

# ENAMEL PEARLS AND ENAMEL EXTENSIONS: Anthropological and Clinical Significance

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## ABSTRACT

**Objective:** To define the anthropological and clinical significance of enamel pearls and enamel extensions.

**Methods:** Computer search of relevant scientific databases (PubMed, SCOPUS, ERIC, ScienceDirect, Wiley Online Library) using keywords in English and Bosnian language (enamel extensions, enamel pearls, ASUDAS, clinical aspects), followed by collection, selection, systematization of relevant information and finally derivation of conclusions through critical analysis and logical thinking.

**Conclusions:** Enamel pearl and enamel extensions are of great anthropological and clinical significance. They could be used as markers of geographical origin because of higher prevalence in certain populations, as well as, for dental profiling of victims, while clinically they can be used in the diagnosis and prognosis of associated clinical implications such as periodontal disease, furcation involvement, caries, deciduous tooth retention and permanent tooth malposition. Removal of these formations should be considered while planning periodontal treatment to ensure better treatment outcomes.

**Keywords:** enamel pearls; enamel extensions; enamel projections, clinical significance, anthropological significance, ASUDAS

## 1. Introduction

The enamel is a mineralized tissue which forms the outer layer of the tooth crown and, in most cases, ends at the cemento-enamel junction (CEJ) located on the tooth cervix. However, in rare cases, ectopic enamel accumulations, enamel pearls and enamel extensions can be seen. [1][2][3]

This review article aims to define the anthropological and clinical significance of anatomical variations and anomalies - enamel pearls and enamel extensions.

For this purpose, definitions, classifications, as well as morphological, histological and radiological characteristics are listed.

The most common locations for enamel pearls and enamel extensions are presented, as well as their significance as morphological traits.

As part of describing the clinical significance, it is necessary to determine the prevalence of enamel pearls and enamel extensions, their impact on the surrounding tissues, their importance in the onset of periodontal disease and other complications, the possibility of preventing complications related to enamel pearls and enamel extensions, as well as the therapeutic methods of related periodontal disease and the outcomes of those treatments.

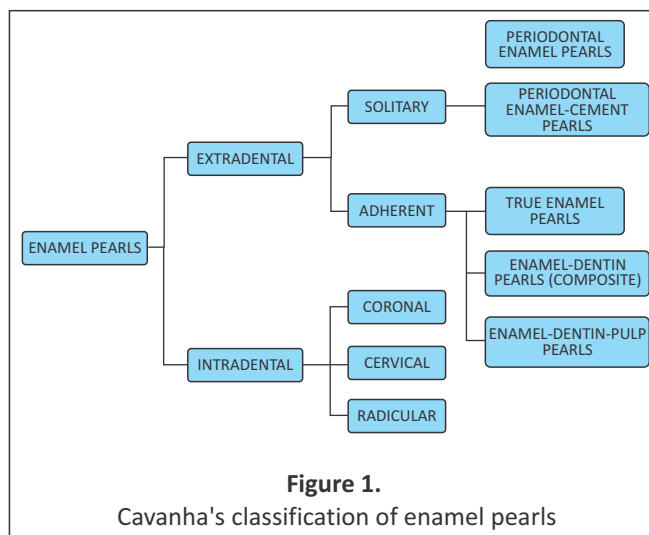
## 2. Anthropological significance

Enamel pearls and enamel extensions are white, smooth enamel accumulations formed beyond the cemento-enamel border occupying the cervix and roots of predominantly posterior permanent teeth. [4][5]

They are easily discerned from tooth cement, especially on radiographs where they show higher radiopacity than cement. [6][7]

**Enamel pearls** are spherical formations of enamel that can occur in the dentin (intradental), on the cementum or dentin of the tooth root (extradental adherent), or even completely separated from the tooth in the periodontal ligament area (extradental solitary). [3][8][9] They mostly appear as extradental pearls in the area of furrows and

furcations of multi-rooted teeth, especially maxillary third and second molars. [5][6][8][9] The prevalence of enamel pearls on premolars is low while they rarely occur on the incisors, canines and deciduous teeth. [11][12] A sketch of an enamel pearl is shown in Figure 1.



They show a preference for the mesial and distal surface of maxillary teeth while in mandibular teeth they are most commonly found on buccal and lingual surfaces of teeth. [1][8] They can come in various sizes but mostly in the 0.3-4mm range. [6][8]

Enamel pearls are often found connected to enamel extensions. There are cases of multiple enamel pearls and enamel extensions on a single tooth with very rare cases of three enamel extensions or four pearls on a single tooth. [6][10]

Enamel pearls tend to form further from the cemento-enamel junction than enamel extensions with a reported distance of 2.8+-1mm. [6][8]

The largest enamel pearl documented, a true enamel pearl, 8 mm in length and resembling to a rudimentary root, was reported by Mao in 2014. [13]

**Enamel extensions** are flat, triangular, vertical stripes of enamel extending from the enamel-cement border towards the bifurcation of roots in multi-rooted teeth, with a preference for mandibular second and first molars. [4][14][15]

The maxillary first molar has been adopted into the ASUDAS by Turner et al as the key tooth for observation of enamel extensions. [16]

Enamel extensions exhibit a high predilection for

the buccal and lingual surfaces of molars. [2][4][17]

Some enamel extensions reach horizontally into the furcation of the roots. [13][16][17] They occur in continuous and intermittent forms, while intermittent enamel extensions may be interrupted in one or more places. [15][18]

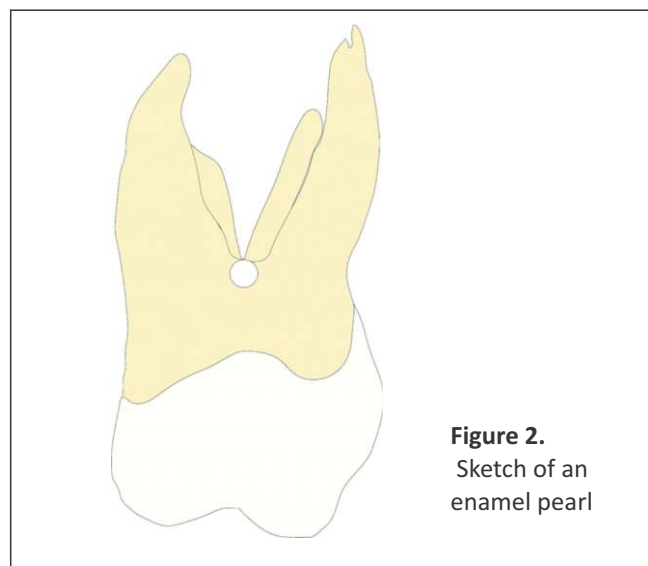
Enamel extensions occur far more often than enamel pearls. They present a much higher prevalence in Asians compared to Caucasians in general and the most common type in Caucasians is grade 1, while in Asians most prevalent enamel extensions are of grade 3. [2][15][21]

Both enamel extensions and enamel pearls are associated with the occurrence of other anomalies, especially favoring incompletely separated roots and accessory roots. [4][22][23][24][25][26][27]

Enamel pearls are structurally different from enamel extensions. Histologically, an enamel pearl can contain a dentin core or a core of dentin and pulp. Some enamel pearls may be covered by acellular cementum allowing it to form a connection with the periodontal ligament while enamel pearls covered by a reduced enamel epithelium have also been observed. [4][6][17]

Composite enamel pearls are pearls containing a dentin core covered by an enamel layer and are the most common type of pearl documented in research. True enamel pearls, containing only enamel are less common. [11][28][29]

Observed under a microscope, the enamel of enamel pearls and enamel extensions resembles to immature enamel due to irregular prisms. Enamel pearls present more irregularities in their enamel compared to coronary enamel, with areas of hypomineralization and hypermineralization and surface concavities filled with organic matter



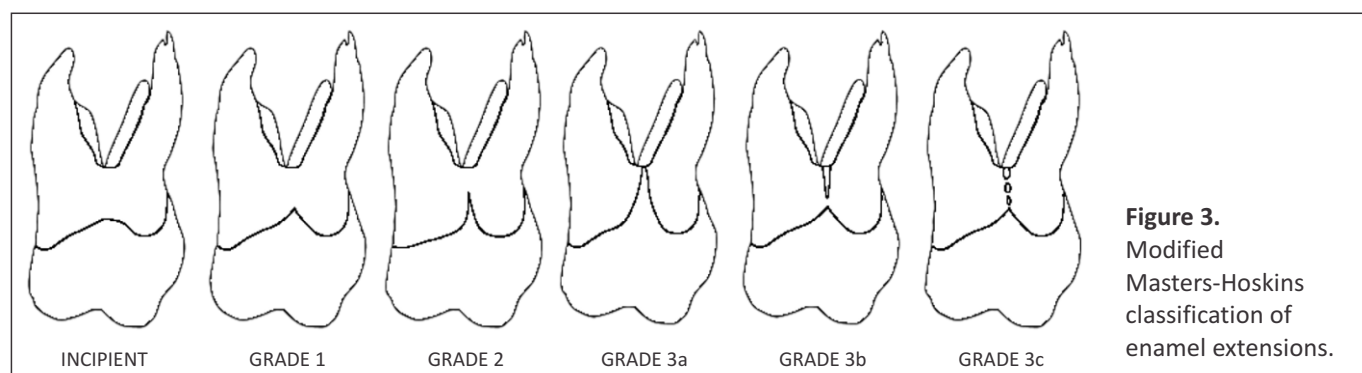
**Figure 2.**  
Sketch of an  
enamel pearl

alongside a slightly different direction of enamel prisms, interprismatic substance, and Hunter-Schreger lines. [5][28][29]

Various authors have made their contributions to the classification of enamel pearls (Euler and Meyer 1927, Gollner 1928, Cavanha 1964, Pindborg 1970, Risnes 1974, Kocsis and Marcsik 1983) although today we mostly use the Cavanha classification of enamel pearls for its comprehensiveness and coherence. [3][10][28][29][30] This classification is shown in Figure 2.

As for enamel extensions (previously classified by the following authors: Pedersen 1949, Masters and Hoskins 1964, Carlsen 1967, Zee et al 1991, Turner et al 1991, Lekkas and Townsend 1996), the ASUDAS and Master-Hoskins classifications are most often used. [3][15][16][18][20] The modified Masters-Hoskins classification is shown in Figure 3.

The ASUDAS system includes enamel pearls as components of the enamel extension in classification while ignoring enamel extensions that are not



**Figure 3.**  
Modified  
Masters-Hoskins  
classification of  
enamel extensions.

connected to the cementoenamel junction, while modified Master-Hoskins classification (Zee et al 1991, Lekkas and Townsend 1996) includes different variants of enamel extensions. [15][16] [18][20][31]

The ASUDAS system just like Masters and Hoskins's classification classifies enamel extensions into three grades, according to distance from furcation in mm (grade 3 >4mm), unlike Masters-Hoskins where they are classified according to their relation to the furcation of roots with Grade 3 being an enamel extension entering horizontally into the furcation. [2][16][14][31]

The etiology of enamel pearls and enamel extensions has been debated throughout their history. It is known that they occur due to ectomesenchymal interaction errors but the exact process is unknown. [22]

The most common theory states that enamel pearls and enamel extensions originate from the Hertwig's epithelial root sheath or the rests of Mallassez. [1][3][5]

Since the cervical loop, located at the margin of the future tooth crown, is a source of stem cells, its replacement by Hertwig's root sheath may be related to the loss of Notch protein in the epithelium and growth factors in the mesenchyme. Hence retention of these factors is probably the cause of the continuous presence of reticulum stellatum and stratum intermedium in the root area leading to the formation of enamel pearls on its surface. If the cells of Hertwig's sheath remain in contact with root dentin, this can lead to their differentiation into ameloblasts then forming enamel in the area of the tooth root. [32][33][34][35]

Enamel pearls and enamel extensions exhibit strong ethnic and racial predispositions. They mostly occur in East Asians and New World populations (up to 50%), Southeast Asians, and Polynesians (20-30%), while they are rarely found in Western Eurasians, Sub-Saharan Africans and Sahul-Pacific groups (under 10%). [12][31] Prevalence of enamel pearls and extensions in various populations is shown in Table 1 and Table 2 by reflecting on the results of latest and most relevant research.

Grine et al. observed a composite enamel pearl on the Florisbad fossil, which is currently the oldest

GEOGRAPHICAL AREA (POPULATION)	SAMPLE	PREVALENCE	MOST COMMON LOCATION	REFERENCE
SAUDI ARABIA	642 SUBJECTS	4.82% SUBJECTS		AL ZOUBI ET AL (2018)
TURKEY	6912 SUBJECTS OVER 15 PANORAMIC RADIOGRAPHS 97362 POSTERIOR TEETH	5.1% SUBJECTS 0.85% MOLARS	MANDIBULAR FIRST AND SECOND MOLAR (45.2%, 36.1%)	COLAK ET AL (2014)
Unknown origin	2532 EXTRACTED TEETH	0.74% TEETH	MAXILLARY THIRD AND SECOND MOLARS (50%, 44.5%) DISTOBUCCAL AND PALATAL FURCATION	VERSIANI ET AL (2013)

Table 1 - Epidemiologic studies on enamel pearls

GEOGRAPHICAL AREA (POPULATION)	SAMPLE	PREVALENCE	MOST COMMON LOCATION	MOST COMMON GRADE	FURCATION INVOLVEMENT	REFERENCE
KOREA	425 SUBJECTS OVER 20 CBCT 982 MANDIBULAR MOLARS (only buccal and lingual surfaces)	76% MANDIBULAR MOLARS 71% BUCCAL, 27% LINGUAL SURFACES		GRADE 1 (54.8%) GRADE 2 (34.8%)	67.5% TEETH	LIM ET AL (2015)
BRAZIL	234 EXTRACTED MOLARS	17.1% TEETH	22.7% MANDIBULAR MOLARS (BUCCAL SURFACES)	GRADE 1 (10.3%)		DESOUZA ET AL (2014)
INDIA	89 DRY SKULLS 944 UPPER AND LOWER FIRST, SECOND, AND THIRD PERMANENT MOLARS	11.9% MOLARS	MANDIBULAR AND MAXILLARY SECOND MOLARS (14.7%, 14.6%)	GRADE 3 (73.2%)	87.5% MOLARS	BHUSARI ET AL (2013)
KERALA INDIA	1743 EXTRACTED TEETH	8.47% TEETH				BABY ET AL (2017)
ESKIMO	133 DRY SKULLS 834 MOLARS	72% MOLARS	MANDIBULAR SECOND MOLARS		SIGNIFICANT ASSOCIATION BETWEEN CEP AND FURCATIONS	ZEE AND BRATHAL (2003)

Table 2 – Epidemiologic studies on enamel extensions

GEOGRAPHICAL AREA (POPULATION)	SAMPLE	PREVALENCE	MOST COMMON LOCATION	REFERENCE
CROATIA	7088 EXTRACTED TEETH	0.54% TEETH 1.13% MOLARS	MAXILLARY THIRD AND SECOND MOLARS (3.6%, 1.78%) DISTAL AND MESIAL SURFACE	ŠUTALO ET AL (1986)
SLOVENIA	1180 PERMANENT MOLARS	3.05% MOLARS		GAŠPERŠIČ (1985)
	601 MAXILLARY MOLARS	5.10% MOLARS		GAŠPERŠIČ (1985)
	18 SECOND AND 26 THIRD PERMANENT MAXILLARY MOLARS WITH 2 PALATAL ROOTS	16.3% WITH CEP (65.1% GRADE 3) 2.3% WITH EP		HITIJ AND ŠTAMFELJ (2020)

**Table 3** – Prevalence of enamel pearls and enamel extensions on The Balkans

recorded humanoid specimen with this anomaly. The pearl's structure, size and location coincide with cases in recent populations. The occurrence of an enamel pearl on the distal root surface of the maxillary third molar shows that enamel pearls have stayed preserved through time as a morphological trait. [11]

This information indicates the possibility of enamel pearls and enamel extensions being useful tools in dental profiling in archeology, ancestral profiling and forensic profiling of victims.

### 3. Clinical significance

Enamel pearls and enamel extension are of great clinical significance, especially in populations with a high prevalence of these anomalies. They have been

connected to various complications, such as root caries, rapid localized periodontal destruction, furcation involvement, endo-periodontal syndrome, deciduous tooth retention and delayed permanent tooth exfoliation. [18][36]

The diagnosis of enamel pearls and enamel extensions requires extensive investigation of the patient's data, (medical, dental, family, social history, review of dental records), and thorough clinical examination. For definitive diagnosis, diagnostic radiology (periapical radiographs, ortopantomographs), plays the key role, since these anomalies are mostly only visible in cases with severe gingival recession. [22]

Even though periodontal disease is primarily a result of plaque build-up and microbial activity, it can be modified by anatomic and other factors (environmental, hormonal, immunity). Most researches emphasize the association of these formations with periodontal disease, considering that in the presence of these formations, connective tissue attachment of the gingiva, which is more resistant to physical and chemical attacks, cannot be formed leaving behind only an epithelial attachment. This causes rapid localized gingival destruction leading to the formation of narrow and deep periodontal pockets. The anatomy and location of enamel pearls and enamel extensions (proximity to the furcation area) along with the anatomy of the root trunk (short root trunk means fast furcation involvement independently of enamel pearl/extension size or its removal) favors plaque accumulation and tissue destruction consequently leading to severe localized furcation involvement. [7][33][37][38][39]

The deepening of periodontal pockets and recession of the alveolar bone opens a pathway for microbial colonization of cement, causing root caries and further deterioration of the surrounding periodontal tissue thus increasing the possibility of transfer of the pathologic processes from the periodontal area to the endodontic space and the consequent necrosis of the pulp. [19][39][40]

Enamel pearls and enamel extensions can prevent the exfoliation of deciduous teeth because of slower enamel resorption in comparison to dentin and cement which can in turn lead to the malposition of their permanent successors. [8][41]

Therefore, enamel pearls and enamel extensions, if their anatomy and location favor inflammation and destruction of the surrounding tissues, should be diagnosed and removed in time to prevent need for endodontic treatment and possibility of tooth loss.

Timely and correct diagnosis consequentially leads to adequate treatment planning and a favorable final prognosis. [6][39][40]

Not all enamel pearls and enamel extensions are related to periodontal destruction hence only monitoring is indicated. [6][8][37]

In cases where periodontal destruction is present several treatment modalities according to excessiveness of tissue damage are used to ensure proper and effective resolution of periodontal disease.

If the enamel pearl or enamel extension needs to be removed, enameloplasty is the procedure of choice. It is recommended by many authors for various reasons such as: removal of these anomalies as plaque accumulation and retention niches, prevention of periodontal destruction and furcation involvement, enabling formation of more resistant connective tissue attachment. [2][8][37][33][42] Enameloplasty can potentially lead to dentin hypersensitivity. [38]

If an enamel pearl contains pulp tissue, endodontic treatment should be performed before enameloplasty. [40]

Primarily, it is necessary to perform initial periodontal therapy (removing calculus and improving oral hygiene). If enamel pearls and enamel extensions are already exposed, they are surgically removed by enameloplasty. Flap surgery and curettage may be performed along with enameloplasty. In cases of severe periodontal involvement, tunnel preparation (furcacioplasty), root separation and resection, as well as excision procedures for a new attachment may be indicated in addition to previously mentioned procedures. In presence of endoperiodontal communication, endodontic treatment is vital. [2][33][37][39][44]

After adequate therapy, there is a complete resolution of the inflammation, reduction of mobility and resolution of the periapical pathology. [8]

It is of crucial importance to include supportive

therapy in order to prevent the recurrence and progression of periodontal destruction. [33]

## 4. Discussion

Upon analysis of literature some issues that can give direction to further research have been uncovered regarding various themes of interest.

The first issue presented while studying enamel pearls and enamel extensions is the existence of various names and definitions used by different authors throughout their history. [3][11][45] Many different names may prevent researches from finding information relevant to their research.

This leads to the issue of classifications. Various classifications exist and none are all-inclusive yet and they may prevent systematization of data. For example, modified Masters-Hoskins classification encompasses interrupted enamel extensions while the ASUDAS categorizes enamel pearls within the scope of enamel extensions for ease of result systematization but yet disregards enamel extensions which are not connected to the cemento-enamel junction. [3][15][16][18]

Enamel pearls and enamel extensions are most probably affected by both genetic and environmental factors, yet further research is necessary to determine the exact factors and their definite impact. [16][22]

Perhaps more archeological findings containing these anomalies might help to find more connections regarding origin of the human species as well as the origins of various populations.

As many authors point out, systematization of data is also hindered by using different research methods and materials. Research has been done on cadavers, live patients, dry skulls, extracted teeth and radiographs. Various methods have been used in research such as: clinical evaluation of patients by probing the region of the cemento-enamel junction, microscopic analysis on extracted teeth and during periodontal surgery, analysis of various radiographs taken for diagnosis of enamel anomalies or for other reasons (periapical radiograph, ortopantomograph, CBCT image), inclusion of only specific tooth groups in epidemiologic studies. [12] [14] [19] [43] [46] [47]

[48]

There is still little epidemiologic data on enamel pearls and enamel extensions.

Several authors point to investigation of microscopic forms of these anomalies as to ensure correct epidemiologic data. [5][8][17][36]

Few authors have taken the sex of the subject into account in epidemiologic research of enamel pearls and enamel extensions [1][9][14][19][36][49][50], but the ones that had were getting opposing results, some researchers indicating neglectable result variations between genders [9] [36][49], while others recorded higher occurrence in a certain sex. [1][14][19] Mostly males had higher rates of enamel pearls and enamel extensions.[1][14][19]

Not many authors included the tooth surface on which enamel pearls and enamel extensions appeared in their epidemiologic studies. [5] [6] [10] [12] [15] [19] [20] [25] [26] [27][51] [52]

There exist even fewer histological and CBCT reports, yet these reports could offer clearer insight into individual cases, and individualistic approaches in the diagnosis, prognosis and treatment and effects of different treatment modalities which may not be visible in short term or by the human eye. [6][9][15][19][27][28][29][44][50][53]

Since enamel pearls and enamel extensions tend to occur alongside other anomalies, more subjects with multiple anomalies should be inspected for enamel extensions and enamel pearls. [20][24][27]

Enamel pearls and enamel extensions can be used as markers for periodontal disease. [54]

Programs for screening and prevention of periodontal destruction associated with these anomalies should be included in populations with high prevalence.

There is very scarce research and information on enamel pearls and enamel extensions on the Balkans. [12][25][55][56][57][58][59] Recorded prevalence are listed in Table 3.

In Bosnia and Herzegovina no epidemiologic studies have been conducted to this date. There is only one study in Bosnia and Herzegovina on enamel extensions [59], and no studies on enamel pearls. This information should be taken into consideration while planning future research.

The 2020 case report performed by Zukić and Bujak [59] provides proof of the presence of enamel extensions in Bosnian population. The fact that two of three cadavers were presented with enamel extensions on deciduous teeth is interesting because enamel extensions rarely occur in deciduous teeth. Zukić and Bujak [59] mention a possible genetic connection between the excavated cadavers. More researches are necessary to ensure proper understanding of the genetics of enamel pearls and enamel extensions.

Research should be done on the prevalence of enamel pearls and enamel extensions for opening its use for identification and possibly preventing complications that can arise with these anomalies.

Epidemiologic and other types of studies in Bosnia and Herzegovina are necessary not only for prevention and resolution of complications related to enamel pearls and enamel extensions, but even dental profiling and ancestral profiling of The Balkans' populations. These studies could be performed on extracted teeth, periapical, OPG and CBCT images of patients.

Since not all enamel pearls and enamel extensions have been connected to periodontal destruction it is necessary to locate the ones that could cause it while taking into consideration all other factors that could affect the progression of periodontal breakdown (occlusal facets, alveolar bone thickness, root-trunk length variation of the root trunk, severity and extension of gingival inflammation, hormonal factors...). [14]

## 5. Conclusions

Upon the conveyed examination and analyses of literature it can be concluded that enamel pearls and

enamel extensions have great anthropological and clinical significance. Anthropological significance of these formations may be found in different prevalence of these formations in various populations and may be used in dental profiling as a marker for determining the identity and geographical origin of a person. From an anthropological perspective, we may deduce a high possibility of changes in the occurrence of enamel pearls and enamel extensions over time in the same population.

Enamel pearls and enamel extension have great importance in periodontology as a predisposing factor to periodontal disease. Removal of these formations should be considered while planning periodontal treatment as to ensure better treatment outcome.

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## Declaration of Interest

I state that there is no conflict of interest to disclose.

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