Measurements of Coronal Dentin of Mandibular Second Premolars in Japanese: Differences in Two Cusp Traits on Dental X-ray Images

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Abstract

We demonstrated radiomorphologically the differences in tooth dimension and coronal dentin thickness among mandibular second premolars (MnP2) by making comparisons between 2-cusp type (MnP2-2C) and 3-cusp type (MnP2-3C), and analyzed the correlation between the maximum mesiodistal diameter (MMD) of MnP2 and the measurement variables. The experimental specimens, including MnP2-2C (n = 82) and MnP2-3C (n = 85), were selected from dried Japanese extracted teeth, which were stored in our laboratory. The dental radiographs were taken mesiodistally and buccolingually. The statistical significance was assessed by the Mann-Whitney *U*-test, and the correlation between the 2 measurement variables was determined by simple linear regression analysis. Compared to the MnP2-2C, the MnP2-3C had a significantly larger tooth weight (TW), lingual mesiodistal diameter (LMD), mesiodistal diameter at the middle of the crown (AB), mesiodistal and buccolingual coronal dentin thickness (CD), perpendicular distance between dentin horn tips (PDHs and PDHs'), and dentin horn height (H_1 and H_2). The MMD of MnP2-3C was highly correlated with the AB ($r = 0.842$), and significantly larger than that of the MnP2-2C ($r = 0.576$). Similar findings were found with CD and CBL, and the relation was stronger in the MnP2-3C than in the MnP2-2C. Within the limit of this study, it was suggested that the increase in the number of lingual cusps in MnP2 affect the increase in the coronal dentin thickness and dentin horn height on the mesiodistal image, and the coronal dentin thickness at cervix on the buccolingual image, as well as the TW and the lingual mesiodistal diameter of the dental crown.

Key words: *Mandibular second premolar, Molarization, cusp trait, Dentin thickness, Dental X-ray image*

Introduction

The mandibular second premolar (referred to below as MnP2) is highly variable,[1] and its crown morphology is under a strong genetic influence.[2] The MnP2 has 2 cusp traits: the 2-cusp type (MnP2-2C) and the 3-cusp type (MnP2-3C).[3, 4] The traits of the lingual cusps of MnP2 have a regionally differential morphology and show racial characteristics.[5] The differentiation of a MnP2-3C into mesiolingual cusp (main cusp) and distolingual cusp (accessory cup) is called "molarization".[6-9] On the other hand, congenitally missing teeth and agenesis are highly frequent in MnP2, following those in the third molars.[9-14] Among maxillary and mandibular premolars (premolar tooth groups), MnP2 differentiates into multiple cusps and shows a tendency toward tooth reduction due to congenitally missing teeth. In other words, these teeth belong to an interesting tooth group characterized by differences in the direction of evolution.[8, 11]

A wide range of studies have been conducted on MnP2, which has a combination of 2 characteristics, and the research studies were about their conventional morphological features, their sexual dimorphism, and a comparison of mesial and distal enamel thickness in intraoral dental X-ray images of mandibular posterior teeth.[3, 15-35] Meanwhile, there is almost no literature on linear measurement studies on the dentin in the 2 traits of MnP2, which differ by their number of lingual cusps.[36, 37]

The aims of this investigation were to clarify the differences between the MnP2-2C and MnP2-3C in terms of size, total weight, and measurements of the coronal dentin using dental radiographic images, and also to analyze the correlation between the maximum mesiodistal diameter and other measurement variables of MnP2.

Materials and Methods

Selection of materials

The investigated samples consisted of dried extracted MnP2 in Japanese, which had been stored in our laboratory. The experimental specimens were composed of MnP2-2C (number: 82 teeth) and MnP2-3C (number: 85 teeth) found less attrition or abrasion but with mild surface enamel caries, which did not affect the measurements. The ages and sexes of the examined teeth were unspecified.

Table 1. Abbreviations for the linear measurements and tooth weight.

Reference points and lines

md and *bl*: Baselines through the cementoenamel junction points *m* and *d*, and *b* and *l* on mesiodistal and buccolingua dental X-ray images

a, b, and c: Mesial, mesiolingual, and distal dentin horn tips on mesiodistal dental X-ray images

d and e: Buccal and lingual dentin horn tips on buccolingua dental X-ray images

Mesiodistal diameter

MMD: Maximum mesiodistal diameter on the occulusal aspect of the dental crown

LMD: Lingual mesiodistal diameter through the mesiolingual or lingual cusp tip on the occulusal aspect of the dental crown

Length

OAL: Overall length of the tooth on buccolingua dental X-ray images

BCL: Buccal crown length of the tooth on buccolingua dental X-ray images

RL: Root length (formula: OAL - BCL)

Weight

TW: Tooth weight

AB and A'B': Mesiodistal and buccolingual diameters on the line crossing the middle half of the dental crown length on mesiodistal and buccolingual dental X-ray images

Middle crown diameter

CD and C'D': Coronal dentin thickness on the line crossing the middle half of the dental crown length on mesiodistal and buccolingual dental X-ray images

PDHs and PDHs': Perpendicular distance between dental horn tips: b to c on mesiodistal and d to e on buccolingual dental X-ray images

BL: Maximum buccolingual diameter of the dental crown on buccolingual dental X-ray images

CMD and CBL: Mesiodistal and buccolingual diameter on lines *md* and *bl* at the cervix on both dental X-ray images

Coronal dentin thickness

H_1, H_2, and H_3: Perpendicular distance between dentin horn tips a, b, and c to line *md* on mesiodistal dental X-ray images,

H_1' and H_2': Perpendicular distance between dentin horn tips d and e to line *bl* on buccolingual dental X-ray images

Dental X-ray macrophotography of the studied teeth

Dental radiographic images of the MnP2 were taken from the buccolingual direction (Mesiodistal image) and from the mesiodistal direction (Buccolingual image) with the film surface set on the lingual and mesial sides, respectively, and with the tooth fixed at 3 sites: for the former, the mesiobuccal and distobuccal line angles and the root apical region; for the latter, the distobuccal and distolingual line angles and the root apical region, using a small amount of utility wax and a jack in order for each one to be uniformly horizontal.

In both cases, the optical axis of the incident X-ray beam during radiography was perpendicular to the film surface. The focus film distance, perpendicular distance between the film and the focus of the dental X-ray device, was 25 cm. In prevention of scattered radiation during radiography, the films were placed on a 1-mm-thick lead plate, and the dental X-ray exposure was set at 0.5 s. After radiographic images were taken, the X-ray films were developed using an automatic processor.

The films were converted to JPG images using a scanner and were printed in a size 3 times bigger than the original; the reference lines were measured under 1–3 times magnifying lens by using a digital caliper with a vernier scale of 1/100 mm, and some were calculated using a formula.

Measurement sites and measurement methods

Table 1 shows the measurement sites of the teeth and their abbreviations. The actual measurements of the maximum mesiodistal diameter (MMD) and the overall length (OAL) of the studied teeth were performed in accordance with Fujita's method (Fig. 1A). The measurements of the coronal diameter and dentin thickness were performed on the basis of the straight lines *bl* and *md* connecting the cemento-enamel junctions in reference to Macho and Thackeray[38] (Figs. 1B and 1C).

The middle coronal indices on the image were measured on lines parallel to the baselines bl and md, which pass through half the length of the buccal side of the dental crown, and that cross the dentinoenamel junction (DEJ) and the coronal surface. RL were calculated from the formula (OAL−BCL). The tooth weights (TW) of an experimental specimen were measured with a Libror ED-200 (Shimadzu, Kyoto, Japan).

Figures 1B and 1C show the measurement sites on the coronal dentin. On the mesiodistal and buccolingual radiographic images, 5 points were drawn on the DEJ,

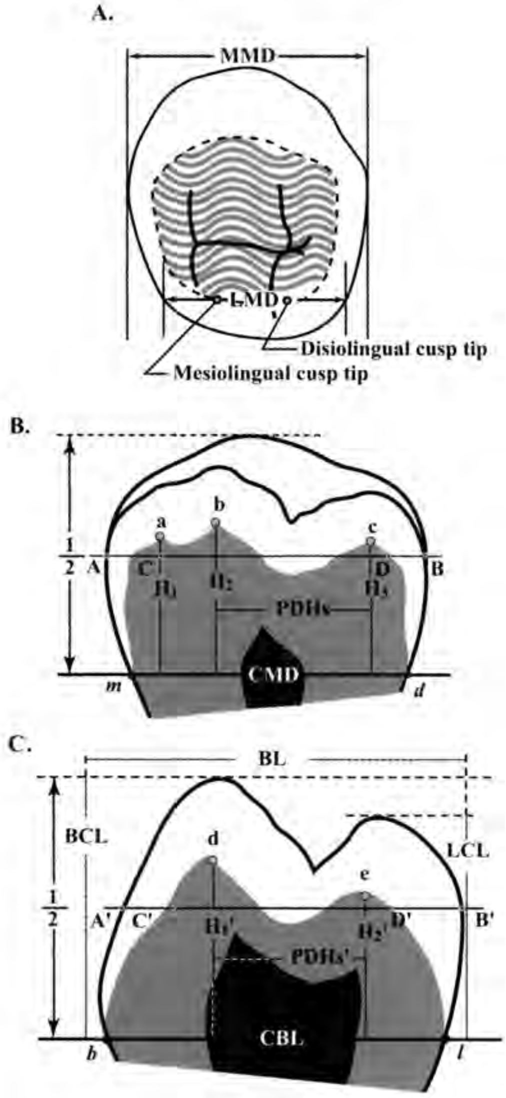

Fig. 1. Reference points and lines of the mandibular second premolars with 3-cusp type: occulusal aspect (A), mesiodistal images (B), and buccolingual images (C)

namely the mesial (a), mesiolingual (b), distal (c), buccal (d), and lingual (e) dentin horn tips. The 6 horizontal sites: the middle diameter of the dental crown, the diameter of the middle dental crown, the mesiodistal diameter at the cervix, the maximum coronal thickness, the perpendicular distance between dentin horn tips, the thickness of the cervix at the buccal aspect, and the 5 vertical sites: the dentin horn height (DHH) at the dental crown were measured radiomorphometrically. Sites where measuring points were vague were excluded from the data.

Statistical analysis

Means and standard deviations were calculated by using Microsoft Excel (Microsoft, USA) from data measuring for mesiodiatal and buccolingual thickness and height of the coronal dentin on dental X-ray images as well as actual measurement of tooth dimensions and employed for StatView-J ver. 4.0.2 (Avacus concepts, Inc, CA, USA) as statistical analysis software. The difference in mean values between MnP2-2C and MnP2-3C was estimated by statistical significance using Mann-Whitney *U*-test.

After the correlation between maximum mesiodistal diameter (MMD) and the other variables; crown and overall measurements of tooth anatomy calculated Peason's correlation coefficients using Microsoft Excel, it was tested significance statistically by a linear regression analysis. The significant difference in correlation coefficients of between r_1 (MnP2-2C) and r_2 (MnP2-3C) was evaluated by using Fisher's Z-transformation.

Results

1. Tooth size and weight

Table 2 shows the mean values and standard deviations in each of the measurement parameters, based on the actual and linear measurements of MnP2. A comparison of the mean values of the 2 cusp traits of MnP2 showed that in the MnP2-3C, LMD and TW were 0.37 mm and 40 mg significantly larger than those in the MnP2-2C, respectively.

2. Measurements of the coronal dentin on mesiodistal and buccolingual dental radiographic images

Tables 3 and 4 show the mean values and standard deviations of the measurement parameters on the coronal dentin on mesiodistal and buccolingual radiographic images. In the MnP2-3C, the CD, PDHs, H_1, and H_2 measured on mesiodistal images were significantly 0.37 mm, 0.70 mm, 0.16 mm, and 0.19 mm greater than those in the MnP2-2C, respectively. The PDHs measured on buccolingual images were also significantly 0.12 mm greater in the MnP2-3C than those in the MnP2-2C.

3. Correlation between maximum mesiodistal diameter and variables for the measurement parameters of the MnP2

Table 5 shows the correlation between MMD and the variables in the actual and linear measurement parameters. In both the MnP2-2C and the MnP2-2C, the correlations between MMD and LMD and TW were significant and moderate. However, the correlations between MMD and OAL, and RL were low, and no significant difference was found.

Tables 6 and 7 showed the correlation of the MMD with the variables in the mesiodistal and buccolingual measurement parameters of the coronal dentin. In mesiodistal images, MMD and AB showed a significantly high correlation in the MnP2-3C and a significant moderate correlation in the MnP2-2C, as well the correlations between MMD and LMD, CD and CMD were significant and moderate in both traits. In the MnP2-3C, a significant and moderate correlation was found between MMD and PDHs and H2. Meanwhile, the correlation between MMD and AB and CD was significantly higher in the MnP2-3C (r

Table 2. Comparison of the mean values of the demension and tooth weight of the mandibular second premolars with 2- and 3-cusp types

	Cusp traits						
	3-cusp type			2-cusp type			
Demension	N	Mean	SD	N	Mean	SD	*P* values
Mesiodistal diameter (mm)							
MMD	85	7.37	0.37	81	7.32	0.34	0.3666
LMD	85	6.65	0.39	80	6.28	0.45	0.0001**
Length (mm)							
OAL	85	20.37	1.74	81	20.44	1.73	0.7953
BCL	85	6.82	0.53	79	6.92	0.55	0.2375
RL	85	13.55	1.76	81	13.52	1.78	0.9132
Weight (mg)							
TW	84	1,020	110	80	980	110	0.0212*

Abbreviation for parameters: To see Table 1
$*p < .05$, $**p < .01$

Table 3. Comparison of the mean values of the demension of the mandibular second premolars with 2- and 3-cusp types on mesidodistal dental X-ray images

	Cusp traits						
	3-cusp type			2-cusp type			
Demension	N	Mean	SD	N	Mean	SD	*P* values
Middle crown diameter (mm)							
AB	85	6.89	0.47	80	6.85	0.38	0.5475
Dentin thickness (mm)							
CD	81	4.79	0.36	79	4.42	0.39	0.0001**
PDHs	72	3.11	0.47	82	2.41	0.39	0.0001**
CMD	84	5.02	0.36	82	4.99	0.39	0.6075
Dentin horn height (mm)							
H_1	84	3.60	0.46	81	3.44	0.42	0.0210*
H_2	73	3.72	0.43	79	3.53	0.40	0.0054**
H_3	82	3.27	0.35	81	3.27	0.45	1.0000

Abbreviation for parameters: To see Table 1
$*p < .05$, $**p < .01$

Table 4. Comparison of the mean values of the demension of of the mandibular second premolars with 2- and 3-cusp types on buccolingual dental X-ray images

	Cusp traits						
	3-cusp type			2-cusp type			
Demension	N	Mean	SD	N	Mean	SD	*P* values
Buccolingual diameter (mm)							
BL	85	8.40	0.46	82	8.40	0.43	1.0000
Middle crown diameter (mm)							
A'B'	85	7.96	0.46	82	7.97	0.42	0.8837
Dentin thickness (mm)							
C'D'	80	5.77	0.46	77	5.83	0.52	0.4446
PDHs'	84	3.77	0.38	80	3.65	0.27	0.0206*
CBL	85	7.26	0.59	80	7.23	0.39	0.6990
Dentin horn height							
H_1'	83	4.98	0.45	82	5.02	0.66	0.6503
H_2'	85	3.78	0.42	82	3.90	0.52	0.1036

Abbreviation for parameters: To see Table 1
$*p < .05$

Table 5. Correlation of the maximum mesiodistal diameter (MMD) with the valiables for the dimension and tooth weight of the mandibular second premolars with 2- and 3-cusp types

	Cusp traits			
	3-cusp type		2-cusp type	
Variables	N	r_1	N	r_2
LMD	85	0.648**	80	0.556**
OAL	85	0.112	81	-0.014
BCL	85	0.252	79	0.241
RL	85	0.034	81	-0.039
TW	85	0.678**	80	0.497**

Abbreviation for parameters: To see Table 1
TW in mg and other parameters in mm
r_1 and r_2: correelation of coeficients
** p <.01

Table 6. Correlation of the maximum mesiodistal diameter (MMD) with the valiables for the dimension of the mandibular second premolars with 2- and 3-cusp types on mesiodistal dental X-ray images

	Cusp traits			
	3-cusp type		2-cusp type	
Variables	N	r_1	N	r_2
Middle crown diameter				
AB	85	0.842**	85	0.576**,††
Dentin thickness				
CD	81	0.645**	81	0.287*,†
PDHs	84	0.560**	84	0.206
CMD	84	0.333**	84	0.411**
Dentin horn height				
H_1	84	0.239	84	0.004
H_2	73	0.454**	73	0.229
H_3	82	0.249**	82	0.146

Abbreviation for parameters: To see Table 1 ; All parameters in mm; r_1 and r_2: correelation of coeficients ; †, ††: Significant differences between r_1 and r_2; *,† $p < .05$, **,†† $p < .01$

Table 7. Correlation of the maximum mesiodistal diameter (MMD) with the valiables for the dimension of the mandibular second premolars with 2- and 3-cusp types on buccolingual dental X-ray images

	Cusp traits			
	3-cusp type		2-cusp type	
Variables	N	r_1	N	r_2
Middle crown diameter				
A'B'	85	0.472*	82	0.293*
Dentin thickness				
C'D'	80	0.361	77	0.197
PDHs'	84	0.280**	80	0.227
CBL	85	0.366**	80	0.040††
Dentin horn height				
H_1'	83	0.100	82	0.271
H_2'	85	0.097	82	0.164*

Abbreviation for parameters: To see Table 1 ; All parameters in mm; r_1 and r_2: correelation of coeficients ; †, ††: Significant differences between r_1 and r_2; *,† p <.05, **,†† p <.01

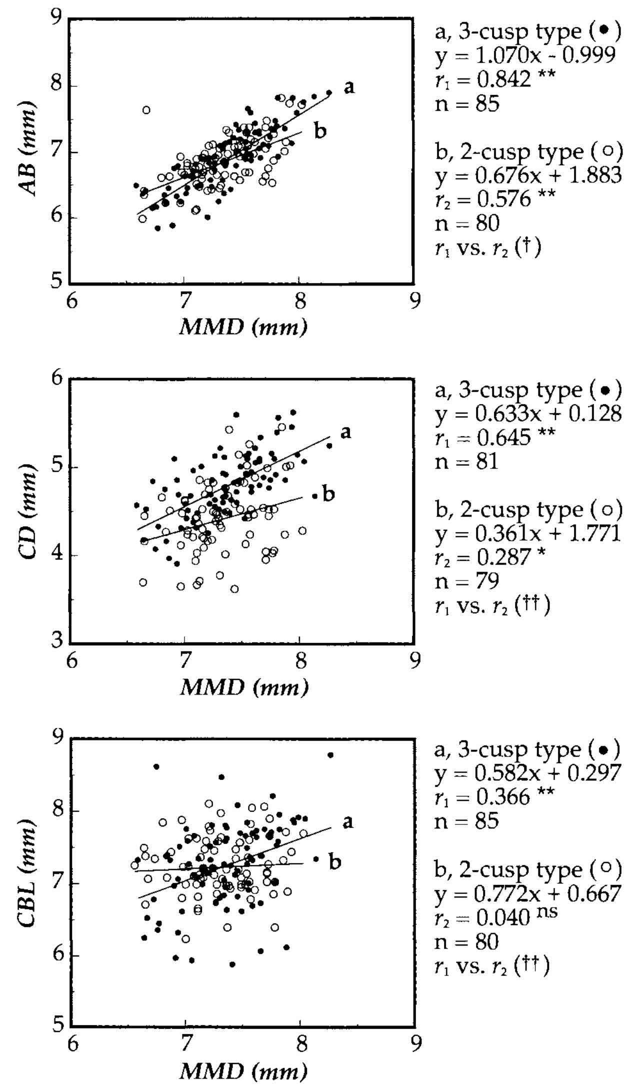

Fig. 2. Sctttergrams showing the linear relationship between the maximum mesiodistal diameter (MMD) and the coronal variables for AB, CD, and CBL of the mandibular second premolars with 2- and 3-cusp types
ns: not significant, *,† $p < .05$, **,†† $p < .01$

= 0.842, r = 0.645) compared to that in the MnP2-2C (r = 0.576, r = 0.287) (Fig. 2). In the MnP2-3C, the correlation between MMD and H2 was significant and moderate. The buccolingual images showed that the correlations between MMD and AB were significant and moderate in both types. The correlation between MMD and CD was significant and moderate in the MnP2-3C. A significant difference in the correlation coefficients between MMD and CBL was found in the 2 cusp traits of MnP2.

Discussion

The two-dimensional radiographic evaluation of the external and internal morphology of the dental crown revealed that an increase in the number of lingual cusps of MnP2 caused an increase in the LMD, TW, DDHs, PDHs', CD, H_1, and H_2. The MMD also was highly associated with the AB and moderately associated with the LMD, TW, CD, and CMD. Moreover, in terms of the association between MMD and AB, CD, and CBL, a stronger linear relation was found in the MnP2-3C than in the MnP2-2C.

Recently, many reports have mentioned the use of μ-CT analyses for the study of the structure of teeth, but the plain radiographic examinations that we used in this study were performed for comparison with intraoral radiographic analyses that will be conducted in the future.

Tooth size and weight

The observation of the occlusal surfaces of MnP2 allows an easy distinction between the 2 traits of cusps. Odontometric studies have shown that in comparison to the MnP2-2C, a larger increase in both the LMD (0.37 mm) and the TW (40 mg) occurs in the MnP2-3C, in which a small lingual cusp was formed on MnP2. In general, it has been reported that the weight of the teeth increases gradually from the anterior teeth to the molars, that maxillary teeth are heavier than mandibular teeth, and that canines and third molars have high coefficients of variance.[39] Our study confirmed that the increase in the number of cusps in MnP2 demonstrably affected the increase in TW.

Measurements of the coronal dentin

Because the PDHs was significantly 0.70 mm greater in the MnP2-3C than in the MnP2-2C, the 2 lingual cusp tips of the MnP2-3C did not only move mesiodistally, but might have also separated the mesiolingual and distal dentin horn tips in a similar way. The dentin thickness at the middle coronal region (CD) was also apparently 0.37 mm greater in the MnP2-3C than in the MnP2-2C; the DEJ at the dental crown in which an accessory cup had formed might have had a convexed curvature toward both proximal surfaces, causing an increase in the mesiodistal coronal dentin thickness. Conventionally, coronal dentin growth is known to be facilitated by the Y chromosome,[40, 41] and mesiodistal coronal dentine thickness has been found to have sexual dimorphism and is greater in men than in women.[42] Moreover, our study has revealed that the increase in the number of lingual cusps influences on the increase in mesiodistal coronal dentin thickness.

Mesiodistal images have shown that among all 3 DHHs at the dental crown, the H_1 and H_2 of the MnP2-3C were greater than those of the MnP2-2C, thus showing that when the differentiation of the lingual cusps occurs, the tips of the mesial and the lingual dentin horns of the dental crown also become elongated toward the occlusal surface. In buccolingual images, PDHs' is also greater in the MnP2-3C than in the MnP2-2C, implying that the increase in the number of cusps causes a change in the positions of the tips of the mesial and lingual dentin horns, which are then directed towards the lingual side.

Correlations

The linear regression analysis between the MMD and measurement variables of MnP2 showed that in the MnP2-3C, AB was highly influenced by the MMD, and that the linear relationship between them was stronger in the MnP2-3C than in the MnP2-2C. The LMD also was moderately influenced by the MMD, regardless of the cusp type. In other words, for MnP2s in which accessory cusps have formed, the MMD showed a close relation with the increase in the LMD and the middle diameter of the dental crown. The relation was similar to that described in the results reported by Fujita *et al.*[43] and Aoki *et al.*[44] regarding lower first and second molars, which had sixth and seventh cusps. In addition, the MMD contributed to the TW, and this tendency was stronger in the MnP2-3C than in the MnP2-2C. Moreover, the MMD of MnP2-2Cs also had a moderate influence on CD and CMD, and the linear relationship between the MMD and the CD showed a stronger slope in the MnP2-3C than in the MnP2-2C (Fig. 2). A similar tendency has been reported in maxillary molars[45] and mandibular posterior teeth.[42]

On the other hand, the MMD has a weak influence on the variables of the measurements of the buccolingual coronal dentin, which was similar to the results reported by Stroud *et al.*[33] and Harris and Hicks[46] regarding mandibular posterior teeth. In this study, the association between MMD and C D, CBL and PDHs showed a significant linear inclination only in the MnP2-3C, which was similar to the results of maxillary molars[47] and mandibular posterior teeth.[33] In other words, the MMD of MnP2 contributed to AB, CD, and CBL, and the relationship between these was stronger in 3-cusp type MnP2 than in the 2-cusp type.

In conclusion, we were able to demonstrate that when the number of the lingual cusp on MnP2 increases, changes occur on the contour of their occlusal surface and that the increase in the TW, MMD, LMD, CD, PDHs, PDHs', H_1, and H_2 is more pronounced in the MnP2-3C than in the MnP2-2C. The MMD of MnP2-3C with increased number of cusps also changed, while maintaining a close linear relationship with AB, CD, and CBL. Therefore, it was suggested that the increase in the number of lingual cusps in MnP2 affects the morphological changes not only in the occlusal surfaces, but also in the TW, LMD, and the coronal dentin.

Conclusion

Within the limit of this study, the presence of lingual accessory cusps on MnP2 had a significant influence on the increase in the LMD, TW, PDHs, CD, H_1, and H_2. It was demonstrated that the MMD of MnP2-3C had a higher association with AB, and that the MMD had a stronger linear relationship with AB, CD, and CBL in the MnP2-3C than in MnP2-2C. These results suggested that the differences in the number of lingual cusps on MnP2 are closely related to lingual mesiodistal diameter, tooth weight, dentin thickness, and dentin horn height with morphological changes in the DEJ.

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