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Morphology of the cemento-enamel junction in premolar teeth

Kapila Arambawatta, Roshan Peiris and Deepthi Nanayakkara

Department of Basic Sciences, Faculty of Dental Sciences, University of Peradeniya, Peradeniya, Sri Lanka

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Abstract: The present study attempted to describe the distribution of the mineralized tissues that compose the cemento-enamel junction, with respect to both the different types of permanent premolars of males and females and the various surfaces of individual teeth. The cervical region of ground sections of 67 premolars that had been extracted for orthodontic reasons were analyzed using transmitted light microscopy to identify which of the following tissue interrelationships was present at the cemento-enamel junction: cementum overlapping enamel; enamel overlapping cementum; edge-to-edge relationship between cementum and enamel; or the presence of gaps between the enamel and cementum with exposed dentin. An edge-to-edge interrelation between root cementum and enamel was predominant (55.1%). In approximately one-third of the sample, gaps between cementum and enamel with exposed dentin were observed. Cementum overlapping enamel was less prevalent than previously reported, and enamel overlapping cementum was seen in a very small proportion of the sample. In any one tooth, the distribution of mineralized tissues at the cemento-enamel junction was irregular and unpredictable. The frequency of gaps between enamel and cementum with exposure of dentin was higher than previously reported, which suggests that this region is fragile and strongly predisposed to pathological changes. Hence, this region should be protected and carefully managed during routine clinical procedures such as dental bleaching, orthodontic treatment, and placement of restorative materials. (J Oral Sci 51, 623-627, 2009)

Keywords: cemento-enamel junction; morphology; variations; premolar teeth.

Correspondence to Dr. AKS Arambawatta, Division of Dental Anatomy, Department of Basic Sciences, Faculty of Dental Sciences, University of Peradeniya, Peradeniya, Sri Lanka
Tel: +94-81-2397232
Fax: +94-81-2388948
E-mail: arambawatta@yahoo.com

Introduction

The cemento-enamel junction (CEJ) is the anatomical juncture of the enamel that coats the crown of a tooth and the cementum that covers its root. The CEJ serves as an important point of reference in clinical dentistry, as it is usually the site where gingival fibers attach to a healthy tooth. In young adults, the CEJ of permanent teeth is protected by the gingival tissues. However, with increasing age, continuous passive eruption, which compensates for wear at the incisal and occlusal surfaces along with the recession of the gingiva, results in a shift of the CEJ to the gingival sulcus. These changes expose the CEJ to the oral environment, thus making it vulnerable to pathological changes such as root caries and cervical erosion, resorption, and abrasion.

Three possible relationships of the mineralised tissues composing the CEJ have been described in textbooks of oral histology (1). In approximately 60% of cases the enamel is overlapped by cementum, in approximately 30% of cases an edge-to-edge relationship between cementum and enamel is seen and, in the remaining 10% of cases, enamel and cementum fail to meet, resulting in a strip of exposed dentin. Although the exact sources of these data are somewhat obscure, they may have been derived from the initial light microscopic studies on CEJ done by Cloquet in 1899 (2) and Thorsen in 1917 (3) using ground sections of teeth.

The CEJ has become an area of clinical interest because the prevalence of cervical and root surface lesions involving the CEJ is likely to increase along with the population of

dentate elderly (4-5). In recent reports on the morphology of the CEJ, researchers have questioned the validity of the data found in textbooks of oral histology and have highlighted deficiencies in our current understanding of the morphology of this region (5,6). Even more recently, several studies have reviewed the morphology of the CEJ in both permanent (7-10) and deciduous teeth (11,12).

Muller and van Wyk (8) examined 150-µm-thick sections from 152 teeth extracted from a South African "Cape Colored" population and reported that 17.7% had gap junctions with dentin exposure mainly on the buccal and lingual aspects, and 45.2% had an edge-to-edge relationship. The authors suggested that the difference in the prevalences noted in their study and those derived from a Scandinavian population studied by Thorsen (2) might be race-specific.

Schroeder and Scherle (5) used scanning electron microscopy combined with light microscopy to examine eight extracted freshly erupted premolars and found that edge-to-edge contact of cementum and enamel was the predominant (70%) type of relationship and that gap junctions were very rare (1%).

In 1993, Bevenius et al. (9) used a replica technique for scanning electron microscopy-combined with polarization microscopy of thin (<40 µm) ground sections to investigate the CEJ of 50 freshly erupted premolars extracted for orthodontic reasons. They noted that edge-to-edge contact of cementum and enamel was most frequent (76%), and that overlapping of cementum onto the enamel (14%) was less prevalent than previously reported.

The above observations suggest that research is needed to better understand the anatomical profile of the CEJ. Thus, the objective of the present study was to determine the interrelationship of the mineralized tissues that compose the CEJ, both in different types of permanent premolars from males and females and in the various surfaces of individual teeth.

Materials and Methods

Sample

All the subjects enrolled in this research responded to an informed consent protocol approved by the Research, Ethical and Higher Degrees Committee of the Faculty of Dental Sciences, University of Peradeniya, Sri Lanka and conforming to the provisions of the Declaration of Helsinki of 1995 (as revised in Edinburgh 2000). The study material was obtained from a collection of premolars available at the Department of Basic Sciences, Faculty of Dental Sciences, University of Peradeniya, Sri Lanka. The teeth had been extracted for orthodontic reasons at the Dental Hospital, Peradeniya and at general dental practices in and around Peradeniya.

Immediately after extraction, the teeth were stored individually in 10% formalin until the time of investigation. Only morphologically sound teeth were selected for the study. Excluded from the sample were teeth with morphological/developmental abnormalities, caries, fracture/trauma, or erosions/attrition. After analysis, a sample of 67 permanent premolars (age range, 11-18 years) were selected for the study. The teeth were cleaned taking special care to avoid any damage to the cervical region.

Ground sections of teeth were prepared by cutting through the buccolingual plane perpendicular to the cervical margin of the crown by using a half-tooth technique (13) and a hard-tissue microtome (Leica, SP 1600, Germany). Selected sections were then ground using grinding stones, until the required thickness (approximately 70 µm) was achieved (both coarse and fine). Final polishing was done using polishing sheets (10 µm and 3 µm). The prepared sections were then dehydrated by immersing them in ascending concentrations of alcohol, after which they were mounted on glass slides.

Data recording

The cervical region of the ground sections was observed under ×10 magnification using an Olympus transmitted light microscope to establish the relationship of the mineralized tissues composing the CEJ. The type of tissue relationship present at the buccal and lingual aspects of all teeth was recorded.

The interrelationship of mineralized tissues that compose the CEJ was classified into four different categories (Fig. 1): enamel overlapped by cementum, edge-to-edge contact of cementum and enamel, cementum overlapped by enamel, and gaps between cementum and enamel that exposed a strip of dentin.

Results

The sample consisted of 44 permanent maxillary premolars (23 males and 21 females) and 23 permanent mandibular premolars (13 males and 10 females) (Table 1).

The mineralized tissues composing the CEJ presented four different interrelationships: cementum over enamel, edge-to edge relationship of cementum and enamel, gaps between cementum and enamel, and enamel over cementum (Fig. 1). Table 1 shows the distribution of interrelationships between the mineralized dental tissues at the CEJ on different tooth surfaces of maxillary and mandibular premolar teeth from males and females in the present sample. The Wilcoxon rank-sum test revealed no statistically significant differences by sex, or between

Table 1 Distribution of interrelationships between mineralized tissues at the cemento-enamel junction on buccal and lingual aspects of maxillary and mandibular premolars of males and females

Cemento-enamel junction	Maxillary				Mandibular			
	Male		Female		Male		Female	
Morphology	*n*	Frequency	*n*	Frequency	*n*	Frequency	*n*	Frequency
Buccal								
1	23	3 (13.2)	19	4 (21.2)	11	2 (18.2)	9	-
2	23	10 (43.4)	19	12 (63.1)	11	6 (54.5)	9	5 (55.5)
3	23	10 (43.4)	19	3 (15.7)	11	3 (27.2)	9	4 (44.5)
4	23	-	19	-	11	-	9	-
Lingual								
1	21	2 (9.5)	21	2 (9.5)	13	2 (15.4)	10	1 (10)
2	21	10 (47.7)	21	15 (71.4)	13	5 (38.4)	10	7 (70)
3	21	9 (42.8)	21	3 (14.4)	13	6 (46.2)	10	1 (10)
4	21	-	21	1 (4.7)	13	-	10	1 (10)

Figures in parentheses denote percentages.
On the Wilcoxon rank-sum test, the differences were not statistically significant between males/females, maxillary/mandibular teeth, or lingual/buccal surfaces.
1: cementum over enamel, 2: edge-to-edge relationship of enamel and cementum, 3: gaps between cementum and enamel with exposed dentin, 4: enamel over cementum

Table 2 Distribution of interrelationships between mineralized tissues at the cemento-enamel junction in the total sample (n = 127)

Cemento-enamel junction type	Frequency
1	16 (12.6)
2	70 (55.1)
3	39 (30.7)
4	2 (1.6)

1: cementum over enamel,
2: edge-to-edge relationship of enamel and cementum,
3: gaps between cementum and enamel with exposed dentin,
4: enamel over cementum

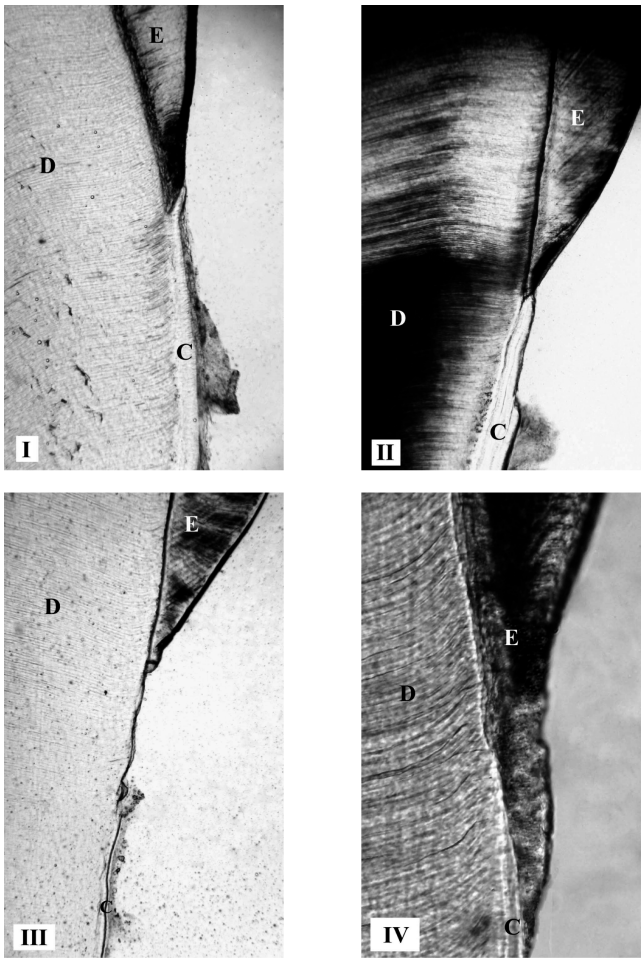

Fig. 1 Morphology of the cemento-enamel junction. I: cementum over enamel, II: edge-to-edge relationship of enamel and cementum, III: gaps between cementum and enamel with a strip of exposed dentine, IV: enamel over cementum (E: enamel, D: dentine, C: cementum).

maxillary and mandibular teeth, first and second premolars, or buccal and lingual surfaces. Consequently, it was decided to describe the distribution of the interrelationships among the mineralized tissues at the CEJ by aggregating all surfaces, irrespective of sex or tooth type (Table 2).

The edge-to-edge relationship between root cementum and enamel was most frequent (Table 1). The presence of gaps between enamel and cementum, with exposed dentin, was seen in approximately one-third of the sample. Root cementum overlapping enamel was seen in 12.6% of the sample. The fourth relationship – enamel overlapping cementum – was rare.

Discussion

The morphology of the CEJ of permanent teeth is becoming an area of great clinical significance due to its

association with dentin sensitivity and the susceptibility of the CEJ to pathological changes, such as root surface caries and cervical erosion, resorption, and abrasion. With the predicted increase in the elderly population, there is likely to be an increase in the number of lesions in the cervical root surface involving the CEJ.

Several researchers have challenged the validity of data on the relationship of enamel and cementum at the CEJ, as presented in textbooks of oral histology, and have called for a review of the morphology of the CEJ to address the scarcity of current information (5,7,9).

The material used in the present study comprised carefully selected freshly erupted premolar teeth extracted for orthodontic reasons. In young adults, the CEJ of permanent teeth is covered by gingival tissues. However, with increasing age, continuous passive tooth eruption, which compensates for wear at the incisal and occlusal aspects, exposes the CEJ to the oral environment. The CEJ is then subjected to various chemical as well as physical agents, such as tooth brushing, which alter the morphology of the CEJ. It is reasonable to assume, however, that the CEJs of the teeth in our study were not exposed to the oral environment and were therefore intact.

Most available data regarding the CEJ indicate that there are three salient morphological interrelations among the mineralized tissues that compose it: cementum over enamel, the edge-to-edge relationship of enamel and cementum, and the presence of gaps between cementum and enamel that expose a strip of dentin (5-7, 9). However, an extremely small proportion of our sample showed a fourth type of tissue interrelationship – cementum overlapped by enamel. This relationship was described by Neuvald and Consolaro in 2000 (10) and by Ceppi et al. in 2006 (11) in studies on permanent and deciduous teeth, respectively.

During tooth development, the deposition of enamel does not cease simultaneously along the entire perimeter of the tooth. When enamel deposition is completed in a particular area of the tooth bud, Hertwig's epithelial root sheath (HERS), which is composed of the inner and outer dental epithelia, begins to form at the cervical margin. Odontoblasts, which differentiate under the influence of HERS cells, secrete the initial layer of dentin. The sheath then fragments at varying times at different sites, thus promoting the irregular onset of cementum formation throughout the cervical circumference, which gives rise to an irregular contour and varying interrelationships among the tissues that compose the CEJ. Consequently, the relationship between cementum and enamel at the CEJ varies.

The CEJs in the present sample exhibited the three previously observed tissue interrelations and are therefore consistent with prior descriptions (5,7-10). Our result showing that an edge-to-edge relationship of enamel and cementum predominated (55.1% of the sample) accords with the results of other recent studies (5,7,9). Investigating the CEJs of freshly erupted premolars, Bevenius et al. (9) found that edge-to-edge contact of enamel and cementum was predominant (76%) and that a cementum over enamel relationship was present in 14% of the sample.

The rare occurrence of a fourth type of tissue interrelationship, i.e., enamel over cementum, is difficult to explain from an embryological standpoint, because cementum formation begins after enamel formation is completed. Muller and van Wyk (8) regarded this novel morphology as an optical illusion that arose due to the thickness of ground sections; however, Ceppi et al. (11) and Neuvald and Consolaro (10) reported a similar morphology in their SEM investigation of primary and permanent teeth.

The above observations indicate that there is considerable morphological diversity at the CEJ, both for any tooth type and for any individual tooth of a given type.

In the present series, we used light microscopy and ground sections of teeth to analyze the tissue interrelationship at the CEJ. The results are limited, however, by the use of ground sections, which enable analysis of only two focal points of the CEJ. Moreover, this technique does not allow examination of the entire circumference of the CEJ. Nonetheless, our findings are in agreement with those of other recent studies and offer further evidence that the distributions of the three mineralized tissues, and their relationships at the cervical region, are irregular and unpredictable.

The presence of gaps with exposure of dentin suggests that the CEJ is a site strongly predisposed to the development of pathological changes during clinical procedures such as placement of clamps, stainless steel crowns and restorative materials; utilization of dental instruments; and, especially, dental bleaching.

Dental bleaching has been reported to be associated with external root resorption (14,15). Although the exact mechanism by which bleaching induces external root resorption is not yet fully understood, it has been hypothesized that bleaching agents that penetrate open dentinal tubules can initiate inflammatory reactions that result in root resorption. Dentin sensitivity, too, has been reported to be a common consequence of tooth bleaching (15). The irregularity and fragility of the CEJ necessitate careful handling during clinical procedures involving this region, so as to avoid structural damage that could lead to dentin sensitivity and external root resorption.

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