Prevalence of Cervical Enamel Projection and Its Impact on Furcation Involvement in Mandibular Molars: A Cone-Beam Computed Tomography Study in Koreans

HYUN-CHANG LIM,[1] SEOK-KYUN JEON,[2] JAE-KOOK CHA,[2] JUNG-SEOK LEE,[2] SEONG-HO CHOI,[2] AND UI-WON JUNG[2]*
[1]Department of Periodontology, School of Dentistry, Kyung Hee University, Seoul, South Korea
[2]Department of Periodontology, Research Institute for Periodontal Regeneration, College of Dentistry, Yonsei University, Seoul, South Korea

ABSTRACT
This study evaluated the prevalence of cervical enamel projections (CEPs) in mandibular molars, and analyzed the correlation between CEPs and furcation involvement (FI) based on cone-beam computed tomography (CBCT) data in a Korean population. CBCT images obtained from March 2012 to August 2012 were analyzed. CEPs and FI on the buccal and lingual surface were classified in three-dimensionally reconstructed images and cross-sectional views, and the correlation between these two parameters was analyzed. In total, 982 teeth in 425 patients were analyzed. The overall prevalence rate of CEPs was 76% (71% and 27% on the buccal and lingual surfaces, respectively). Grade I CEPs were the most common, followed by CEPs of grades II and III. There was a statistically significant, but negligible correlation between the CEP grade and the degree of FI on the buccal and lingual surfaces. Within the limitations of this cross-sectional study, a high prevalence of CEPs were found in a Korean population, but the role of CEPs in provoking FI appeared not to be decisive. Anat Rec, 299:379–384, 2016. © 2015 Wiley Periodicals, Inc.

Key words: cone-beam computed tomography; furcation defects; dental enamel; tooth cervix; prevalence

Predicting the prognosis of multirooted teeth is one of the main concerns for clinicians. Previous studies have commonly pointed out that breakdown of interroot periodontal tissue in multirooted teeth, that is furcation involvement (FI) is one of the main factors determining the prognosis of multirooted teeth (Hirschfeld and Wasserman, 1978; McFall, 1982; McGuire and Nunn, 1996). Due to its clinical significance, FI has been classified in several systems for treatment plan decision (Hamp et al., 1975; Tarnow and Fletcher, 1984; Al-Shammari et al., 2001). Despite such efforts, it has been demonstrated that it is difficult to manage FI even with professional therapy and maintenance program

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*Correspondence to: Ui-Won Jung, Department of Periodontology, College of Dentistry, Yonsei University, 50-1, Yonsei-ro, Seodaemoon-gu, Seoul 120-752, South Korea. Fax: +82-2-3920398. E-mail: drjew@yuhs.ac

Hyun-Chang Lim and Seok-Kyun Jeon equally contributed to this article.

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(Pretzl et al., 2008), and by experienced specialists (Nordland et al., 1987; Fleischer et al., 1989)

Several factors for provoking FI have been investigated, which has been found to be mostly related to the resistance against the challenge of bacterial plaque, whether this is associated with oral hygiene practices or certain innate characteristics—given an equivalent level of oral hygiene, a fixed level of bacterial challenge can result in more deterioration when certain innate characteristics are present. A cervical enamel projection (CEP) is known as an anatomic factor relevant to FI. As a product of continuing activity of ameloblasts after enamel formation on the crown (Chan et al., 2010), CEP is defined as a continuous structure of enamel that extends from the cementoenamel junction to the furcation area (Bissada and Abdelmalek, 1973). The enamel surface of a CEP favors epithelial attachment, which is more susceptible to bacterial challenge than is connective-tissue attachment (Machtei et al., 1997). Accordingly, a CEP can represent a shortcut for bacterial plaque to the furcation. Correlations between CEPs and FI of degrees II and III have been demonstrated (Hou and Tsai, 1987, 1997).

Previous studies on CEPs have been performed by observations in extracted teeth or cadavers, using macroscopy during periodontal surgery, or by probing in the region of the cementoenamel junction (Bhusari et al., 2013; Hou and Tsai, 1987; Leib et al., 1967; Swan and Hurt, 1976; Zee and Bratthall, 2003). However, these methods can be subject to limitations such as the inconvenience of performing cadaver examinations, the limited number of samples, the need for invasive surgery, and the possibility of inaccurate assessments.

Cone-beam computed tomography (CBCT) is now widely used in dentistry, and detailed assessments can be made with less radiation compared to conventional computed tomography (Laky et al., 2013). CBCT is widely used in implant therapy (Bornstein et al., 2014), and its benefits in periodontal treatment have also been reported (Braun et al., 2014; Walter et al., 2009; Walter et al., 2010). In addition, three-dimensional reconstruction of CBCT images enables clinicians to visualize the actual morphology of a defect and the overall tooth structure prior to performing surgery. Accordingly, CBCT can be used to determine the presence and extent of a CEP, and aid the treatment planning.

The aim of this study was to determine the prevalence of CEP in mandibular molars and the correlation between CEP and FI based on CBCT data in a Korean population.

MATERIALS AND METHODS

All CBCT images that were obtained between March 2012 and August 2012 at the Dental Hospital of Yonsei University were enrolled in the present study. This study was approved by the institutional review board of the Dental Hospital of Yonsei University (IRB no. 2-2014-0021).

Study Subjects

In total, 1,027 CBCT images were collected during the study period. Image selection and abandonment were performed based on the following inclusion and exclusion criteria.

Inclusion criteria.

1. Korean adults aged 20 years or older.
2. At least one mandibular molar present.

Exclusion criteria.

1. Loss of both mandibular first and second molars or/ and their replacement by a dental implant.
2. The mandibular first and second molars not providing clear visualization of the intact cervical area, such as due to the presence of a cervical defect or a restoration covering the cervix.
3. The presence of apical pathoses in the mandibular first and second molars.

CBCT Analysis

The CBCT images were acquired using two types of systems: Alphard 3030 (Asahi Roentgen, Kyoto, Japan) and Raycan Symphony (Ray, Suwon, Korea). The settings for the former were a tube voltage of 80 kV, a tube current of 5 mA, a shooting time of 17 second, a field of view (FOV) of 102×102 mm^2, and a voxel size of 0.2 mm; the corresponding settings for the latter were 90 kV, 10 mA, 19.5 second, 147×97 mm^2, and 0.38 mm, respectively. The acquired images were saved in the DICOM (Digital Imaging and Communications in Medicine) file format.

The presence of CEPs and FI was analyzed in both cross-sectional and three dimensionally reconstructed images (OnDemand3D, CyberMed, Seoul, Korea) by two of the authors (H.-C.L. and S.-K.J.). CEPs and FI were classified according to the grading systems by Masters and Hoskins (1964) (Fig. 1) and Hamp et al. (1975), respectively. The analysis was performed on both buccal and lingual surfaces. H.-C.L. and S.-K.J. independently analyzed 10 samples prior to analyzing the whole samples for examiner alignment. When they had disagreement, the senior investigator (U.-W.J.) participated in the analysis and decided the classification. After full agreement was achieved, the whole samples were analyzed.

Statistical Analysis

SPSS software (SPSS 20.0, IBM Corporation, Armonk, NY) was used for the statistical analysis. The interexaminer agreement for determining the CEP grade and the degree of FI was analyzed using Cohen's κ (Cohen, 1960). The prevalence of CEPs depending on sex and site was analyzed using Chi-square tests. The correlations between the CEP grade and the degree of FI were analyzed using Spearman's correlation tests. The strength of the correlation was categorized based on the value of coefficient R as follows: 0.9–1.0, very strong; 0.7–0.9, strong; 0.4–0.7, moderate; 0.2–0.4, weak; and 0.0–0.2, very weak. The cutoff for the presence of statistical significance was set at $P<0.05$.

RESULTS

In total, 982 teeth from 425 patients were analyzed. The age of the patients ranged from 20 years to 77 years (Table 1). Of the 982 teeth, 174 were right mandibular second molars, 327 were right mandibular first molars, 323 were left mandibular first molars, and 158 were left mandibular second molars.

Cohen's κ between the two investigators was 0.912 for CEPs ($P<0.001$) and 0.916 for FI ($P<0.001$), which

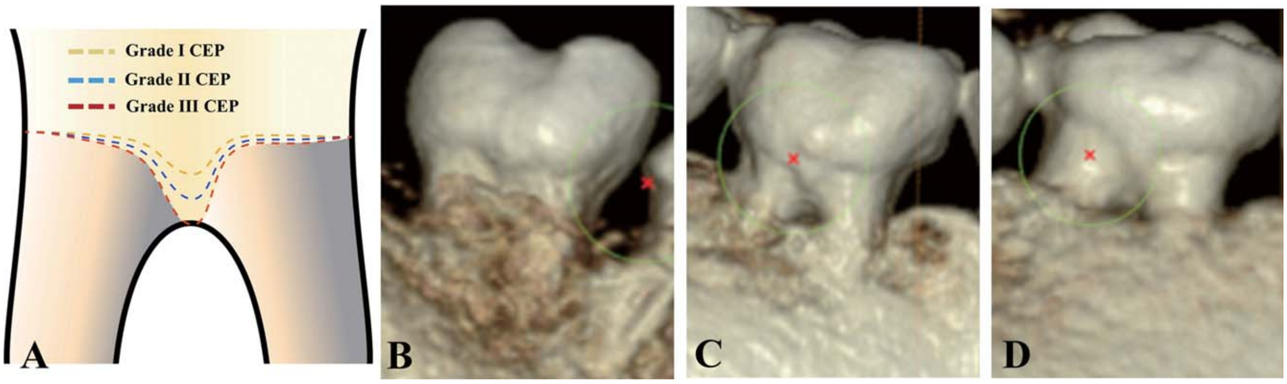

Fig. 1. Classification of the cervical enamel projection (CEP) and the corresponding three-dimensionally reconstructed images. (A) Schematic drawing of CEPs, Grade I=yellow dashed line; Grade II = blue dashed line; and Grade III = red dashed line. (B) Grade I CEP on a reconstructed image. (C) Grade II CEP on a reconstructed image. (D) Grade III CEP on the reconstructed image.

TABLE 1. Age and sex distribution of the included patients

Age, years	Male (n=224)	Female (n=201)	Total (n=425)
20–29	68	73	141
30–39	42	38	80
40–49	45	24	69
50–59	51	37	88
60–69	14	22	36
70+	4	7	11

TABLE 2. Chi-square test for the prevalence of cervical enamel projections (CEPs) disaggregated by sex, side, and tooth number.

Variables		Chi square	DF	P
Male versus female	Buccal	10.838	1	**0.001**
	Lingual	6.762	1	**0.009**
Right molar	Buccal	0.517	1	0.472
versus left molar	Lingual	0.162	1	0.687
First molar	Buccal	0.041	1	0.840
versus second molar	Lingual	23.051	1	**<0.001**

DF: degrees of freedom.
Bold numbers indicates $P<0.05$.

according to Landis and Koch (1977) indicates almost perfect agreement.

Prevalence of CEP

Most of the patients had at least one CEP (87.5% in males and 91.5% in females). The percentage of teeth having CEP on either the buccal or lingual surface was 76.0% (746/982). Buccal CEPs were more common (70.9%, 697/982) than lingual CEPs (27.0%, 265/982). CEPs were present on both surfaces in 22.0% of teeth (216/982). The prevalence of buccal CEPs was significant correlated with sex (P=0.001), while the prevalence of lingual CEPs was significant correlated with both sex (P=0.009) and tooth number (P<0.001) (Table 2).

The distribution of CEPs according to classification on each tooth is shown in Fig. 2. Grade I CEPs were the most common on the buccal surface (54.8%), followed by grade II CEPs (34.8%), and grade III CEPs (10.3%). Most CEPs on the lingual surface were grade I (90.5%), followed by grade II (9.0%), and grade III (0.006%).

Prevalence of FI

FI was present in 663 of the 982 teeth (67.5%). FI of degrees I, II, and III accounted for 61.5% (356/579), 34.5% (200/579), and 4.0% (23/579), respectively, of the FI on the buccal surface of the teeth; the corresponding proportions on the lingual surface were 75.4% (364/483), 19.9% (96/483), and 4.8% (23/483). FI was seen in 69.2% and 58.9% of first molars on the buccal and lingual surfaces, respectively, and in 48.2% and 40.4% of second molars. Among teeth with FI, 70.1% had buccal CEPs (379/569) and 30.5% had lingual CEPs (147/482).

Correlation of CEP With FI

The total distributions of FIs and CEPs are shown in Fig. 3. The CEP grade and the degree of FI were significantly but weakly correlated for both buccal and lingual surfaces (P=0.027 and 0.003, respectively, and Spearman's R=0.07 and 0.094). When CEPs and FI were disaggregated into categories of male versus female, first molar versus second molar, and right molar versus left molars, the correlation in each category was either statistically insignificant or very weak (Table 3).

When the teeth from patients older than 40 years were pooled separately, there was no significant correlation for the buccal surface (P=0.980) and a negligible correlation for the lingual surface (P=0.002, Spearman's R=0.142). The correlations in the categories of male versus female, first molar versus second molar, and right molar versus left molar were either statistically insignificant or very weak (Table 4).

DISCUSSION

FI is one of the main factors predictive of the prognosis of multirooted teeth. It has been suggested that the

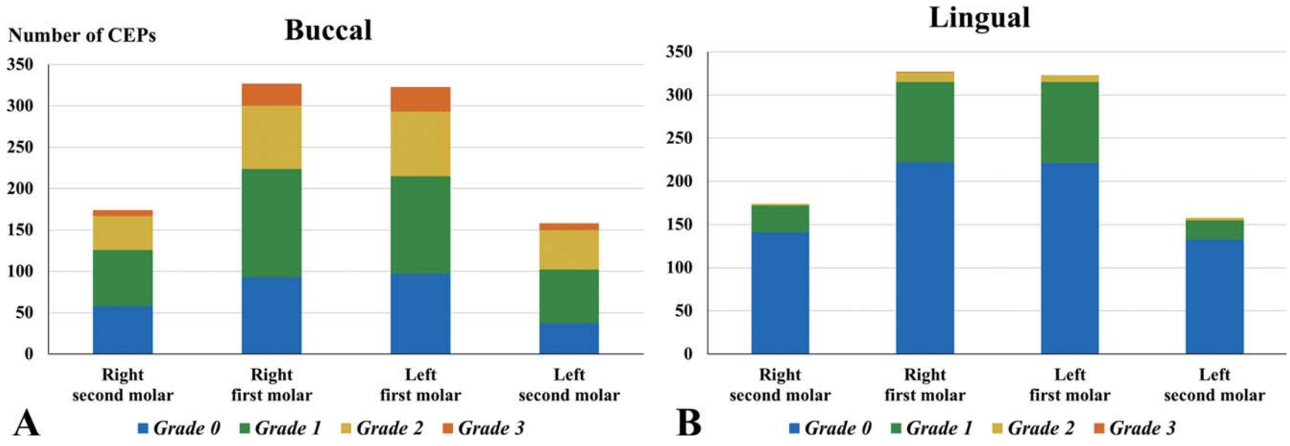

Fig. 2. Distribution of CEPs on molar (A) buccal surfaces and (B) lingual surfaces.

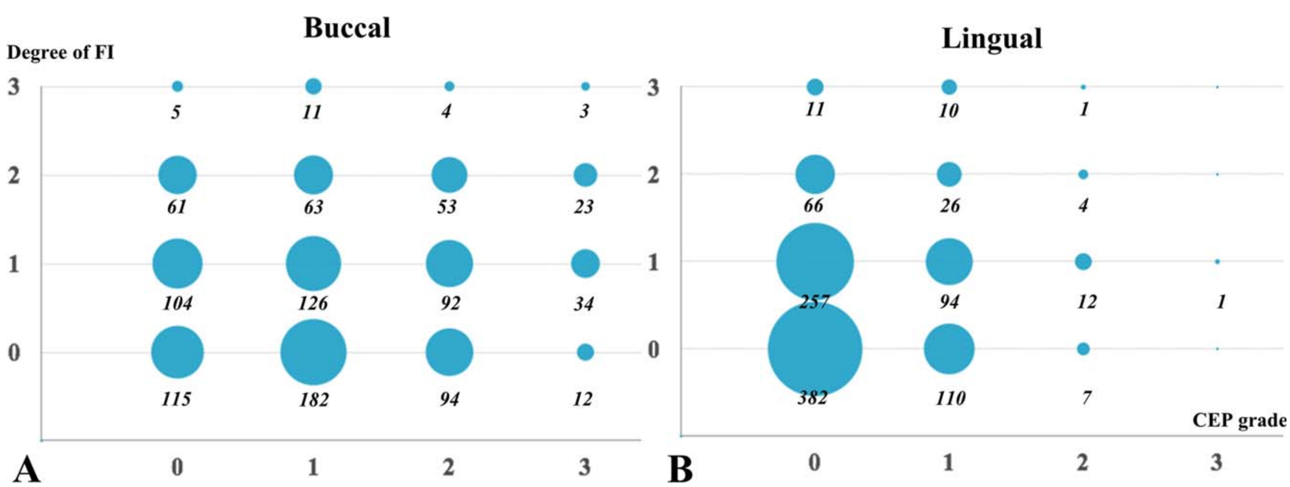

Fig. 3. Association between CEPs and furcation involvement (FI) (A) on the buccal surface and (B) on the lingual surface. X and Y axes indicate the CEP grade and the degree of FI, respectively.

TABLE 3. Spearman correlation between the CEP grade and the degree of furcation involvement (FI).

Variables			Spearman's *R*	*P*
Total		Buccal	0.07	**0.027**
		Lingual	0.094	**0.003**
Sex	Male	Buccal	0.040	0.360
		Lingual	0.098	**0.026**
	Female	Buccal	0.115	**0.014**
		Lingual	0.091	0.051
Side	Right molar	Buccal	0.111	**0.013**
		Lingual	0.043	0.332
	Left molar	Buccal	0.029	0.518
		Lingual	−0.005	0.907
Tooth number	First molar	Buccal	0.078	0.086
		Lingual	0.070	0.122
	Second molar	Buccal	0.066	0.142
		Lingual	0.096	**0.035**

Bold numbers indicates $P<0.05$.

TABLE 4. Spearman correlation between the CEP grade and the degree of FI in the teeth from patients older than 40 years.

Variables			Spearman's *R*	*P*
Total		Buccal	0.001	0.980
		Lingual	0.142	**0.002**
Sex	Male	Buccal	−0.035	0.586
		Lingual	0.135	**0.033**
	Female	Buccal	0.044	0.530
		Lingual	0.157	**0.025**
Side	Right molar	Buccal	−0.028	0.669
		Lingual	0.073	0.262
	Left molar	Buccal	0.032	0.632
		Lingual	0.211	**0.002**
Tooth number	First molar	Buccal	−0.030	0.609
		Lingual	0.125	**0.031**
	Second molar	Buccal	0.053	0.509
		Lingual	0.080	0.319

Bold numbers indicates $P<0.05$.

susceptibility of FI can be modified by certain anatomical factors, including CEPs. The present study evaluated the prevalence rate of CEPs in mandibular molars using CBCT data. CBCT images can be reconstructed in three dimensions as well as cross-sectionally using computer software; this makes it relatively easy to identify the presence of CEPs noninvasively.

Previous studies have found various prevalence rates of CEP in mandibular molars. Grewe et al. (1965), Leib et al. (1967), and Bissada and Abdelmalek (1973) reported rather low prevalence rates of 25.2%, 25.4%, and 10.37%, respectively, while higher rates of 48%, 85%, 78%, and 79% were reported by Hou and Tsai (1987, 1997), Zee and Brattall (2003), and Zee et al. (1991), respectively. The overall prevalence rate of CEPs in the Korean population included in the present study was 76% (70.8% on the buccal side and 26.6% on the lingual side). These markedly different rates have been attributed to the involvement of different study subjects, including in terms of their ethnicity. The studies of Grewe et al. (1965) and Leib et al. (1967) involved Americans with possibly mixed ethnicities, while Bissada and Abdelmalek (1973) investigated Egyptians. On the other hand, the prevalence rates in Far East populations, such as Taiwanese (Hou and Tsai, 1987, 1997), Chinese (Zee et al., 1991), and Koreans, and among Eskimos (Zee and Bratthall, 2003) have been much higher (over 70%). Anthropologically these populations can be categorized as Mongoloids, which suggests a genetic effect on the prevalence of CEPs. Managing CEPs may have greater clinical relevance in such populations.

Interestingly, the prevalence of CEPs in mandibular molars appears to vary geographically among Asians. A recent study involving Indians found very low prevalence rates of 10% and 14% in the first and second mandibular molars, respectively (Bhusari et al., 2013). The prevalence in Asia increases when moving to East Asia, as demonstrated for Chinese (Zee et al., 1991), Taiwanese (Hou and Tsai, 1987, 1997), and the Koreans in the present study. Reich et al. (2009) demonstrated that Indians can be classified into two groups on a basis of genotypes: (1) "Ancestral North Indian," who are genetically close to Middle Eastern, Central Asian, and European populations (39%–71% in Indian substructural populations), and (2) "Ancestral South Indian." Such findings may explain the difference in the prevalence of CEPs among Asian countries. Studies investigating the prevalence of CEPs in Egyptians (a Middle Eastern population) found a similar prevalence rate to that in Indians (Bhusari et al., 2013; Bissada and Abdelmalek, 1973).

Among the 425 patients and the 982 teeth that were included in the present study, CEPs were observed in 87.5% of the males, 91.5% of the females, and 76% in all of the teeth. Despite its high prevalence, the CEP grade was only very weakly correlated with the degree of FI in total, but this result should be interpreted cautiously. The detection of CEPs requires clear visualization of the cervix. Initially collected CBCT images that indicated a defective cervix, restorations covering the cervix, loss of teeth, or replacement by dental implants were all excluded, which might have reduced the number of molars included from older patients and molars with FI. Moreover, relatively few teeth had grade III CEP and/or FI of degree III. These factors might also have affected the correlation analysis in the teeth from patients older than 40 years, despite age being positively correlated with the prevalence of periodontitis (Renvert et al., 2013).

In previous studies, the influence of CEP in the subjects without information about their periodontal conditions was inconsistent. Most studies have found CEP to be associated with FI (Grewe et al., 1965; Bissada and Abdelmalek, 1973; Hou and Tsai, 1987; Zee and Bratthall, 2003; Bhusari et al., 2013), but other studies—including the present one—found no such relation (Leib et al., 1967; Zee et al., 2003). When confining targets to periodontally-involved teeth, a significant relationship between CEP and FI was found (Hou and Tsai, 1997; Machtei et al., 1997). However, it should be noted that above studies have cross-sectional design, which implicates the necessity of studies having higher evidence level.

CEPs on the buccal surface were clinically easy to detect due to the good visibility, while those on the lingual surface as well as their severity were difficult to determine due to lower visibility and accessibility. Moreover, clinicians generally recognize that CEPs mostly exist on the buccal side. These factors increase the likelihood that the presence of lingual CEPs will be underestimated. The prevalence rate of CEPs on the lingual surface was 26.6% in the present study, which is similar to or much greater than the prevalence rates reported for Americans, Indians, and Egyptians (Bhusari et al., 2013; Bissada and Abdelmalek, 1973; Grewe et al., 1965; Leib et al., 1967). Mandibular molars anatomically have a lingual inclination, which leads to a more-apical position of the furcal entrance compared to the buccal entrance. Such anatomical features can interfere with the correct contact of oral hygiene devices, and the presence of lingual CEPs may modify the susceptibility of FI.

Walter et al. (2009) assessed the validity of using CBCT for maxillary molars, and reported that the interpretation of CBCT images can result in both over- and underestimations. FI of degree I was frequently underestimated in maxillary molars in CBCT compared to intrasurgical findings (Walter et al., 2010). Demineralization at an early stage of disease can be seen as bone defect. Altered passive eruption and presence of a calculus lining on CEPs may affect the determination of the grade. Although the above-mentioned errors were not confirmed macroscopically in the present study, our approach did have the significant advantages of being based on the noninvasive interpretation of CBCT images and being able to deal with a large number of samples.

Within the limitations of the present study, the high prevalence of CEPs detected in the mandibular molars of the Korean subjects showed an insignificant or only a very weak correlation with the degree of FI. These findings may be due to the specific characteristics of the study population and the limitation of the cross-sectional study, but more importantly, they indicate that FI is a product of multiple factors. A long-term follow-up for monitoring the progression of periodontal disease in molars with CEPs is required in future studies.

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