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Comparative morphological analysis of the root developmental groove with the palato-gingival groove

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The palato-gingival groove is an anomaly of shape that modifies dental tissues organization while the developmental root groove is described within normal root anatomy. The morphology of dental tissues in relation to the presence of the developmental root groove has not been properly described. This study analyzed microscopically the morphology of dental tissues related to the root developmental groove comparing it with that presented on teeth affected by palato-gingival groove. Many similarities were observed such as the increased cementum thickness, decreased dentin thickness, pulp compartment surface alteration, irregularity of the dentin–cementum junction and of the cementum surface. These results suggest a common determining factor to this structure organization pattern. It is possible that the palato-gingival groove could be the result of an alteration of genetic mechanisms, rather than a dental germ folding, determined by privation of space, as previously hypothesized.
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Introduction

The palato-gingival groove, first described by Black (1908) has been considered as a type of anomaly of shape, which occurs after the embryonic period; alternatively, it may be an ectopic anomaly, if classified by the organization of the involved tissues. Its prevalence is high, i.e. between 1.58 and 8.5%, independently of race or sex. The most frequent tooth affected by the palato-gingival groove appears to be the lateral maxillary incisor (Pindborg, 1970; Pécora and Cruz Filho, 1992). Its occurrence, although less frequent, at several locations on different teeth (Pindborg, 1970) diminishes the probability of a theory to explain its formation: Atkinson (1943), suggested that an imbalance in growth between different areas of the maxilla would deprive the lateral incisior dental germ of adequate space in which to develop, thus the palato-gingival groove would be a consequence of dental germ folding. On the contrary, some authors believe that this anomaly could possibly be an indication of an attempt at supernumerary root formation (Goon *et al*, 1991).

The root developmental groove is described within normal root anatomy of mandibular incisors and both maxillary and mandibular premolars. The morphology of the dental root is determined by the cervical loop and Hertwig epithelial sheath, as it migrates to the apex. The folding of cervical loop is related to root developmental grooves and the complete separation of roots. Wheeler (1965) described it as the root continuity of a depression, which initiated on the proximal faces, from the medial to the cervical third, on the crowns of first maxillary premolars. This depression would extend up to the root bifurcation. On single-rooted teeth, the depth of the root developmental groove varies and, in some cases, precedes root bifurcation. Sicher and Dubrull (1991), commented that the deep groove on the first maxillary premolar roots suggested the arrest of the developing process of root separation. Other authors have described the root morphology of teeth presenting the root developmental groove by a passing reference to its presence and without performing a detailed analysis (Berkovitz *et al*, 1978; Figun and Garrino, 1994). The investigation of dental tissue structure in relation to the root developmental groove might reveal information to aid understanding of its formation and possibly demonstrate a morphological similarity with the structure of the palato-gingival groove, offering a clue towards a common determining factor for this pattern of structural organization.

The aim of this study was to analyze the morphology of dental tissue structures in relation to the presence of root developmental groove and to compare it with that of the palato-gingival groove, previously described by Lara *et al* (2000) and finally, an attempt was made to correlate these observations to palato-gingival groove etiopathogenesis.

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Materials and methods

Fifteen teeth presenting the root developmental groove were selected from the collection of human teeth of the Human Anatomy Course of the Federal University of Mato Grosso do Sul, Brazil. Mandibular teeth comprised: one central incisor, one lateral incisor, five canines and one first premolar. Maxillary teeth comprised: two first premolars and five second premolars.

All teeth were prepared for microscopic analysis as follows. Initially, the teeth were embedded in epoxy resin (Redelease®, São Paulo, Brazil) to provide small rectangular blocks for sectioning with a diamond knife (Isomet Buehler, Lake Bluff, IL, USA), which resulted in sections of 1.0–2.0 mm thick. The sections were manually abraded with wet sandpaper of decreasing coarseness (nos 150, 400, 500 and 600: Norton, São Paulo, Brazil) down to a thickness of 60 or 90 μm, as controlled by a digital micrometer (Digimatic, São Paulo, Brazil). The sections were kept between wet sandpapers fitted to a small piece of wood and to a glass slice (size $12 \times 3.0 \times 1.0$) so that the fragments could be ground against them in a back-and-forth motion under constant irrigation. Next, each identified section was immersed inside an individual bag made from folded gauze, sewed together, to hold the section in place and kept under running water for 24 h to eliminate the residue resulting from the grinding. Finally, the sections were allowed to dry at room temperature for 48 h, removed from the container and mounted with Canada Balsam, as described by Lara *et al* (2000).

The structure of the dental tissues was analyzed using a light microscope (Carl Zeiss, Jena, Germany) to verify the organization of dental tissues, the morphology of the pulp compartment and the root surface. Dentin and cementum thickness, regularity of the cement–dentin junction and cementum surface were observed. The type of cementum, the presence of interglobular dentin and the irregularity of dentin tubules were also analyzed. These microscopic characteristics were recorded on charts and the results were compared with those obtained by Lara *et al* (2000) while studying the palato-gingival groove morphology.

Results

Microscopic observation of the sections revealed the presence of the root developmental groove on both surfaces of 14 dental roots examined. There was one example in which the root developmental groove was on the mesial surface of the root. The depth of the root developmental groove varied. Nine examples showed a very deep groove. Twelve presented separation of canals, at the apical third. Fusion by cement was identified in six root apices. Cementum thickness was almost always increased (14 of 15 teeth) in the area adjacent to the root developmental groove (Figures 1–4). As the groove depth increased, so did cementum thickness (Figure 3). The most frequent type of cementum found in groove areas was the cellular mixed stratified cementum (Figures 1–4), even over the root

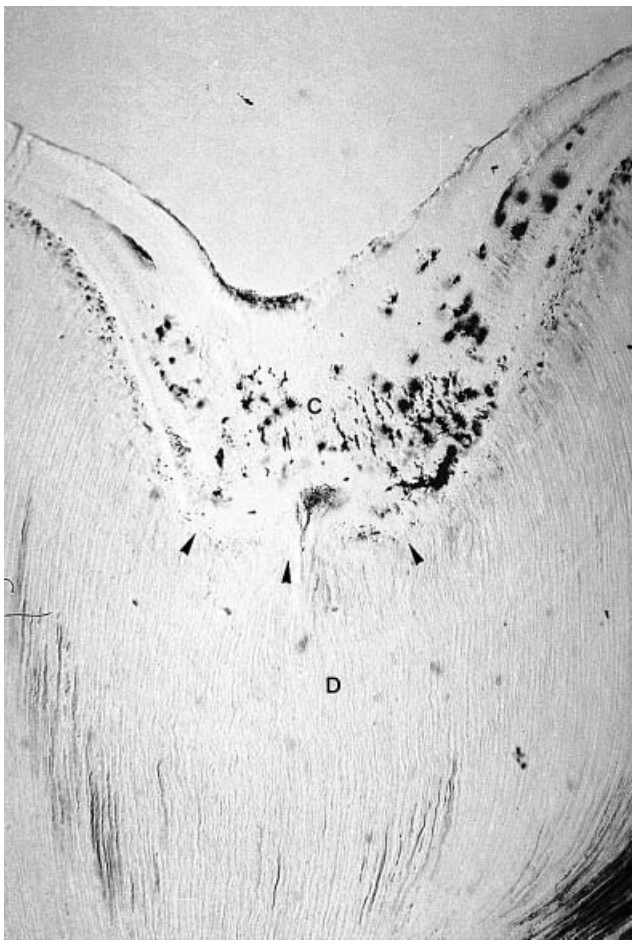

Figure 1 Increased thickness of cementum, decreased thickness of dentin, cement–dentin junction irregularity (arrows) and presence of stratified mixed cementum. C, cementum; D, dentin (magnification ×100)

developmental groove in cervical areas, where the remaining part of the root surface was covered with acellular cementum. The surface of the cementum was most commonly irregular in the root developmental groove area (nine of 15 teeth).

The cement–dentin junction was altered in the majority (12 of 15) of the sample (Figures 1, 2 and 4), especially in those areas were the groove was pronounced, in the areas prior to root bifurcation (Figure 4a,b) and related to fusion by cement. In these areas, the cement–dentin junction appeared to be interrupted.

Dentin thickness was diminished in the areas related to the root developmental groove (Figures 2–4a). The structure and disposition of dentin tubules was altered in areas related to the groove (Figures 2 and 4a). Dentin thickness on the area adjacent to the palato-gingival groove was also decreased in all cases. Interglobular dentin was not identified. The contour of pulp cavity periphery tended to reach the root surface, but was mainly a reflection of the cement–dentin junction (Figure 4a). As the depth of the groove increased, so the pulp periphery contour also was altered. Deformation of the pulp cavity periphery contour was identified in more than half of the samples (9 of 12).

Figure 2 Increased thickness of cementum, decreased thickness of dentin, cement–dentin junction irregularity (arrows), alteration of dentin tubules structure and distribution (*). Presence of stratified mixed cementum. C, cementum; D, dentin (magnification ×50)

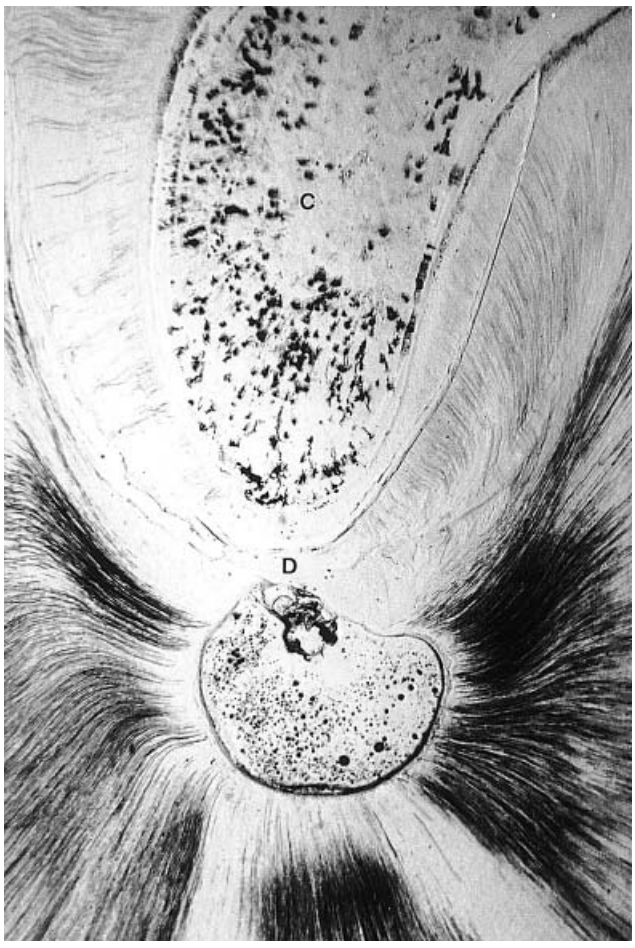

Figure 3 Decreased thickness dentin and presence of stratified mixed cementum. C, cementum; D, dentin (magnification ×50)

Discussion

Similarities were observed in the related dental tissues of teeth presenting developmental root grooves when analyzed and compared with those described for the palato-gingival grooves (Lara *et al*, 2000). A comparison of these morphological aspects is presented in Table 1.

Variation of groove depth, an increase of the cementum layer, decrease of dentin thickness, altered structure and distribution of dentin tubules, discontinuity of the cement–dentin junction, surface cementum irregularities and alteration of the pulp cavity contour in the areas related to the groove were observed in both root developmental groove and palato-gingival groove (Lara *et al*, 2000), although those related to the latter were sometimes more marked. Cementum and dentin discontinuity were not observed in the root developmental groove sections analyzed, but were previously described on palato-gingival groove examples, as well as communication with the periodontum (Lara *et al*, 2000).

Unexpectedly, the presence of cellular and stratified (Bosshardt and Selvig, 1997) cementum was observed in this study on the surface related to the root developmental groove of three canines and one incisor. This type of cement was also described in the dental structures related to the palato-gingival groove (Lara *et al*, 2000). It has been postulated that the cellular type of cementum is not present on incisor root surfaces (Bosshardt and Selvig, 1997; Ten Cate, 2001), which suggests a correlation between its presence and the events related to the formation of grooves, requiring complementary studies.

This morphological correlation between the root developmental groove and the palato-gingival groove permits an assumption in relation to the etiopathogenesis of the latter. It has been suggested that an undesirable position of the maxillary lateral incisor dental germ, surrounded by the central incisor, canine and the premolar, during maxillary growth, leads to a dental germ folding and the formation of the groove (Atkinson, 1943).

First of all, it must be considered that other teeth might also be affected by the palato-gingival groove (Benenati, 1985). Then, an analysis of the growing dental germ surrounding tissues should be taken into account in a discussion of the theories of palato-gingival groove etiopathogenesis. Cellular mediators are involved in bone remodeling events and also are produced as

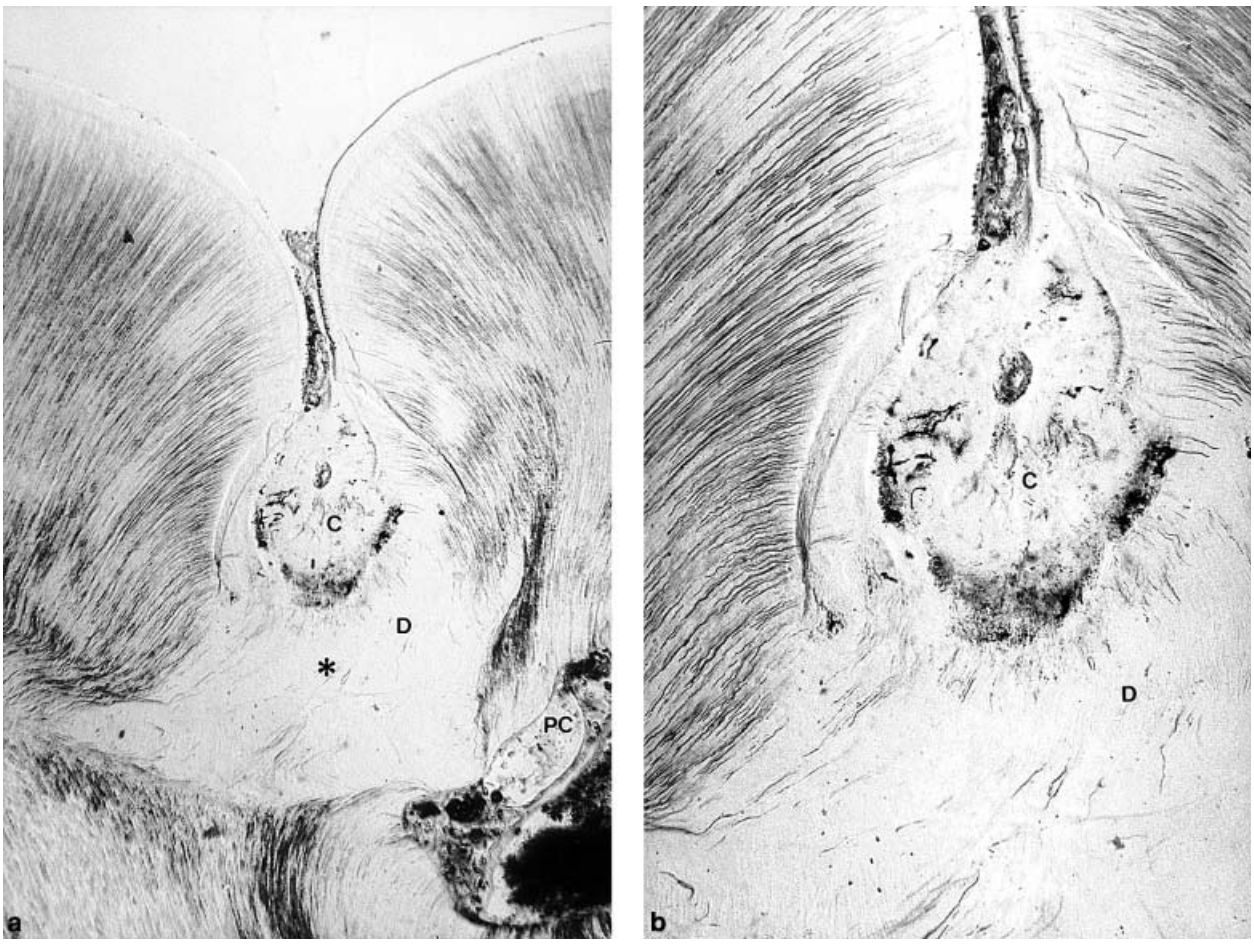

Figure 4 Microscopic aspects of dental tissues related to root developmental groove just before root bifurcation. (**a**) Decreased thickness dentin, alteration of dentin tubules structure and distribution (*), alteration of pulp cavity superficial contour and presence of stratified mixed cementum. (**b**) cement–dentin junction irregularity. C, cementum; D, dentin; PC, pulp cavity (magnification **a** ×50, **b** ×100)

Table 1 Dental tissues microscopic aspects comparison between teeth presenting palato-gingival groove and root developmental groove

	Root developmental groove (%)	*Palato-gingival groove (%) (Lara et al, 2000)*
Cementum		
Thickness increased	93.33	92.31
Discontinuity	0	15.38
External surface irregularity	60	46
Cement–dentin junction irregularity	80	92.31
Dentin		
Thickness decreased	100	100
Discontinuity	0	15.38
Root pulp cavity		
External contour irregularity	60	69.23

a result of the transduction of a physical stimulus into a biological signal, or mechanotransduction (Young *et al*, 1997). Therefore, bone remodeling would occur constantly in response to growing forces, providing enough space for the growing dental germ. So, it is improbable that growth impulses in the maxilla would result in dental germ folding, determined by privation of space, as once postulated (Atkinson, 1943). Also, epidermal growth factor, produced by epithelial cells of the enamel organ, the cervical loop and Hertwig's root sheath, would participate as a local mediator inducing bone resorption (Lin *et al*, 1996; Shroff *et al*, 1996), assuring enough space for dental germ development.

Based on this interpretation of biologic events and the similarities of the dental tissue structures observed in both root developmental groove and palato-gingival groove it can be suggested that similar morphogenetic events might be involved in their formation and that the hypothesis postulated to support the palato-gingival etiopathogenesis must consider the interaction between tissues of dental germ and the molecular expression of their constituent cells. However, the interactions between Hertwig's epithelial sheath, the dental follicle and papilla have not been fully elucidated in root development (Thomas, 1995). In view of this, it has been difficult to predict if, how and when an altered genetic manifestation influences the events involved in formation of the palato-gingival groove. *In vivo* studies have yet to be done to determine the correlation of altered gene expression in dental germ cells with the

development of certain dental defects. It remains a challenge to verify if the palato-gingival groove is related to alteration of genetic mechanisms, similar to other anomalies of teeth, such as short root anomaly (Apajalahti and Pirinen, 1999), anodontia (Vastardis, 2000), oligodontia and others (Thesleff, 2000).

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