RESEARCH

Enamel pearls in permanent dentition: case report and micro-CT evaluation

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Objectives: To investigate the frequency, position, number and morphology of enamel pearls (EPs) using micro-CT (μ CT) and to report a case of an EP mimicking an endodontic–periodontic lesion.

Methods: Cone beam CT (CBCT) was performed in a patient to evaluate a radio-opaque nodule observed on the left maxillary first molar during the radiographic examination. Additionally, 23 EPs were evaluated regarding frequency, position, number and morphology by means of μ CT. The results were statistically compared using the Student's *t*-test for independent samples.

Results: 1 pearl was presented in 13 specimens, while 5 specimens presented 2 pearls. The most frequent location of the EPs was the furcation between the disto-buccal and the palatal roots of the maxillary molars. Overall, the mean major diameter, volume and surface area were 1.98 ± 0.85 mm, 1.76 ± 1.36 mm³ and 11.40 ± 7.59 mm², respectively, with no statistical difference between maxillary second and third molars ($p > 0.05$). In the case report, CBCT revealed an EP between the disto-buccal and the palatal roots of the maxillary first left molar associated with advanced localized periodontitis. The tooth was referred for extraction.

Conclusions: EPs, located generally in the furcation area, were observed in 0.74% of the sample. The majority was an enamel–dentin pearl type and no difference was found in maxillary second and third molars regarding diameter, volume and surface area of the pearls. In this report, the EP mimicked an endodontic–periodontic lesion and was a secondary aetiological factor in the periodontal breakdown.

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Introduction

Developmental abnormalities such as palatal grooves, cervical enamel projections or enamel pearls (EPs) may pre-dispose the affected area to plaque accumulation causing periodontal breakdown.^{1–9} The EP-associated lesion often presents as a periapical or a periodontal lesion with angular bone loss along the root surface on

the radiograph.^{3,5,9–11} In some cases, its clinical features may result in drainage in the sulcus area, swelling, sinus tract, simulating an endodontic–periodontic lesion.^{11,12} A thorough examination including pulp vitality tests and careful radiographic examination is necessary to aid in the diagnosis and treatment options.¹²

The first description of an EP was recorded in the first half of the 19th century¹³ and, since then, it has been referred to as enamel droplet, enamel nodule, enamel globule, enamel knot, enamel exostose, enameloma and adamantoma.⁵ The EP has been described as a

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well-defined globule of enamel, generally round, white, smooth and glasslike, that firmly adheres to the external root surface of teeth.^{11,14} Although it consists primarily of enamel, in most instances, a core of dentine or a pulp cavity may be found within it.^{5,15} Its aetiology remains obscure. The most acceptable theory is that the pearl develops because of a localized developmental activity of the Hertwig's epithelial root sheath cells that remained adherent to the root surface during root development differentiating into functioning ameloblasts.^{1,3,6,15,16} The EP has been evaluated *in vivo* and *ex vivo* using conventional radiography^{2,6,17} and cone beam CT (CBCT).¹⁰ In the last decade, micro-CT (μ CT) has gained increasing significance as a non-invasive reproducible method for three-dimensional (3D) assessment of dental hard tissues.¹⁸ Using this technology, Anderson *et al*¹⁵ evaluated the mineral content gradient of EPs and found that the mineral content in the surface and deeper enamel regions of the pearl were similar to those observed in premolar enamel. To date, no study has attempted to investigate and compare the morphology of the EP in different teeth using μ CT.

Thus, the aim of this study was to report a case of one EP associated with advanced localized periodontal destruction in a maxillary molar simulating an endodontic-periodontic lesion and to investigate the frequency, position, number and morphology of EPs using μ CT. The null hypothesis was that the EPs located in maxillary second and third molars have a similar morphology.

Materials and methods

Case report

A 27-year-old male was referred by a general practitioner for the root canal treatment of the left maxillary first molar after presenting a swelling and a sinus tract on its disto-buccal surface (Figure 1a). The general health history was non-contributory and periodontal probing revealed a 10-mm pocket on the distal aspect of the tooth. The tooth was tender on palpation and exhibited no mobility or caries (Figure 1b). Pulp tests showed values within normal limits. The radiographic finding revealed the presence of deep resin restorations on the mesial and distal aspects of the crown and a narrow pulp chamber. Attempts to trace the sinus tract with a gutta-percha point revealed a round radio-opaque structure in the distal aspect of the tooth (Figure 1c). Informed consent was obtained and a CBCT scan (85 kVp, 10 mA, isotropic voxel size of 76 μ m and exposure time of 10.80 s) with a limited cylindrical field of view (50 $\times$ 37 mm) was performed (Kodak 9000 3D System; Carestream Health, Inc., Rochester, NY), following international statements.^{19,20} The CBCT exam showed the presence of a well-defined radio-opaque nodule similar in density with the enamel of the crown between the disto-buccal and the palatal roots of left maxillary first molar (Figure 1d–g) consistent with the diagnosis of EP. Then, an immediate drainage of the purulent exudate was carried out and the tooth was

Figure 1 (a) Swelling on buccal gingival of left maxillary first molar; (b) occlusal view of the maxillary left first molar; (c) periapical radiograph showing a narrow pulp chamber, deep composite resin restorations and severe bone loss, mainly in the distal aspect of the disto-buccal root of the maxillary left first molar. Gutta-percha cone tracing the sinus tract revealed the presence of a small, round radio-opaque structure in the distal aspect of the root; (d–f) coronal, sagittal and axial views, respectively of the maxillary left first molar obtained in the cone beam CT examination showing an enamel pearl (arrow) between the disto-buccal and the palatal roots; (g) three-dimensional volumetric view of the hard tissues of the maxillary left region showing the presence of an enamel pearl in the distal aspect of the first molar (arrow). MB, mesio-buccal; DB, disto-buccal; P, palatal

referred for extraction and planning for an implant placement.

Micro-CT evaluation

After approval was obtained from the Ethics Committee of the Dental School of Ribeirão Preto, University of São Paulo, São Paulo, Brazil (protocol 2009.1.972.58.4, CAAE 0072.0.138.000-09), 18 human teeth presenting one or more EPs on the root surface were selected from a pool of 2532 extracted teeth (origin and reasons for extraction unknown) and stored in labelled individual plastic vials containing 0.1% thymol solution. After being washed in running water for 24 h, each tooth was dried, mounted on a custom attachment and scanned in a μ CT scanner (SkyScan 1174v2; Bruker-microCT, Kontich, Belgium) at an isotropic resolution of 19.6 μ m. Images of each specimen were reconstructed from the apex to the coronal level with dedicated software (NRecon v. 1.6.3; Bruker-microCT), which provided axial cross-sections of the inner structure of the samples.

For the calculation of the morphometric parameters and surface representations of the specimens, the original greyscale images were processed with a slight gaussian low-pass filtration for noise reduction, and an automatic segmentation threshold was used to separate root dentine from the enamel using CTAn v. 1.12 software (Bruker-microCT). This process entails choosing the range of grey levels necessary to obtain an image composed only of black and white pixels. The high contrast of enamel to the dentine yielded excellent segmentation of the specimens. Separately and for each slice, regions of interest containing the EP were chosen entirely to allow the calculation of its major diameter (mm), the volume (mm³) and the surface area (mm²). Then, a polygonal surface representation was constructed. The location of the EPs was acquired using DataViewer v. 1.4.4 (Bruker-microCT). CTVox v. 2.4 and CTVol v. 2.2.1 software (Bruker-microCT) were used for 3D visualization of the specimens.

The results of the morphological analysis of the EPs located at the second and third maxillary molars were statistically compared using Student's *t*-test with the significance level set as 5% by using SPSS® v. 17.0 for Windows (SPSS Inc, Chicago, IL).

Results

Table 1 shows the distribution of 23 EPs according to the type of tooth. Overall, 23 EPs were observed in 0.74% of the sample (18 out of 2532 teeth). 10 EPs were found in 9 maxillary second molars, 12 pearls in 8 maxillary third molars and 1 pearl in 1 mandibular second molar.

Figure 2 shows the 3D reconstruction of the sample. The EPs were located more frequently at the furcation between the disto-buccal and the palatal roots ($n = 9$; 39%), the disto-buccal and mesio-buccal roots ($n = 5$;

Table 1 Distribution of EPs according to the type of tooth

Tooth type	One EP	Two EPs	Number of teeth	Percentage	Number of EPs
Maxillary second molar	8	1	9	50.0	10
Maxillary third molar	4	4	8	44.5	12
Mandibular second molar	1	—	1	5.5	1
Total	13	5	18	100.0	23

EP, enamel pearl.

22%) and the mesio-buccal and palatal roots ($n = 5$; 22%). Macroscopically, EPs appeared spheroid, conical, ovoid, tear-drop or irregular in shape.

Only 1 pearl was presented in 13 specimens (72%), while 5 specimens (28%) presented 2 pearls (Table 1; Figure 3a–e). The presence of cervical projections connecting the EP to the crown was also observed in four specimens (Figure 3f–i). No contact between the EPs and the root canal system was observed (Figure 3j–l, n). Only one specimen had a true EP, consisting entirely of enamel (Figure 4a, b), while the rest of the sample ($n = 22$; 96%) had a core of dentine (enamel–dentin pearl type; Figure 4c–g).

Overall, the mean major diameter, volume and surface area of the EPs were 1.98 ± 0.85 mm, 1.76 ± 1.36 mm³, and 11.40 ± 7.59 mm², respectively, with no statistical difference between maxillary second and third molars ($p > 0.05$) (Table 2). Therefore, the null hypothesis was accepted.

Discussion

Clinically, an accurate early diagnosis of an EP may be helpful for the selection of an appropriate treatment aiming to prevent periodontal breakdown and avoiding unnecessary non-surgical root canal treatment or retreatment.² In some cases, an EP does not produce symptoms, but, as soon as it is detected, follow-up programmes are crucial to prevent exacerbation of the lesion. If the pearl is exposed to the oral environment, odontoplasty, tunneling, root separation, resection, intentional replantation or extraction are indicated.^{4,12,17}

Anatomic abnormalities of root surfaces, such as EPs, are usually not apparent without the assistance of radiology.^{8,10} In a conventional radiographic examination, EP is depicted as a dense, smooth radiopacity overlying any portion of the crown or root of an otherwise unaffected tooth.² Despite the fact that the diagnosis of EP could be achieved with conventional radiography, in the present study, the limited field of view CBCT scan was used to determine the extent of the lesion and its effect on surrounding structures.²⁰ This imaging technique may be useful in selected cases of infrabony defects and furcation lesions where clinical and conventional radiographs do not provide the information needed for proper management.^{19,20} Besides, the radiation dose of

Figure 2 Three-dimensional reconstruction of 18 molar teeth showing the location of 23 enamel pearls (EPs). Specimen 4 was the only one presenting a true EP (black arrow). DB, disto-buccal; DP, disto-palatal; MB, mesio-buccal; ML, mesio-lingual; MP, mesio-palatal; P, palatal

Figure 3 Morphological features of the enamel pearls (EPs). (a–e) Five specimens showed two EPs located on the root surface; (f–i) four specimens with a cervical enamel projection connecting the pearl to the crown; (j–n) relationship between the EPs and the root canal system of five maxillary molars

a limited field of view CBCT is similar to two periapical radiographs and, in complex cases, evolving tooth extraction and implant placement, it may provide a dose saving over multiple traditional images.²⁰ In the reported case, CBCT was valuable in showing that the bone loss affected the furcation area and surrounding structures of

left maxillary first molar and did not allow for a conservative treatment.

The reported prevalence of EPs has varied significantly among studies. Moskow and Canut⁵ reviewed previous studies on EPs and reported its prevalence ranging from 1.1% to 9.7%. This variation was associated

Figure 4 Morphological features of the enamel pearls (EPs). (a) reconstruction of three-dimensional (3D) Specimen 4 showing a true EP (consisting entirely of enamel) between the palatal and the mesiobuccal roots; (b) axial view of the true EP; (c–e) Partial view of a 3D reconstruction of a mandibular second molar showing the presence of an EP in the mesial aspect of the mesial root containing a core of tubular dentine (enamel–dentine pearl); (f) axial view of the EP presenting a core of dentine; (g) internal and external aspects of the enamel–dentine pearl

with methodological and ethnic differences.^{5,17} EPs have a distinct predilection for the furcation area of molar teeth and furrow within the root structure.^{5,6} Although there are few reports of the occurrence of EPs on roots of maxillary premolars, canines and incisors,⁵ it is generally accepted that they are found most frequently on the roots of the maxillary molars followed by mandibular molars.^{2,5,6,10} When occurring on the roots of maxillary molars, they are most commonly seen between the disto-buccal and the palatal roots^{2,5,6} as in this case report.

In the present study, the frequency of EPs (0.74%) was consistent with two previous studies.^{2,10} Chrcanovic et al² evaluated 45 785 extracted teeth and found that 0.82% of the specimens presented one or more EPs. They also found that pearls were most frequent in the furcation

between the disto-buccal and the palatal roots of maxillary first (43.03%) and second molars (39.24%). Akgül et al,¹⁰ in an *in vivo* study using CBCT scanning, reported that 0.83% of the molar teeth (36 out of 4334 specimens) had at least one EP. It is most common to

Table 2 Major diameter, volume and surface area of the enamel pearls in maxillary second and third molars (mean ± standard deviation)

Specimen	Number of pearls	Major diameter (mm)	Volume (mm ³)	Area (mm ²)
Maxillary second molar	10	1.86 ± 0.48	2.26 ± 1.79	13.80 ± 9.48
Maxillary third molar	12	2.09 ± 1.08	1.34 ± 0.71	9.40 ± 5.17
p-value		0.53	0.11	0.18

find one EP *per* root; however, two of such structures located on opposite sides of the root can sometimes be found. According to Cavanha,¹ the finding of three EPs is rare, and the presence of four pearls is exceptional.^{2,5,17} In the present study, only teeth with one ($n = 13$) or two pearls ($n = 5$) were identified.

EPs can be connected also to the cervical enamel extensions by a ridge of enamel.⁵ In the present study, this anatomical feature was observed in four specimens. In such cases, this extension of the enamel may contribute to enhancing plaque retention and protecting oral micro-organisms from the action of salivary enzymes and oral hygiene measures, pre-disposing a particular site to periodontitis.¹¹

In the present study, it was observed that one small pearl was constituted solely of enamel, while the others have a core of dentine within. Root excrescences, which consist solely of enamel, are usually quite small (approximately 0.3 mm in diameter) and are called true EPs or simple EPs.^{1,5} Nevertheless, most of the pearls are enamel–dentin pearls, where the enamel layer caps a core of dentine.^{1,5,16,21} Some larger EPs may contain pulp tissue also, and these have been called enamel–dentin–pulp pearls.¹

The major diameter of the pearls ranged from 1.15 mm to 4.48 mm, with a mean of 1.98 mm, which is in accordance with previous studies. Risnes⁶ evaluated 8854 human molars and found that the diameter of the EPs ranged from 0.3 mm to 4 mm, mostly varying from 0.5 mm to 1.5 mm in diameter. Loh²² studied 5674 teeth and found that 57% of the pearls ranged in diameter from 1.0 mm to 1.9 mm. Sutalo *et al*²³ analysed over 7000 teeth and found that the mean diameter of these enamel structures was 1.7 mm. The results of volume and surface area of the EPs achieved in the present study cannot be compared with others, as there is no information on this subject in the literature to date. Thus, the clinical relevance of such findings is still to be determined.

In conclusion, the evaluation of 18 molar teeth revealed the presence of 23 EPs located generally in the furcation area. The majority was an enamel–dentin pearl type and no difference was found in pearls located in maxillary second and third molars regarding diameter, volume and surface area. In this report, the EP mimicked an endodontic–periodontic lesion and was a secondary aetiological factor in the periodontal breakdown.

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