Studies on root enamel

(2) Enamel pearls. A review of their morphology, localization, nomenclature, occurrence, classification, histogenesis and incidence


Abstract. Enamel pearls are one of a number of different enamel structures that can be found on the roots of deciduous and permanent teeth. They have a distinct predilection for the furcation areas of molar teeth, particularly the maxillary third and second molars. They can consist primarily of enamel, but in most instances, a core of dentin is contained within them. On rare occasions, even pulpal tissues can be found. Enamel pearls usually occur singularly, but up to 4 enamel pearls have been observed on the same tooth. Depending on the study, enamel pearls on permanent molar teeth have an incidence rate of between 1.1%–9.7% with distinct differences among racial and national groups. The incidence of enamel pearls increases greatly in histological studies, suggesting that they are often obscured by a covering of cementum.

Key words: root enamel; enamel pearls; covering cementum.
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In the September 1841 issue of the American Journal of Dental Science, under the heading Singular Phenomenon, the following description was found: “We were presented a few months since by Dr. Jenks, Dentist, of Frederickstown, Md., with a superior molar tooth, on one of the sides of the neck of which, about the eighth of an inch above the termination of the enamel upon the crown, and just where the bifurcation of two of its roots takes place, is a protuberance, the size of a pin’s head, or perhaps a little larger, covered with enamel. Now, what seems remarkable is this, that this protuberance is covered with enamel. We can very readily conceive that it could have been formed by a deposition of bone, but the presence of enamel, according to the prevailing theory of the manner of formation of this substance, renders its explanation somewhat difficult.”

While this observation may have been considered unique some 150 years ago, it set off a chain reaction in which similar discoveries of enamel structures on the root were subsequently observed, described and reported in the literature (Linderer & Linderer 1842, Wedi 1873, Virchow 1886, Busch 1886, Baume 1890). Indeed in Salters (1984) classic text, he described the enamel nodule as an excrescence of enamel not infrequently found on molar teeth. “It occurs on teeth which are otherwise healthy and generally well formed ... I have usually seen it on molars and not far from the neck of the tooth, it generally occupies the groove at the side between the two fangs, and very frequently there is a conical process of enamel passing down towards the nodule, the two resembling in form a note of exclamation, thus!

By the latter part of the 19th century and well into the 20th century, interest in this area of dental morphology reached a crescendo, particularly in Austria and Germany, where detailed morphologic studies of Schmelztropfen including histologic descriptions were published by Schlenker (1891), Walkhoff (1896), Loos (1902), Kantorowicz (1904), Gottlieb (1921), Fleischmann (1922), Weski & Contreras (1924), Watson & Woods (1926), Euler & Meyer (1927), Göllner (1928), Lartschneider (1929), Pfluger (1931), Bohm (1938) and Euler (1939). It might seem bizarre that these early descriptions of root enamel were as detailed and accurate as they were, given the instrumentation that was available in these early days. However, the dental scientists of this era were as thorough and careful as any modern day dental investigators. Indeed, many of the more recent descriptions of radicular enamel lack the detail and accuracy of those of their predecessors.

Modern-day interest in radicular enamel stems from a publication by Masters & Hoskins (1964) who fortuitously noted a cervical enamel extension on a lower molar tooth which presented a bifurcation involvement directly adjacent to the extension. They attempted to associate these enamel “anomalies” with defects in the adjacent alveolar process, implicating them as a predisposing factor in periodontal destruction in molar teeth. A long series of studies has followed in an attempt to accurately determine the distribution and incidence of cervical enamel projections and to try to confirm the accuracy of the theory that the presence of enamel extensions can make a patient more vulnerable to some forms of periodontal disease (Grewe et al. 1965, Leib et al. 1967, Bernaba & Watanabe 1973, Bissada & Abdelmalek 1973, Tsatsas et al. 1973, Abe 1975, Andrews 1975, Swan & Hurt 1976, Pennel & Keagle 1977, Shilloah & Kopczyk 1979, Rattner 1979, Gaspersic 1984, 1985a, Praglia et al. 1985, Hou & Tsai 1987, Chan et al. 1988. While no clear cut picture has emerged as yet, clinical periodontists are acutely aware
of the presence of cervical enamel extensions and continue to routinely consider such anatomical variations as potential periodontal lesions, if not true periodontal destruction.

Given the tremendous interest in cervical enamel extensions in recent years, it seems odd that other forms of enamel on the roots of the teeth have not stimulated a similar interest. This study is an attempt to describe the various forms that enamel takes on the root surface, the histogenesis of their formation and their detailed morphology and incidence in humans. The relationship of root enamel to adjacent periodontal structures and its possible association with destruction lesions of the periodontium, was also investigated.

Surface Description

When examined grossly or macroscopically, enamel pearls most commonly appear spheroid, however other shapes such as conical, ovoid, tear-drop, cylindrical and irregular have been observed (Negra & Olliveira 1974). They vary in size from a pine-head smaller to that of a large cusp of a tooth. In one study of over 7000 teeth, the mean diameter of these enamel structures was found to be 1.7 mm (Sutato et al. 1986). Risnes (1974) in a study of 8854 human molars, found a distribution in size of macroscopically detectable enamel pearls on roots from 0.3 mm to 4 mm. The greater proportion of these bodies varied in size from 0.5 mm to 1.5 mm in diameter. Loh (1986), in his study of 5674 teeth, found that 57% of the pearls ranged in diameter from 1.00 mm to 1.9 mm. The larger enamel pearls often resemble a cusp or even a small tooth. They appear as discrete, glass-like globular bodies attached to the root by a sessile base. They are easily differentiated from the cemental surface by their color and texture (Fig. 1).

It is most common to find 1 enamel pearl per root, however 2 such structures located on opposite sides of the root can sometimes be found (Fig. 2). According to Cavanha (1965), the finding of 3 enamel pearls is rare, and the presence of 4 pearls is exceptional. Enamel pearls can be connected to cervical enamel extensions by a ridge of enamel. This anatomical variation will be described in greater detail in another section of this paper.

Localization of Enamel Pearls

Enamel pearls have a distinct predilection for the furcation area of molar teeth and for concavities or furrows within the root structure. However, they have been found less commonly on the cervical and apical portions of the root (Cavanha 1965). They are most frequently encountered on the mesial or distal surfaces of maxillary 2nd and 3rd molars, less frequently on the buccal or lingual surfaces of mandibular molars and rarely on the roots of incisors or bicuspids teeth (Bernaba & Watanabe 1973, Risnes 1974, Oliveira et al. 1977, Loh 1980). When occurring on the roots of maxillary molars, they are most commonly seen between the distobuccal and palatal roots, while they occur on the buccal in between the mesial and distal roots of lower molars (Risnes 1974). Intradental, also called internal or intradental enamel pearls, are found within the dentin and can have a coronal, cervical or radicular location. They are considered to be rare, but the fact they can only be identified radiographically limits the possibility of their recognition (Cavanha 1965, Kaugers 1983).

Nomenclature

They have been also referred to as enamel droplets (Linderer & Linderer 1842), enamel nodules (Salter 1875), enamel globules, enamel knots, enamel exostoses (Virchow 1886) and enamelomas (Shafer et al. 1958), Thoma & Goldman 1960). The latter term refers to its earlier delineation as an odontogenic tumor which has been shown to be inaccurate. All of the above are considered to be extradental and can be viewed with the naked eye, macroscopically, or microscopically.

Occurrence

While enamel pearls have been reported widely as occurring in human permanent molar teeth, their presence on deciduous teeth have also been observed. In a microradiographic study of 40 human deciduous molar teeth, an unexpected high-frequency of 33% was found at the interradicular line (Arys & Dourov 1987). Enamel pearls on deciduous teeth have been reported as rare in other studies (Bernaba & Watanabe 1973). These so-called anomalies have been further described in dogs (Schneck 1973), primates (Bernick & Levy 1968), rodents (Kalnins 1952), Tibetan wild sheep (Hooijer & Eulderink 1975) and Rhinoceroses (Pattie 1934, Hooijer 1946). An example of an “enameloma” in a prehistoric indian skull has even been reported by Koritzer (1970).
Classification

Root excrescences which consist solely of enamel are usually quite small (approximately 0.3 mm in diameter) and are called true enamel pearls or simple enamel pearls (Euler & Meyer 1927, Göllner 1928, Cavanha 1965). They lie directly over a smooth surface of dentin. Making up the largest category, are pearls which contain a core of tubular dentin within them. These have traditionally been termed composite enamel pearls (Bohm 1938), but more recently have been classified as enamel-dentin pearls (Cavanha 1965). The thickness of the dentin core varies according to the size of the pearl. Some larger composite enamel pearls may also contain pulpal tissue and these have been called enamel-dentin-pulp pearls (Cavanha 1965).

As mentioned earlier, intradental pearls are contained within the dentinal structure and can assume a coronal, cervical or radicular location (Kaugers 1983).

Histogenesis

Extra dental enamel pearls are most commonly thought to represent the localized activity of portions of Hertwig's epithelial root sheath which have remained adherent to the dental surface after root development (Pfluger 1931, Böhm 1938, Fujita & Nakayama 1941, Pindborg 1970). These cells then may differentiate into functioning ameloblasts and produce enamel deposits on the root. Other portions of the root

Fig. 3. Composite enamel pearl situated in furcation region of maxillary third molar tooth. Alveolar bone from the crest adjoins the radicular enamel structure. Note the inflammatory lesion in the adjacent gingiva. EP: enamel pearl. D: dentin. IF: inflammation. GS: gingival sulcus. C: cementum. (H&E x 40).
sheath are subsequently fragmented and are dispersed into the periodontal ligament as epithelial cell rests of Malassez (Malassez 1910). In their article, entitled Enamel Pearls, Malassez & Gallipe (1908) argue against this theory of enamel pearl formation. They stated that, since most enamel pearls contain enamel and dentin, their formation cannot be attributed to a simple recurrence of activity in the internal membrane of the enamel, but must have occurred at an earlier period of tooth development. They regard the embryogenesis of pearls as similar to supernumerary tubercules or cusps, and so the deformity owes its presence to something that happened prior to the initiation of dentin formation. In addition, they proposed that another anomaly exists in the embryogenesis of enamel pearls: “The cells of the interior layer of the enamel, which normally do not secrete any enamel at this level, became active in the same way as those that produce the crown tubercules (extrt. tooth cusps). Afterwards, when the cement is formed on the root, it invades more or less under the enamel of the pearl”. The intradental enamel pearls apparently result from ameloblastic activity during tooth formation in which the ameloblasts become invaginated into newly forming dentin, thus forming enamel which is surrounded by dentin (Cavanaugh 1965). Kaugers (1983) proposed that enamel-producing epithelium originates from some portion of the enamel organ, most probably the enamel knot, cervical loop or internal enamel epithelium. The enamel knot represents a spontaneous, but temporary proliferation of epithelial cells within the developing tooth germ which invade the dental papilla prior to the formation of dentin. Similarly, cells from the inner enamel epithelium could transgress into the connective tissue of the dental papilla. It is possible that following the initiation of mineralization of the dentin, the ameloblasts could elaborate enamel matrix which could then inhibit movement of the ameloblasts into the dental papilla. The cervical loop consists of inner and outer enamel epithelium layers which contribute to the formation of enamel in the cervical portion of the tooth (Provenza, 1964). The author again suggests that focal proliferation of the loop could result in enamel epithelial entrapped within the newly forming dentin, thus providing another potential mechanism for an internal enamel pearl (Kaugers 1983).

In their study of the development of the bifurcation in multirooted teeth in the Marmoset monkey, Bernick & Levy (1968) noted that migrating epithelium cells from the distal and lingual surface of developing molars formed an incomplete epithelium diaphragm. The epithelial continuity was subsequently destroyed by invading cells of the dental papilla. The epithelial cord which was later formed, proliferated into a multilayered structure which then initiated root formation. Quite commonly, they found that the centrally located epithelial cells further differentiated into a typical enamel organ which formed enamel in the bifurcation region.

While these explanations on the possible embryogenesis of the enamel pearl seem plausible enough, the reasons for

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**Fig. 4.** Higher magnification of enamel pearl. Note the interior core of dentin. A thin layer of cementum covers the periphery of the enamel structure. Cementicle-like bodies are present in the connective tissue directly adjacent to the surface of the pearl. EP: enamel pearl. DC: dentin core. CC: cementum covering. C: cementicle-like structures. D: dentin. CE: cementum. (H&E x 90).
the occurrence of enamel pearls on certain teeth and in a particular location are still unexplained.

Incidence
The prevalence of macroscopically discernable enamel pearls on human teeth has been evaluated in a number of large investigations (Turner 1945, Cavanna 1965, Bernaba & Watanabe 1973, Risnes 1974, Negra & Oliveira 1974, Loh 1980, Gaspersic 1985a, Sutalo et al. 1986). Most of these studies are in relative accordance with each other with the exception of the study of an Eskimo population (Pederson 1949). This investigation presented a significantly higher prevalence of enamel pearls than in other racial and national groups studied. All incidence studies have been based on the examination of skulls and extracted teeth. Where extracted teeth were employed, there usually existed some uncertainty about tooth determination, particularly in the separation of maxillary 2nd and 3rd molars. In the evaluation of the above studies, the overall occurrence of enamel pearls among all molars teeth was between 1.1%–5.7%. The mean occurrence of enamel pearls in 9 large studies of enamel pearls in humans was 2.69%. The incidence of enamel pearls on molars in the Eskimo population was 9.7%.

In all of the above investigations, far and away the highest incidence of enamel pearls was found on the roots of maxillary third molar teeth. Approximately 75% of all enamel pearls seen on molars occur on maxillary third molars. The mandibular third molar and the maxillary second molar are the 2nd most common sites for enamel pearl location. They are seen less frequently on maxillary first molars and mandibular 2nd molar roots (Risnes 1974, Loh 1980). Pearls are rarely seen on mandibular first molars, but have been reported in unusual instances on the roots of maxillary premolar and incisor teeth (Bernaba & Watanabe 1973, Oliveira, Leite & Neves 1977).

In approximately 8.7% of the cases in which enamel pearls occur on molar roots, they occur in multiples, almost always 2 pearls on a tooth. However, cases in which 3 or even 4 enamel pearls are present have been described (Cavanna 1965, Loh 1980) (Fig. 2).

It is interesting to note that Gollner (1928), in an histological study, reported an incidence of enamel pearls in the bifurcation of almost 50% in the molar teeth examined. In a more recent microscopic investigation of 40 lower molar teeth of young individuals, enamel pearls were found in 37 teeth. In 11 of these teeth, the pearls occurred singularly, but 26 had 2 or more pearls (Pedler 1959). The inconsistency between these 2 studies and the others reported herein is unsettling. It does, however, suggest that enamel pearls become considerably more common when specimens are examined histologically, rather than grossly or macroscopically (Moskow 1971, Suzuki 1958).

Microscopic Appearance of Enamel Pearls
Histologically, enamel found on the root resembles immature enamel. There are irregular areas of hypomineralization, the enamel rods often appear gnarled and wavy, and the enamel demonstrates positive birefringence. It is possible to observe tufts as well as Hunter-Schreger bands. In most instances, the lines of Retzius in the enamel can

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Fig. 5. Shallow trough in alveolar process associated with composite enamel pearl on mesial root of maxillary second molar. (A) Clinical photograph. (B) Radiograph. (Courtesy of Journal of Periodontology, taken from vol. 42 (1971) pp. 92-96, (Moskow, B.S.).)
be seen, but they tend to be irregular (Cavanha 1965, Pindborg 1970, Loh 1980, Gasperis 1985b, Kerebel et al. 1986). According to Cavanha (1965), the enamel prisms do not always end on the free surface because the surface commonly contains thin layers of irregularly structured enamel. The largest number of enamel pearls are composite pearls, which contain a core of dentin of various dimensions depending on the size of the pearl (Pederson 1949). The dentin is morphologically normal with regularly aligned dentinal tubules. Enamel pearls are often covered by a thin layer of afibrillar cementum which is not observable by macroscopic examination (Suzuki 1958, Pedler 1959, Pindborg 1970, Moskow 1971, Grant et al. 1988) (Figs. 3, 4).

**Discussion**

It would appear that the presence of enamel on the root in the form of pearls appears to have the same clinical implications in regard to the possible predisposition to certain types of osseous defects within the periodontal tissues as to what has been described with cervical enamel projections. While enamel pearls apparently have a distinct predilection for maxillary third and second molars, a distribution pattern which is different than that of enamel projections, they do occur most commonly in interradicular areas, and as such, could conceivably be associated with periodontal lesions in the furcation areas (Croft 1971, Vincent 1979, Goldstein 1979, Shiloah & Kopczyk 1979) (Fig. 5).

Enamel pearls and cervical enamel projections can occur on the same teeth, and when they do, can be contiguous with each other. The morphology of these combined radicular enamel structures and their association with the surrounding periodontal structures will be discussed in subsequent papers.

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