)	161	24 (14.9)	137 (85.1)	
16°–75° (mesially angulated)	146	84 (57.5)	62 (42.5)	
> 75° (horizontally angulated)	42	15 (35.7)	27 (64.3)	
CEJ distance (mm)				
< 6	266	55 (20.7)	211 (79.3)	< 0.001*
6–9	88	49 (55.7)	39 (44.3)	
> 9	67	29 (43.3)	38 (56.7)	
Contact point localization				
Above	240	28 (11.7)	212 (88.3)	< 0.001*
At	40	31 (77.5)	9 (22.5)	
Below	141	74 (52.5)	67 (47.5)	
Horizontal position of M3M				
Buccal	244	102 (41.8)	142 (58.2)	< 0.001*
Median	161	25 (15.5)	136 (84.5)	
Lingual	16	6 (37.5)	10 (62.5)	

CEJ distance is the distance between the mesial CEJ of the M3M and the distal CEJ of the M2M

M3M mandibular third molar, CEJ cemento-enamel junction

*Statistically significant ($p < 0.05$ by Pearson's chi-square independence test between categorical variables)

positioned M3M was associated with higher prevalence of distal caries in M2Ms (41.8% and 37.5%, respectively), while distal caries in M2Ms was less observed when the adjacent M3M was in the median position (15.5%).

Since CEJ distance was significantly associated with M3M mesial angulation ($R^2 = 0.809$, $p < 0.001$) (Fig. 4), CEJ distance was not included in the multivariate logistic regression models.

Multivariate logistical regression analysis revealed that M3M with the mesial angulation of 16°–75° significantly increased the prevalence of distal caries in M2Ms (OR = 2.91; $p = 0.018$). Contact point at or below the CEJ of M2M was identified as a risk factor for distal caries in M2Ms (contact point at the CEJ: OR = 15.61; contact point below the CEJ: OR = 4.29; both $p < 0.001$). Both buccal and lingual positions of M3Ms were (2.13 and 4.28 times, respectively) more likely to cause distal caries in M2Ms when compared with M3M in the median position (both $p < 0.05$) (Table 2).

The comparison of the severity of carious lesions among groups classified according to patient age and the radiographic characteristics is shown in Table 3. Carious lesion severity was statistically different among groups with various mesial angulations ($p < 0.05$). Distal caries in M2M was more severe in cases where the mesial angulation of M3M was 16°–75° than that with the angulation outside this range. Patient age, contact point localization, and horizontal position of M3Ms were not associated to the severity of the carious lesions of M2Ms.

Discussion

The prevalence of distal caries in M2Ms associated with M3Ms was 31.6% in this study, which was higher than that in some previous studies (13.4–25.4%) [2, 5, 6, 9]. In those previous studies, panoramic radiographs were used to detect distal caries, while CBCT was employed in this present study. This may

Fig. 4 Correlation between M3M mesial angulation and “CEJ distance” ($r = 0.809$, $p < 0.001$), the distance between the mesial cementoenamel junction (CEJ) of the M3M and the distal CEJ of the M2M

explain the difference of the prevalence of distal caries in M2Ms reported by these studies. By using CBCT images, Kang et al. [8]

Table 2 Multivariate logistic regression models for demographic/radiographic parameters as risk factors for prevalence of distal caries in mandibular second molars

Variables	OR	95% CI of OR		<i>p</i> value
		Lower	Upper	
M3M mesial angulation				
<− 15° (distally angulated)	1			
− 15° to 15° (vertically angulated)	1.20	0.50	2.84	0.687
16°–75° (mesially angulated)	2.91	1.21	7.03	0.018*
> 75° (horizontally angulated)	1.23	0.42	3.60	0.700
Contact point localization				
Above	1			
At	15.61	6.26	38.95	< 0.001*
Below	4.29	2.16	8.54	< 0.001*
Horizontal position of M3M				
Median	1			
Buccal	2.13	1.13	4.05	0.020*
Lingual	4.28	1.13	16.18	0.032*

OR odds ratio, CI confidence interval

*Statistically significant ($p < 0.05$ by multivariate logistic regression analysis)

reported a much higher prevalence of distal caries in M2Ms (52%), probably because patients in their study were those who underwent preoperative assessment for the removal of M3Ms, while patients in our study were randomly selected from an archive of CBCT referred from all departments in our hospital. Therefore, the prevalence of distal caries in M2Ms associated with M3Ms in the present study may reflect the status of distal caries in M2Ms in a Chinese population better. Besides, in our study, we excluded M3Ms or M2Ms associated with extensive carious lesions (when more than one surface was affected) during sample selection because the mesial angulation or impaction depth of the M3M cannot be measured if M2Ms lost the normal occlusal plane, which may also explain the different prevalence.

In the present investigation, M3Ms with the mesioangular inclinations (15°–75°) were found to increase the likelihood of the presence of distal caries in the M2M, which was in line with the other studies in which M3Ms with inclinations of 43°–73° were observed to be 3.51 times more likely to lead to distal caries in the M2M as those outside of the range [8]. Ozeç et al. [5] reported that M3Ms with inclinations of 31°–90° were more likely to cause distal caries in the M2M. CEJ distance is the distance between the mesial CEJ of the M3M and the distal CEJ of the M2M. The more the M3M tilted mesially, the more the CEJ of the M3M moved distally; thus, the CEJ distance became larger. Some previous studies revealed a linear correlation between M3M mesial angulation and CEJ distance [8, 18].

Table 3 Comparison of the severity of carious lesions on mandibular second molars among groups classified according to the radiographic characteristics

Variables	<i>n</i>	Mean rank	<i>p</i> value
Age			
18–27	54	66.31	0.055
28–37	43	59.62	
≥ 38	36	76.86	
M3M Mesial angulation ^a			
≤ 15°	34	54.19 (I)	0.001*
16–75°	84	75.11 (II)	
> 75°	15	50.63 (I)	
Contact point localization			
Above	28	60.63	0.483
At	31	67.89	
Below	74	69.04	
Horizontal position of M3M ^b			
Buccal/lingual	108	67.63	0.632
Median	25	64.26	

Different letters (I, II) indicated statistically significant difference between groups ($p < 0.05$ by post hoc comparisons after Bonferroni correction), while the same letter indicates no statistically significant difference between groups

*Statistically significant difference ($p < 0.05$ by the Kruskal-Wallis test or Mann-Whitney *U* test)

^a The primary groups $< -15^\circ$ and -15° to 15° were merged into a new group $\leq 15^\circ$, due to insufficiency of sample size

^b The primary groups (buccal and lingual) were merged into a new group (buccal/lingual), due to insufficiency of sample size

In the present study, we also found increased CEJ distance was associated with greater M3M mesial angulation. Thus, CEJ distance was not included in the multivariate logistic regression model. Some previous studies have reported that the M3M with contact point at or below the M2M's CEJ increased the prevalence of distal caries in M2Ms [5, 9]. In line with their studies, the present study found that the M3Ms which contacted M2Ms at and below the CEJ were 15.61 and 4.29 times, respectively, as likely to have distal caries in M2Ms as those that contact above the CEJ. We speculate that the proximity relationships between M2M and M3M as the abovementioned three conditions (M3M mesial angulation of 15° – 75° , a CEJ distance of 6 mm to 9 mm, and contact point at or below the CEJ of M2M) facilitated more food impaction and plaque retention, which caused the carious lesions [8].

Notably, the horizontal position of the M3M is a new risk factor evaluated in the present study. To the best of our knowledge, this study was the first to evaluate whether the horizontal position of the M3M can affect the presence of distal caries in the M2M. The present study revealed that M3Ms located to the buccal or lingual side of the molar line increased the likelihood of distal caries in the M2M when compared with M3Ms located in the median position. We speculated that food impaction

between M2M and M3M may happen more frequently and be more difficult to clean when the M3M was either buccally or lingually dispositioned. If the M3M is in the buccal position, food dislodging from the buccal functional cusp of the M2M lodges more easily into the impaction space between the two teeth and allows more plaque accumulation. In the lingual position, tooth brushing is altogether more difficult as the lingually displaced M3M further reduces the space available for maneuvering a toothbrush or other methods for optimum hygiene.

Some previous studies have indicated that the prevalence of distal caries in M2Ms increases with age [4–6, 8]. The present study did not show any correlation between age and the prevalence of distal caries in M2Ms, which partially agreed with Marques et al. [9], probably due to the low mean age of the sample (34 years $\pm$ 12 years). The association between age and carious lesion severity was also not statistically significant, which may be attributed to the insufficient sample size and the method of assessing severity of lesions (131 distributed in 3 age groups and 3 caries severity levels). In addition, these previous studies were performed in population that consulted the hospital for M3 removal, while our sample was randomly selected from an archive of CBCT referred from all departments in our hospital, so the prevalence and the severity of M2M distal caries in previous studies may be higher than that of our study. As caries progresses over time, the association between age and the prevalence of carious lesions could be expected in those studies. It has been suggested that prevalence of distal caries in M2Ms of men was higher than that of women [6]. However, similar with Kang et al. [8], the present study showed that gender did not influence the prevalence of distal caries in M2Ms. It must be pointed out that the retrospective nature of this study meant that oral hygiene and socioeconomic factors were not taken into account and these factors are important in understanding caries prevalence.

Several indices have been used to describe the depth of carious lesions in clinical practice where both enamel and dentine were involved. However, these involved mostly the crowns of teeth whereas carious lesions that we were studying in the circumstances were entirely within dentine of the root. In this study, we have modified the criteria used in the radiographic examination of ICDAS and ICCMSTM and then classified caries severity into slight, moderate, and severe caries according to the radiographic appearance. To the best of our knowledge, this study was the first study to evaluate the effect of the three-dimensional position of M3Ms on the severity degree of distal caries in M2Ms. The present study found that M3M mesial angulation of 15° – 75° increases the severity of distal caries in the M2M. As the prognosis and the treatment of distal caries in M2Ms were dependent on the severity of the lesion [24], the analysis of factors associated with the severity of distal caries in the present study could provide in-depth reference for the treatment planning of involved M2Ms and M3Ms.

While it may be valid to believe that a radiolucent area on the distal of M2M next to an impacted tooth is due to caries,

the present study did not include clinical verification of caries. Further longitudinal multicenter studies should be designed to also include collection of clinical data such as color, texture, plaque index, probing depths, and extent of tooth impaction as it presented clinically, so that radiographic data could be substantiated. Another limitation was that the horizontal position of M3Ms was only qualitatively, but not quantitatively analyzed in this study. By the method of Ishii et al. [20], the horizontal inclination angle of M3M was quantitatively analyzed according to the intersection between the molar line and M3M axis line (from the median of the crown contour to the M3M root apex). But, this angle could be detected only when the M3M was mesially or horizontally inclined. A more precise quantitative method is needed in further studies.

In conclusion, distal caries in M2Ms adjacent to M3Ms is a common clinical condition. When the M3Ms are mesially angulated between 16° and 75° or at buccal or lingual position in relation to the molar line, or presented with contact point at or below the CEJ of M2M, clinicians should carefully diagnose whether there is distal caries in M2Ms, followed by watchful monitoring and cautious consideration of extracting the M3M. Clinicians should also keep their eyes on the presence of any clinical symptoms to make the final decision.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of our institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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