Morphology of the Cementoenamel Junction of Primary Teeth

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ABSTRACT

Purpose: The purpose of this study was to investigate anatomically the cementoenamel junctions (CEJs) of primary teeth by observation of the morphological relationship among enamel, cementum, and dentin.

Methods: One hundred five human extracted primary teeth were analyzed by scanning electron microscopy. The teeth were divided into 7 groups, each with 15 primary teeth, as follows: maxillary central incisors (group 1); maxillary lateral incisors (group 2); maxillary canines (group 3); maxillary molars (group 4); mandibular incisors (group 5); mandibular canines (group 6); and mandibular molars (group 7). The entire cervical region was analyzed, especially concerning regularity of the CEJ, for establishment of the type of enamel-cementum relationship (cementum over enamel, the edge-to-edge relationship between cementum and enamel, and presence of gaps with exposure of dentinal tubuli).

Results: All circumferences represented by CEJs exhibit an interchange and combination of 3 types of relationships: (1) cementum over enamel; (2) enamel and cementum in the edge-to-edge relationship; and (3) the presence of a gap between the enamel and cementum with dentin exposure. There was no predominance as to the dental groups.

Conclusions: All primary teeth exhibited the 3 morphological tissue interrelation types along the circumference of the cementoenamel junction. The irregularity and fragility of cementoenamel junction structures indicate that this region is weak and should be handled with care and protected during application of chemicals and utilization of clamps, dental instruments, and restorative materials.

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The line formed by the cementoenamel junction (**CEJ**) represents the limit between the crown and the root of human teeth. The CEJ was initially studied by Choquet[1] and investigated by analysis of ground sections under light microscopy. The first comprehensive report on the morphology of the CEJ in all groups of permanent teeth by scanning electron microscopy (**SEM**) was published by Neuvald and Consolaro.[2] Several relationships between cementum and enamel may be observed along the CEJ of a single tooth, namely cementum over enamel, the edge-to-edge relationship, and the presence of gaps between the enamel and cementum, with microexposure of dentin.[2] From an embryological standpoint, superimposition of enamel over cementum is not possible. When observed in light microscopy studies, it is considered an optical illusion, according to Muller and van Vyk.[3] In 2006, Ceppi et al,[4] however, demonstrated some small and rare areas of enamel over cementum by SEM analysis. No systematic study has been conducted on the morphology of the CEJ in all groups of primary teeth so far; the reports available are limited to analysis of some specimens.[5-8]

In young adults, the CEJ of permanent teeth is covered by the gingival tissue and is in contact with the connective tissue's extracellular matrix.[9,10] After the third decade of life, continuous passive tooth eruption compensates for wear at the incisal and occlusal aspects. The CEJ is then

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located in the gingival sulcus.[11,12] This exposure to the oral environment may lead to dentin hypersensitivity upon ingestion of hot, cold, sweet, or salty foods. Tooth abrasion and erosion in adults are initiated after the CEJ is exposed to the oral cavity.

The CEJ of primary teeth also should be protected by the gingival connective tissue.[13] The continuous passive eruption and growth vectors of the jaws displace the primary teeth from their original position and expose the CEJ to the oral cavity of 6- to 10-year-old children.[13-16]

In the oral environment, the CEJ may be subjected to the action of chemicals from foods, oral hygiene products, and dental materials, especially tooth bleaching agents, widely used on permanent teeth and extending to primary teeth. Physical agents such as tooth-brushing, dental instruments, and clamps also may change the relationship between mineralized dental tissues at the CEJ, with important clinical consequences. Similarly, morphology of the CEJ also should be considered in cavity preparations and restorations.[10]

The purpose of this study was to evaluate the anatomy of the CEJ in primary teeth.

METHODS

This study's sample was obtained from a collection of teeth at the Bauru Dental School, University of São Paulo, Bauru, São Paulo, Brazil. The teeth were extracted at the Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Bauru, and at the Dental School of the University of Sagrado Coração, Bauru, after review and approval by the latter's Institutional Review Board. The teeth were extracted for orthodontic purposes, presence of caries, or pulp alterations, avoiding direct contact of surgical instruments with the cervical region, and maintained in physiological saline for 24 hours.

Excluded were teeth presenting failures in the integrity of the CEJ due to caries or restorations.

After analysis, a sample of 105 primary teeth was obtained. According to distribution by groups of teeth, the sample was divided into 7 groups containing: 60 maxillary specimens, consisting of 15 central incisors (group 1), 15 lateral incisors (group 2), 15 canines (group 3), and 15 molars (group 4); and 45 mandibular specimens, consisting of 15 incisors (group 5), 15 canines (group 6), and 15 molars (group 7). The mandibular central and lateral incisors, as well as the maxillary and mandibular first and second molars, were included in a single group due to the difficulty to achieve adequate specimens for analysis.

The specimens were prepared following the methodology described by Neuvald and Consolaro.[2] The teeth had their coronal root portions sectioned perpendicularly along their long axis with the aid of a double-faced diamond disc set (FGM – Joinvile/SC/Brazil) with a low-speed handpiece (Dabi Atlante – Ribeirão Preto/SP/Brazil) under constant cooling. It was possible to achieve specimens measuring nearly 0.5 cm high and containing the CEJ's contour throughout. The organic and inorganic material adhered to the specimens' surfaces was removed by immersion in an aqueous solution containing neutral shampoo (Colgate Palmolive Ltda – São Paulo/SP/Brasil) at a ratio of 4 mL/L for 30 days; the solution was changed every 7 days. After this step, the specimens were washed in tap water and immersed in 1% sodium hypochlorite solution for 1 hour to eliminate debris remaining from the previous procedure. Then, they again were washed in tap water, ultrasonicated Thornton T14 (INPEC Ltda – Vinhedo/SP/Brazil), in distilled water for 10 minutes, and dehydrated in solutions with increasing alcohol concentrations of 70º, 85º, 95º and absolute alcohol, in which they were kept in a plastic box, lined, and covered with a paper towel for 24 hours for drying.

The specimens were fixed on metallic cylindrical stubs measuring 1 cm long and 0.9 cm in diameter and numbered to enhance identification. Next, the specimens were protected with absorbent paper and placed under an indirect natural light source to improve dehydration. The specimens were sputter-coated with a 20-nm-thick layer of gold in a Denton Vacuum Desk II machine (Denton Vacuum – Moorestown/NJ/USA).

All aspects of the specimens were analyzed in a scanning electron microscope Jeol JSM-T 220A (Jeol Ltda – Tokio/Japan), set at 15 kV, and photographed with black and white film Neopan 120SS, Fuji Photo Film (Manaus/AM/Brasil), with a camera Mamiya 6 x 7 cm MRH (Mamiya – Elmsford/NY) connected to the microscope.

All of the cervical region was analyzed, especially concerning the regularity of the CEJ line and the establishment of the enamel-cementum relationship. The CEJ was considered regular when a linear contour was observed without a zigzag or zipper-like aspect.

The images were initially read at X35 magnification, considering each tooth aspect. Next, higher magnifications of X100 and X2,000 were used to evaluate the entire region, assessing the different relationships observed between enamel and cementum at the cervical line. All CEJ types found in each specimen were recorded (ie, 1 specimen could present records of the 3 types of junction.

The association between the occurrence of aspects with gaps and groups of teeth was evaluated by the Goodman test for contrast among and within multinomial populations.[12] To indicate the significancy (P<0,05), capital and lower case fonts were placed beside the occurance proportions. All discussions were made at the 5% level of significancy.

RESULTS

The CEJs of all primary teeth groups were morphologically similar, without specific characteristics. The CEJ was linear and uniform in some areas, yet presented repeated mild undulations in others. In many specimens, the undulations were anfractuous and presented marked twisting, leading to the formation of cementum and enamel islets. In some teeth, the CEJ undulations were small and repeated, simulating a zipper-like appearance.

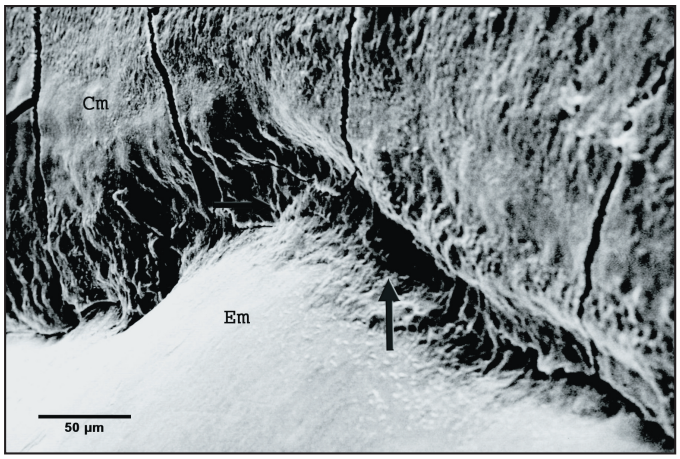

Figure 1. Scanning electron microscopy image of cementum (Cm) over enamel (Em) at the cementoenamel junction of a primary maxillary canine. The line formed by the junction presents an anfractuous and irregular trajectory, sometimes with a zipper-like appearance.

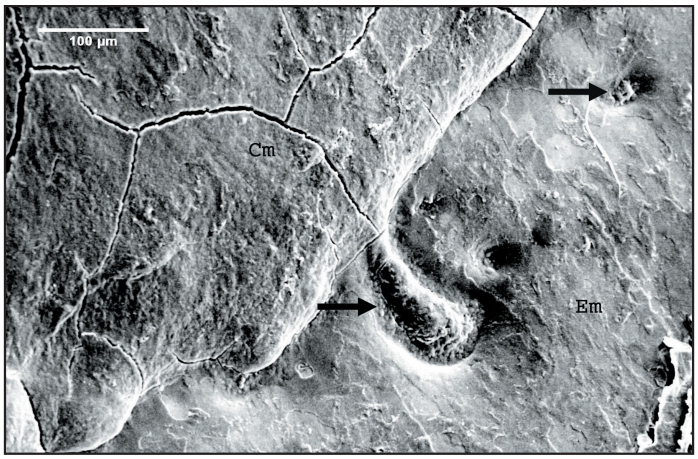

Figure 2. Scanning electron microscopy magnification of the cementoenamel junction of the primary maxillary canine featured in Figure 1, exhibiting cementum (Cm) over enamel (Em).

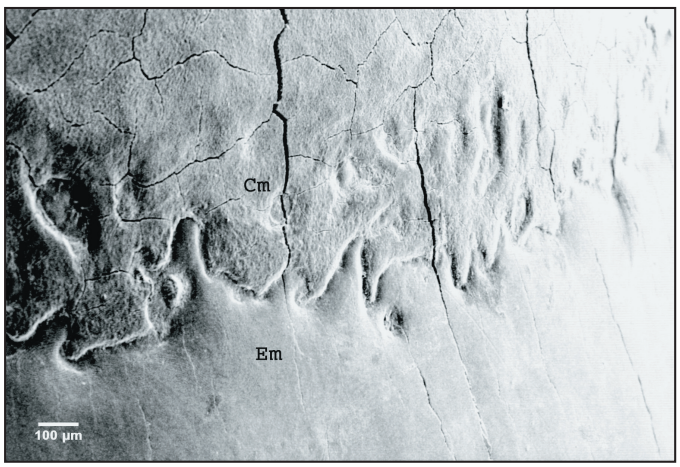

Figure 3. Scanning electron microscopy image showing aspects of the cementoenamel junction of a primary mandibular molar, exhibiting cementum (Cm) over enamel (Em) covering the end line of enamel.

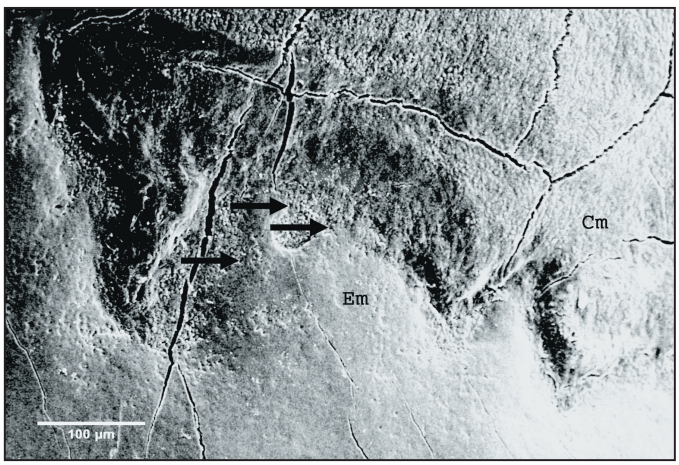

Figure 4. Scanning electron microscopy image showing cementum (Cm) covering the enamel (Em) in a primary mandibular canine, despite the fact that some primary teeth exhibit a depression on the cementoenamel junction.

The CEJ presented 3 different relationships in all primary teeth: cementum over enamel (Figures 1-4); juxtaposition or edge-to-edge relationship between cementum and enamel (Figures 5-8); and presence of gaps between cementum and enamel, leading to areas of dentin exposure (Figures 9-12). All 3 relationship types were found throughout the CEJ contour in every tooth (Table 1).

From an embryological standpoint, odontogenesis does not explain a fourth possible type of CEJ, namely enamel over cementum. Cementogenesis is initiated after completion of enamel formation. Aspect of enamel over cementum may be observed in ground sections, according to the thickness and direction of sectioning. Muller and van Wyk[3] demonstrated that, in fact, this is caused by optical illusion. Conversely, in 2006, Ceppi et al[4] observed rare micro regions of enamel over cementum during SEM analysis of primary teeth. Our results did not reveal any images compatible with this fourth CEJ type.

The results revealed no differences in the number of gaps in any of the tooth aspects. There also was no statistical difference in the number of gaps among the groups of primary teeth (Table 2).

The cementum over enamel relationship was topographically predominant in SEM analysis of all teeth and was observed at most CEJ regions (Figures 1-4). The edge-to-edge relationship also was observed in shorter or longer segments, yet it was not predominant throughout the extent of the junction. The limit of cementum tissue was thin or beveled, especially in regions with gaps (Figures 9, 10, and 12).

The gaps or areas of dentin exposure usually represented irregular focal points (Figure 12) with variable size and shape, which eventually formed strips along the CEJ (Figures 10 and 11). The limits of the gaps were often difficult to distinguish (Figure 9). Gaps were observed in most aspects (Table 2). The number of aspects with gaps was statistically significant, according to Goodman's test.[12]

This test further revealed no statistical difference in the number of aspects with gaps according to the groups of primary teeth, as demonstrated in Table 3.

At the bottom of the gaps, the dentinal tubuli were clearly opened on the surface (Figure 10). Often, however, they were partially covered by a delicate material, probably representing thin layers of intermediate cementum (Figure 4).

The root surface's cementum presented "cracks," which are considered a normal aspect in SEM analysis due to dehydration during preparation of specimens. These cracks were shallow and showed a thin layer of cementum.

Thirty-nine specimens presented cervical foramina, regardless of the tooth group and CEJ type. Four specimens exhibited microregions of external cervical resorption without direct involvement of the CEJ. One specimen presented preservation of the CEJ in its remaining structure, yet the junction was involved by physiological root resorption, which did not impair analysis of the structures. Other 3 specimens demonstrated multiple regions of root resorption irregularly distributed on the cervical surface as part of physiological root resorption, many of which were close but did not involve the CEJ, nor altered the results achieved.

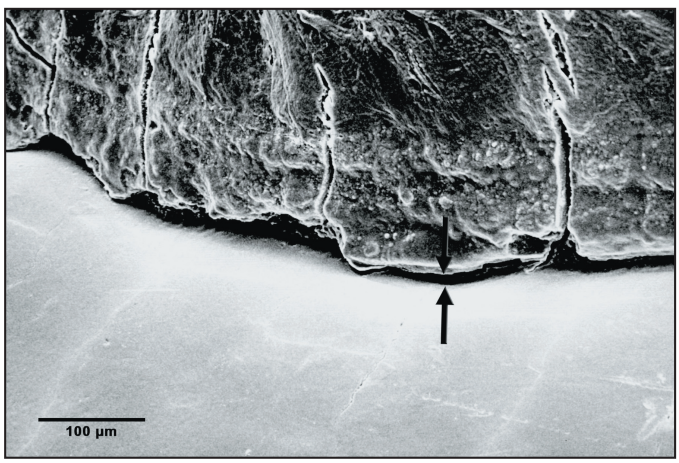

Figure 5. Scanning electron microscopy image of the edge-to-edge relationship (arrows) of cementum (Cm) and enamel (Em) at the cementoenamel junction of a primary central incisor).

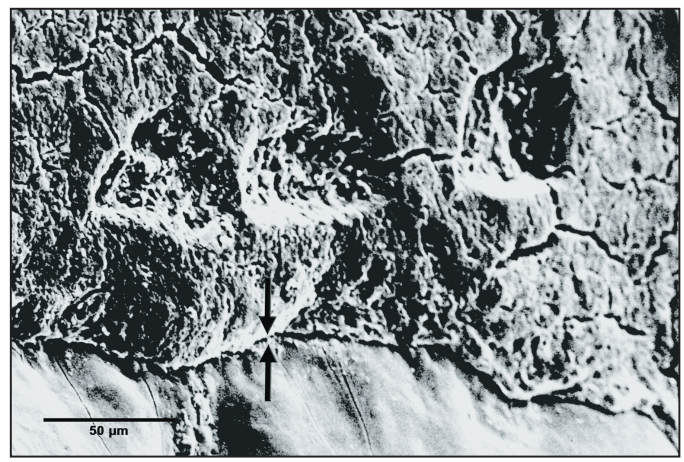

Figure 6. Scanning electron microscopy image showing aspects of the edge-to-edge relationship (arrows) on the cementoenamel junction of a primary central incisor.

Table 1. Distribution of the Cementoenamel Junction Type in 105 Primary Teeth Divided According to Tooth Group and Analyzed by Scanning Electron Microscopy

Group no.	Primary teeth	N	Junction type*		
			C/E	E/E	Gaps
1	Maxillary central incisor	15	x †	x	x
2	Maxillary lateral incisor	15	x	x	x
3	Maxillary canine	15	x	x	x
4	Maxillary molar	15	x	x	x
5	Mandibular incisor	15	x	x	x
6	Mandibular canine	15	x	x	x
7	Mandibular molar	15	x	x	x
Total		**105**			

** C/E+cementum over enamel; E/E=the edge-to-edge relationship; gaps=presence of gaps between cementum and enamel.*
† X= Presence

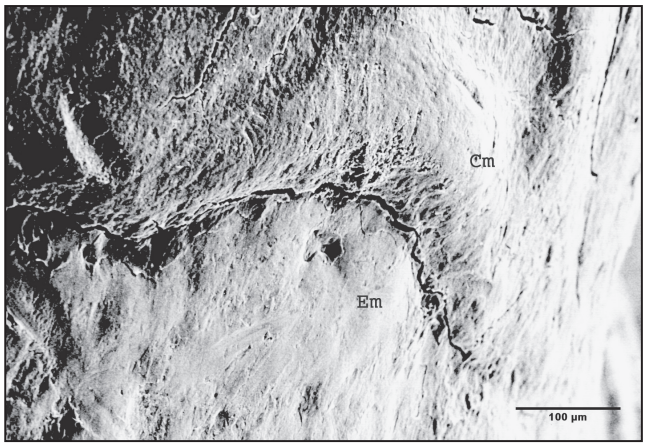

Figure 7. Scanning electron microscopy image showing a well-defined, irregular line demarcated by the edge-to-edge relationship between enamel (Em) and cementum (Cm) on the cementoenamel junction of a primary central incisor.

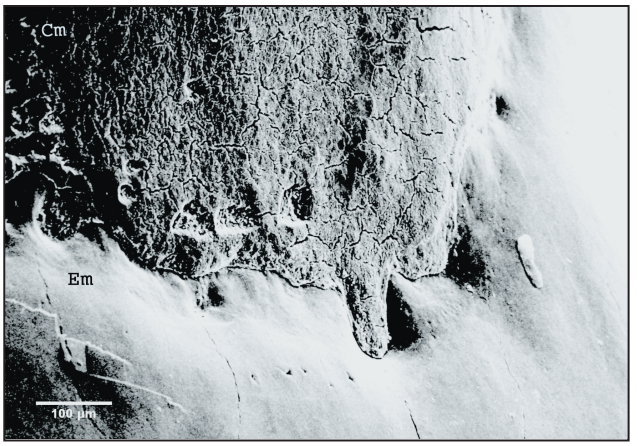

Figure 8. Scanning electron microscopy image showing large invaginations of cementum into the enamel and vice-versa on a primary central incisor. This is mainly detected in the presence of the edge-to-edge relationship between enamel (Em) and cementum (Cm) on the cementoenamel junction.

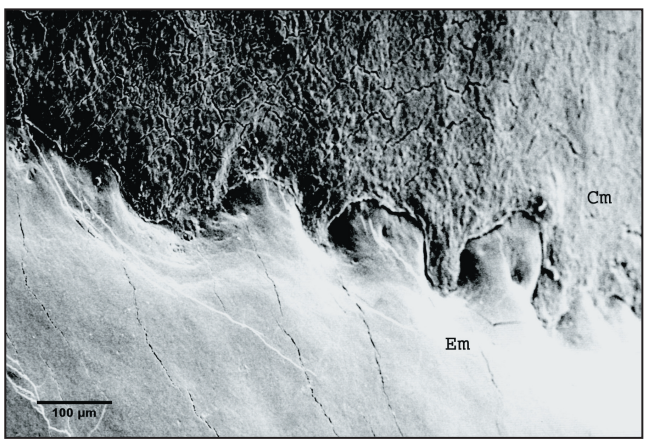

Figure 9. Scanning electron microscopy image of gaps at the cementoenamel junction of a primary maxillary molar. Note the true groove or depression (arrow) between cementum (Cm) and enamel (Em).

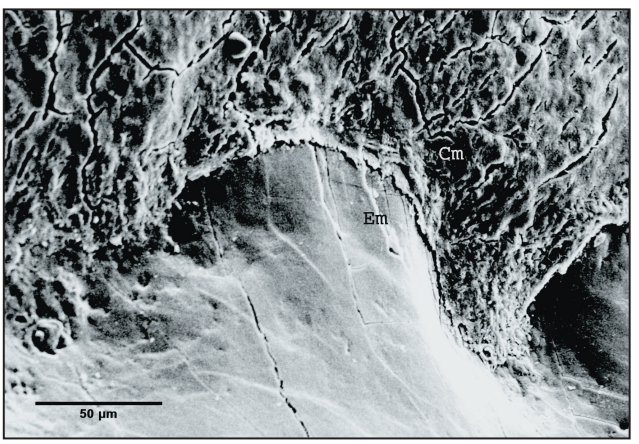

Figure 10. Scanning electron microscopy image of a primary maxillary canine showing gaps with regions of dentin exposure between enamel (Em) and cementum (Cm) exhibiting many openings of dentinal tubuli (arrows).

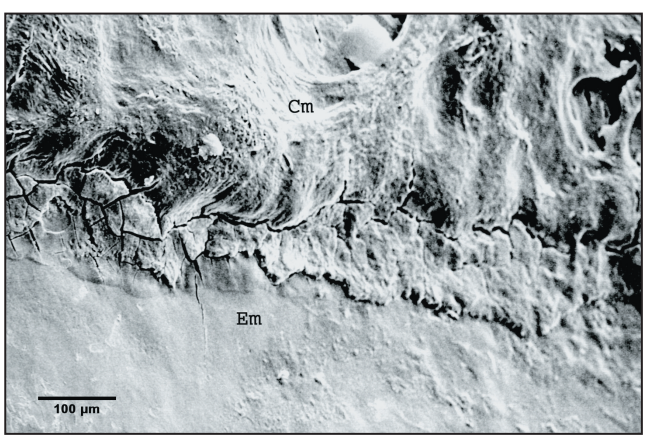

Figure 11. Scanning electron microscopy image of gaps at the cementoenamel junction of a primary maxillary canine forming an anfractuous line between enamel (Em) and cementum (Cm) along the cervical circumference.

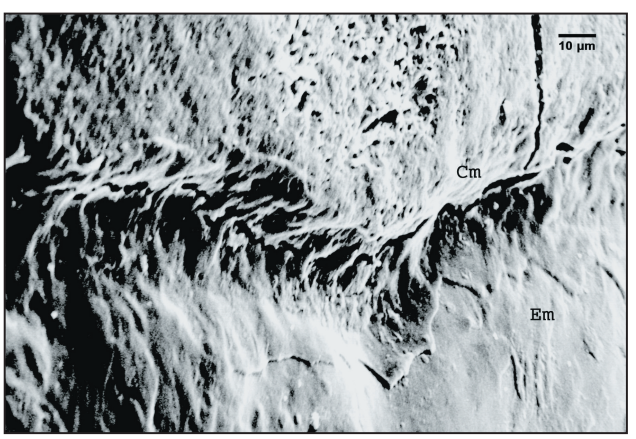

Figure 12. Scanning electron microscopy image of invaginations and islands (arrows) with cementum (Cm) observed in cervical enamel (Em) on the cementoenamel junction of a primary mandibular incisor.

Table 2. Distribution of the Cementoenamel Junction Type With Gaps and Exposure of Dentin According to the Aspect in 105 Primary Teeth Analyzed by Scanning Electron Microscopy

Group no.	Primary teeth	Aspects analyzed (N)				Teeth with gaps (N)
		Mesial	Distal	Buccal	Lingual	
1	Maxillary central incisor	13	14	13	14	15
2	Maxillary lateral incisor	15	13	12	14	15
3	Maxillary canine	13	14	15	13	15
4	Maxillary molar	14	13	15	14	15
5	Mandibular incisor	13	12	13	14	15
6	Mandibular canine	13	14	14	12	15
7	Mandibular molar	15	14	15	13	15
	Total (%)	**96 (91)**	**94 (90)**	**97 (92)**	**94 (90)**	**105 (100)**

Table 3. Distribution of the Aspects of Teeth With Cementoenamel Junctions Containing Gaps Among Primary Tooth Groups According to the Goodman Test*

Groups	No. of aspects with gaps (%)		Total
	+	–	
1	54 (90)aB	6 (10)aA	**60**
2	54 (90)aB	6 (10)aA	**60**
3	55 (92)aB	5 (8)aA	**60**
4	56 (93)aB	4 (7)aA	**60**
5	52 (86)aB	8 (14)aA	**60**
6	53 (88)aB	7 (12)aA	**60**
7	57 (95)aB	3 (5)aA	**60**
Total of aspects	**381**	**39**	**420**

** P<.0145 The horizontal rows compare the significance of aspects with and without gaps (different capital letters among columns=statistical significance). The vertical columns compare the significance of presence of gaps among the groups of primary teeth (lowercase letters among lines=no statistical difference).*

DISCUSSION

The CEJ is not a uniform line with a mild and regular contour, but a complex line, with a linear and regular trajectory. In the odontogenesis of primary and permanent teeth, all 3 types of relationships between the enamel and cementum at the cervical region may occur: cementum over enamel, the edge-to-edge relationship between enamel and cementum, and gaps between enamel and cementum with dentin exposure.[2]

The enamel deposition does not cease simultaneously along the entire tooth circumference. In the tooth bud, regions where enamel formation is completed, the cervical region gives rise to Hertwig's epithelial root sheath, composed of 2 epithelial layers derived from the external and internal epithelia of the enamel organ. The sheath is irregularly fragmented in time and space as it promotes cementum deposition on the newly formed dentin.[9] After this fragmentation, Hertwig's epithelial root sheath also participates in cementogenesis and formation of the periodontal ligament, giving rise to the epithelial rests of Malassez.[9] This irregular fragmentation of Hertwig's epithelial root sheath yields an equally irregular limit of cervical enamel and an irregular onset of formation and deposition of cementum. Consequently, the relationship between cementum and enamel at the CEJ presents an irregular contour, as observed during SEM of the primary teeth.

Fragmentation of Hertwig's epithelial root sheath and exposure of dentin covered by a thin layer of intermediate cementum are fundamental for the onset of cementogenesis. If Hertwig's epithelial root sheath is not fragmented, there will be enamel deposition and it will be transformed into reduced epithelium, thus preventing cementum deposition on its surface.[9] Our analysis did not reveal areas of enamel over cementum, as described by Ceppi et al,[4] in rare micro areas of primary teeth.

The early report on the CEJ by analysis of ground sections of 29 teeth, conducted by Choquet,[1] was followed by Thorsen[18] on 45 teeth. Their results were limited, however, in that ground sections only allow analysis of 2 focal points, whereas SEM enables analysis of the entire extent of the CEJ. In studies by Choquet[1] and Thorsen,[18] dentin gaps were observed in 28% and in 5% to 10% of permanent teeth examined.

All primary teeth in this study presented the 3 known types of morphological relationships between enamel and cementum at the CEJ. A report by Akai et al[5] indicated that the CEJ in primary teeth had an irregular contour, yet there was no description on the relationship among enamel, cementum, and dentin. Conversely, Leonardi et al,[7] analyzing only the buccal aspect of 25 primary teeth with no division in tooth groups, reported a predominance of cementum over enamel compared to the edge-to-edge relationship. They did not, however, observe gaps with dentin exposure in any specimen. These different results may be explained by limitations in the samples analyzed by these authors.

Investigating the CEJ of primary teeth, Carvalho et al[8] described that 47% of teeth presented cementum over enamel, 41% exhibited the edge-to-edge relationship, and 12% presented gaps between enamel and cementum. According to the results in percentages reported by these authors, no primary tooth presented more than one type of relationship between enamel and cementum. Considering the odontogenesis, it is difficult to assume that Hertwig's epithelial root sheath may be uniformly or linearly fragmented throughout the cervical circumference, giving rise to a single type of relationship between enamel and cementum. In the present study, all primary teeth exhibited the 3 known types of relationships between enamel and cementum, regardless of the aspect (Table 1), including the presence of gaps with dentin exposure, as previously demonstrated in permanent teeth.[2] These findings agree with Grossman and Hargreaves' statement[19], that is, the distribution of the 3 hard tissues and their relationships at the cervical region of teeth are irregular and unpredictable.

The greater exposure of the CEJ of primary teeth to the oral environment is related to more than tooth attrition. Bimstein et al[15] reported that facial growth increases the distance between the CEJ and the alveolar bone crest in a specific manner. Even if the primary teeth do not present incisal wear, the CEJ is exposed to the oral environment with the increase of age.

As demonstrated by Furseth,[20] the cementum of human primary teeth is very similar to the cementum of permanent teeth, considering analysis by transmission electron microscopy, radiomicrography, and light microscopy. We observed, however, that primary teeth present a smaller number of incremental lines and have a thinner cementum. Thus, it may be inferred that proportion was the only difference between the cementum of primary and permanent teeth. In the present study, SEM analysis revealed similar characteristics among permanent teeth. The surface cracks inherent to the preparation of specimens for analysis, however, were shallower. The smaller thickness of cementum and possibly of enamel may allow the passage of a greater amount of chemicals, including bleaching agents, when applied both externally and internally in primary teeth.

The presence of gaps with dentin exposure in all junctions of primary teeth indicates the need for special care upon placement of clamps, wedges, and stainless steel crowns, application of restorative materials, utilization of extractors and gingival retractors, surgical curettage at the cervical region of unerupted teeth, trauma, and specifically during internal and external tooth bleaching. Even though these procedures are routinely performed in the dental clinic, special care should be taken with the CEJ to avoid dentin hypersensitivity and external cervical resorption.

CONCLUSIONS

Based on this study's results, the following conclusion can be made: all primary teeth presented 3 morphological types of tissue relationships along the circumference of the cementoenamel junction: cementum over enamel, the edge-to-edge relationship, and gaps with dentin exposure.

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