Root apical third and canal morphology of teeth with hypercementosis

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ABSTRACT

Objective: This study aims at studying the influence of hypercementosis over root and root canal morphology using different methods of observation (clearing technique, radiography, stereomicroscopy and optical microscopy). **Methods:** 130 teeth were selected for morphological comparative evaluation; all teeth were previously radiographed and stereomicroscopically evaluated. Out of these, 60 teeth with hypercementosis and 30 without it were selected for clearing technique evaluation. The analysis was based on aspects such as: type of hypercementosis; root canal number and configuration; root surface and presence of apical foramen and apical deltas. The remaining 20 teeth with hypercementosis were microscopically compared to 20 teeth with normal root formation by means of the Hematoxylin and Eosin (H.E.) staining technique, so as to study the cementum deposition pattern and morphological aspects of the root canal. The evaluation was performed by two examiners and submitted to Kappa agreement test. The data obtained was compared through non-parametric Kruskal-Wallis one-way analysis of variance test, and the Dunn test was applied for individual comparisons. **Results:** The root clearing examination showed higher frequency of club shaped hypercementosis (65%) followed by focal hypercementosis (35%). Teeth with hypercementosis showed significant increase in the presence of apical deltas (53.3%). A higher frequency of root canal constrictions (55%), and changes in the original root canal path (46.6%) were also observed. Microscopic evaluation supports the influence of hypercementosis over the morphological characteristics of root apical third formation. **Conclusions:** These findings show the existence of a complex root canal anatomy at the apical third of teeth with hypercementosis, which may hinder root canal treatment.

Keywords: Hypercementosis. Dental pulp cavity. Endodontics.

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Introduction

Hypercementosis is characterized by excessive deposit of cementum beyond the physiologic limits of the teeth, promoting an abnormal thickness of the apex that becomes round-shaped and/or with a macroscopically altered appearance.

The incidence of hypercementosis by race or population group has not yet been established. Gardner and Goldstein[1] studied the frequency of the phenomenon in 137 individuals, with 529 teeth being compromised by the process. Their study reported an average of 3.8 teeth with hypercementosis per individual, with a mean age of 47.3 years old and whose most affected teeth were the premolars. Another study demonstrated tooth root hypercementosis in 84% of a collection comprising 104 skeletons of Barbadian slaves from XVII to XIX centuries.[2] Additionally, root hypercementosis was found in 10 out of 54 specimens gathered from prehistoric coastal populations of Texas, USA.[3]

The etiology of hypercementosis is attributed to several conditions such as functional stress due to occlusion forces; continuous dental eruption; incorporation of periodontal cementicle during physiologic cementum deposition; inflammatory reactional deposition; as well as systemic factors such as atherosclerosis, acromegaly, arthritis, thyroid diseases and Paget's disease.[1-13]

Alterations in root morphology due to hypercementosis comprise club shape hypercementosis, which results from cementum deposition in all root surfaces; focal hypercementosis, globular cementum deposition in one of the root surfaces; and circular cementum hyperplasia (CCH), cementum lateral deposition on the root surface without affecting the apex.[14]

Hypercementosis does not radiographically alter the biologic space relationship between the root surface, periodontal ligament and the alveolar bone. Although hypercementosis can be identified through common radiographic techniques, the latter do not allow one to estimate the amount of extra cementum in the affected root since dentin and cementum have the same radiodensity.[1,15]

Microscopic studies of hypercementosis report thick layers of cementum characterized by deposition of symmetric, highly basophilic lines parallel to the dentinal surface. Occasionally, atypical cementum depositions are identified in focal areas as external cementum projections. The presence of blood vessels and nervous filaments associated with irregular apical cementum deposition can contribute to the formation of multiple foramina during cementum deposition resulting from hypercementosis, thus originating the apical deltas.[1,9]

The lack of recent studies related to this subject, added to potential endodontic implications, inspire the assessment of morphological differences in the apical third of the root and the root canal of teeth with hypercementosis. The present study applied different methods to perform these morphological observations and a comparative study was established among them in order to judge their diagnostic value.

Material and Methods

The 130 teeth examined in this study were selected from the teeth bank of the routine archives of one of the author's laboratory of Oral Pathology. The specimens were kept in 10% formalin solution, placed into small containers and labeled for identification. A consent for using human tissue was obtained from an Institutional Review Board.

In selecting the sample, the following diagnostic criteria were applied: cementum formation beyond the physiologic limits of the teeth, with changes in root morphology that could be macroscopically detectable. The sample comprised 80 teeth with hypercementosis and 50 without it. Out of these specimens, 60 teeth with hypercementosis and 30 without it were selected for analysis with the clearing technique. Out of the 40 remaining teeth, 20 with hypercementosis and 20 without it were selected for microscopic analysis.

The specimens with hypercementosis were additionally classified by means of stereomicroscopy according to their morphological characteristics, including the type of hypercementosis, the surface, the longitudinal root axis and the visualization of the apical foramen.

After this classification, the teeth were radiographed with a 70Kvp and 7,5mA x-ray device (Dabi-Atlante, SP, Brazil), with a 16-cm cone, during an exposition period of 0.5 seconds. The radiographic films used were Kodak Ultraspeed DF-58 (Eastman Kodak, NY, USA) and the radiographic developing process used was the temperature-time one during a 3.5-minute developing period.

The radiographs were examined by two independently trained observers using an X-ray viewer and magnifying lens (2X) in a dark room. The radiographic aspects of the alterations in root radiodensity between the cementum and the dentin at the apical third were considered.

Additionally, the morphological aspects of the root such as number, distribution and surface, as well as the direction, acquired due to hypercementosis, and root canal breadth at the apical third were also considered. The 50 teeth without hypercementosis were used as comparative basis.

The 90 teeth chosen for this part of the study (60 with and 30 without hypercementosis) were divided into groups of maxillary molars, mandibular molars, maxillary premolars, mandibular premolars, maxillary anterior teeth and mandibular anterior teeth. Each group comprised 10 teeth with hypercementosis and 5 teeth without it.

Access cavities were prepared and the teeth were immersed in 5% sodium hypochlorite solution for 24 hours, followed by ultrasonication (Ultrasonic bath, EM Scope lab Ltd, London, UK) to dissolve the pulp tissue. The teeth were dried and the root canal systems coronally injected with Indian ink (Windsor & Newton Indian Ink, London, UK) with a hypodermic needle (Sherwood Medical Company, St. Louis, MO, USA) apically assisted by vacuum suction. After that, self-cured resin was placed in the coronal access.

After another 12-hour period of drying, the teeth were decalcified in 5% hydrochloric acid for 48–72 hours, and the process was monitored by periodic radiography. The decalcified teeth were washed in running tap water for 4 hours and dehydrated in ascending concentrations of ethanol (60%, 70%, 80%, 90%, 95%) (MJ Patterson, Dunstable, UK) for 2 days, then rendered transparent by immersion in xylene and stored in methyl salicylate for observation (Pharmacos Ltd, Southend-on-Sea, UK).

After transparency was achieved, the specimens were observed by two independent investigators, other than those who evaluated the radiographs, using a light stereomicroscope with magnification set at 5X. They were asked to collect the data by means of a technique similar to that used for the radiographic analysis. The data collected by the observers working with the clearing technique were compared to those obtained from the radiographs.

All data obtained from the 90 teeth mentioned above were entered into a spreadsheet (Excel, Microsoft Corporation, WA, USA). The Kappa agreement test values between evaluators, with regard to the characteristics of root and root canal obtained by the radiographic method and the clearing technique, were computed. Root canal clearing was established as a standard for all morphological aspects studied.

Statistical analysis was carried out by means of the non-parametric Kruskal-Wallis one-way analysis of variance test which was used to determine if there were significant differences between the hypercementosis and no hypercementosis group. The Dunn test was applied for individual comparisons. Differences were considered significant at $P < 0.05$.

The 40 remaining specimens were divided into two groups: A = 20 teeth with hypercementosis; B = 20 teeth without hypercementosis, with 5 maxillary molars, 5 mandibular molars, 5 maxillary premolars and 5 mandibular premolars in each group. The root apical third of the specimens were sectioned for histochemical procedures using a carborundum sectioning disk. Demineralization was performed by means of 5% EDTA solution (pH 7.0). After being embedded in paraffin, the specimens were horizontally sectioned at 5 μm and stained with the Hematoxylin and Eosin (H.E.) technique.

The morphological comparative observation aimed at dentin and cementum root canals, the cementum deposition pattern, presence of lateral canal or apical deltas, presence of periodontal cementicles, incremental lines of cement as well as presence of internal or external root resorption.

Results

The data obtained from the interaction between morphological and radiographic findings; from stereomicroscopy and the tooth clearing technique applied to the different types of hypercementosis; as well as the root canal morphology in each dental group of affected teeth are shown in Tables 1 and 2. Tables 3 and 4 display the morphological findings obtained with the referred methods in teeth with and without hypercementosis as well as the root canal configuration of each dental group.

As for root morphology, out of the 60 teeth with hypercementosis studied by means of the clearing technique, 39 (65%) presented club shape hypercementosis, whereas 21 (35%) presented focal hypercementosis and none of them presented CCH. Kappa test results, comparing the radiographic and root clearing techniques, was substantial ($\kappa = 0.6$) with regard to the type of hypercementosis.

The root surface was found irregular in 86.6% of the teeth with hypercementosis and in 90% of the teeth without it. However, these irregularities were more easily detected through root clearing than through radiographic examination (κ = 0.2 and 0.1 respectively). Deformation of the root longitudinal axis was observed in 66.6% of teeth with hypercementosis and in 60% of teeth without it. This characteristic showed substantial concordance when the radiographic and root clearing techniques were compared (κ = 0.9 and 0.9 respectively).

The most distinguishable alteration during the comparison between teeth with and without hypercementosis was the high frequency of apical deltas in those with hypercementosis: 53.3% (n = 32) against 20% (n = 6) of teeth without hypercementosis. This morphological alteration was the only one that showed significant values (= 0.01) between groups and individual comparison. These apical deltas were only observed by means of the root clearing technique κ = 0 (Fig 1).

Table 1. Morphologic findings of the different types of hypercementosis in each dental group detected trough radiography, stereomicroscopy and tooth clearing technique analyses.

			Maxillary molar	Mandibular molar	Maxillary premolar	Mandibular premolar	Anterior maxillary teeth	Anterior mandibular teeth
Type	Club		9	4	8	9	2	7
	CCH		0	0	0	0	0	0
	Focal		1	6	2	1	8	3
Surface	Regular		1	3	1	0	1	1
	Irregular		9	7	9	10	9	9
Longitudinal axis	Normal		7	4	1	1	4	3
	Deformed		3	6	9	9	6	7
Apical foramen	Visible		10	10	10	10	10	10
	Non-visible		0	0	0	0	0	0
Dental resorption	Internal		0	6	3	3	1	4
	External	Apical	5	7	3	6	7	10
		Lateral	3	0	5	7	8	10

Table 2. Morphologic findings of root canal configuration in each dental group with hypercementosis detected trough radiography, stereomicroscopy and tooth clearing technique analyses.

				Maxillary molar	Mandibular molar	Maxillary premolar	Mandibular premolar	Anterior maxillary teeth	Anterior mandibular teeth
Root canal	Number and distribution	Single root canal		10	6	9	9	10	10
		Two root canals		0	4	1	1	0	0
		Lateral root canal		3	3	2	2	0	2
		Collateral root canal		5	3	5	6	5	4
		Apical delta		6	7	8	4	5	2
	Surface	Regular		3	1	2	4	4	3
		Irregular		7	9	8	6	6	7
	Root canal breadth	Continuous		5	2	5	6	6	4
		Constriction	Progressive	1	1	2	3	0	2
			Abrupt	4	7	3	2	4	4
	Direction	Same		4	7	6	7	5	5
		Modified	Mild	3	2	3	0	3	5
			Moderate	3	3	0	4	0	0
			Severe	0	1	0	0	0	0

Table 3. Morphologic findings of each dental group without hypercementosis detected trough radiography, stereomicroscopy and tooth clearing technique analyses.

			Maxillary molar	Mandibular molar	Maxillary premolar	Mandibular premolar	Anterior maxillary teeth	Anterior mandibular teeth
Surface	Regular		1	0	0	0	2	0
	Irregular		4	5	5	5	3	5
Longitudinal axis	Normal		1	2	1	3	2	2
	Deformed		4	3	4	2	2	3
Apical foramen	Visible		5	5	5	5	5	5
	Non visible		0	0	0	0	0	0
Dental resorption	Internal		0	0	0	0	0	0
	External	Apical	5	5	5	5	4	5
		Lateral	2	5	5	5	4	5

Table 4. Morphologic findings of root canal configuration in each dental group without hypercementosis detected trough radiography, stereomicroscopy and tooth clearing technique analyses.

				Maxillary molar	Mandibular molar	Maxillary premolar	Mandibular premolar	Anterior maxillary teeth	Anterior mandibular teeth
Root canal	Number and distribution	Single root canal		4	1	4	5	4	4
		Two root canals		1	4	1	0	0	1
		Lateral root canal		0	2	2	1	0	1
		Collateral root canal		1	3	4	1	1	2
		Apical delta		2	1	1	1	1	0
	Surface	Regular		2	0	0	0	2	0
		Irregular		3	5	5	5	2	5
	Root canal breadth	Continuous		2	5	4	3	4	4
		Constriction	Progressive	1	0	1	2	1	1
			Abrupt	2	0	0	0	0	0
	Direction	Same		2	1	4	4	5	5
		Modified	Mild	3	2	0	1	0	0
			Moderate	0	2	1	0	0	0
			Severe	0	0	0	0	0	0

Alterations in root canal breadth at the apical third of teeth with hypercementosis revealed abrupt constriction in the apical third of the root canal in 40%, or progressive constriction in 15%, of the 60 specimens evaluated ($\kappa = 0.2$ comparing the radiographic and root clearing techniques). The specimens without hypercementosis showed continuous root canal breadth at the apical third in 73.3% of the 30 teeth assessed ($\kappa = 0.3$ comparing the radiographic and root clearing techniques). In spite of these values, a relative difference among teeth with and without hypercementosis was revealed by the Kruskal-Wallis test (P = 0.5).

Changes in the original root canal path were found in 46.6% of the specimens with hypercementosis (28 specimens). Agreement between the radiographic and root clearing techniques was $\kappa = 0.3$. Teeth without hypercementosis kept the same path in 70% of the cases (21 specimens). Agreement between the radiographic and root clearing techniques was $\kappa = 0.1$. Comparison between groups with and without hypercementosis was P = 0.3. Figure 2 shows changes in root canal path of teeth with and without hypercementosis.

Microscopically, except for cementum thickness and distribution, the morphological aspects of both groups, A and B, showed similar incremental patterns of cementum deposition. In teeth with hypercementosis, the root canal presented spherical or oval horizontal sections just like the ones without hypercementosis did.

Some sections of group A showed irregularities on the root canal wall. Such irregularities were composed by disorganized dentin mixed with cemental tissue. In other instances, the cement root canal was clearly identified, characterized by cementum deposition surrounding the root canal compartment. External cementum deposition on root surface of group A presented a regular, slightly undulated, basophilic and concentric pattern in the majority of cases. Both cellular and non cellular cementum were present in groups A and B; additionally, the demarcating line between dentin and cementum did not always seem to be well defined. The presence of periodontal cementicles in teeth of group A could also be identified, given that they were adhered to the root surface or inserted into the cementum structure (Fig 3).

Numerous canaliculi were found in some of the specimens with hypercementosis. Considering the location, the presence of pulp cellular remnants and their relationship

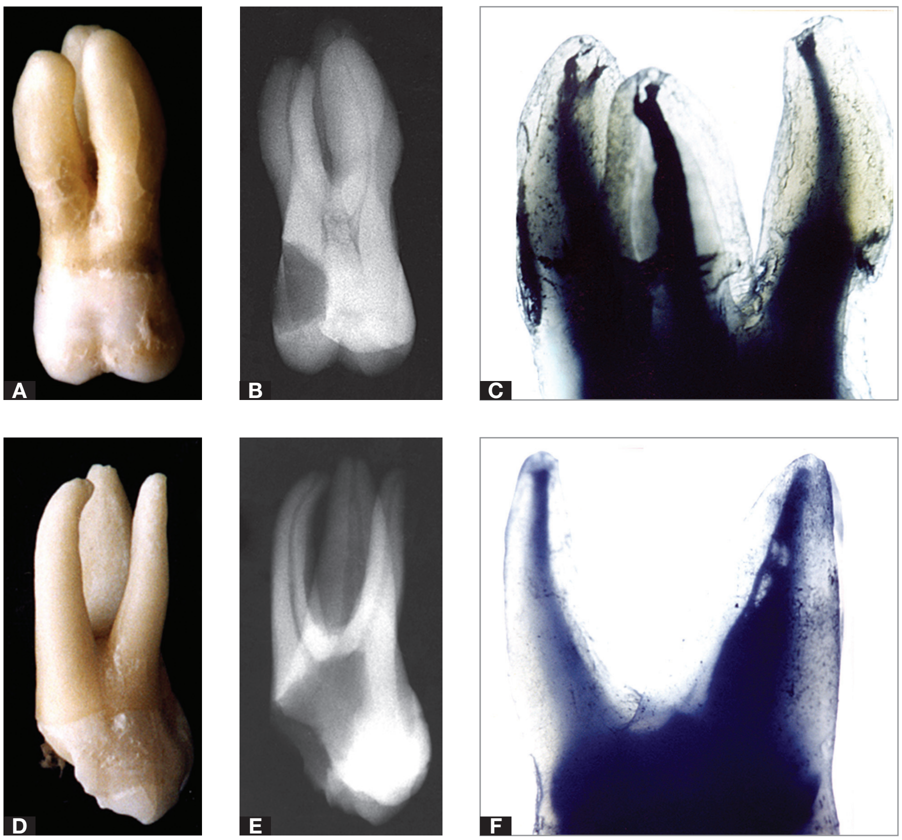

Figure 1. Comparative aspects of maxillary molars with hypercementosis (**A**, **B** and **C**) and without hypercementosis (**D**, **E** and **F**). Note the complex anatomy of the apical third of teeth with club shaped hypercementosis, only detectable through the clearing technique. Original magnification 5X.

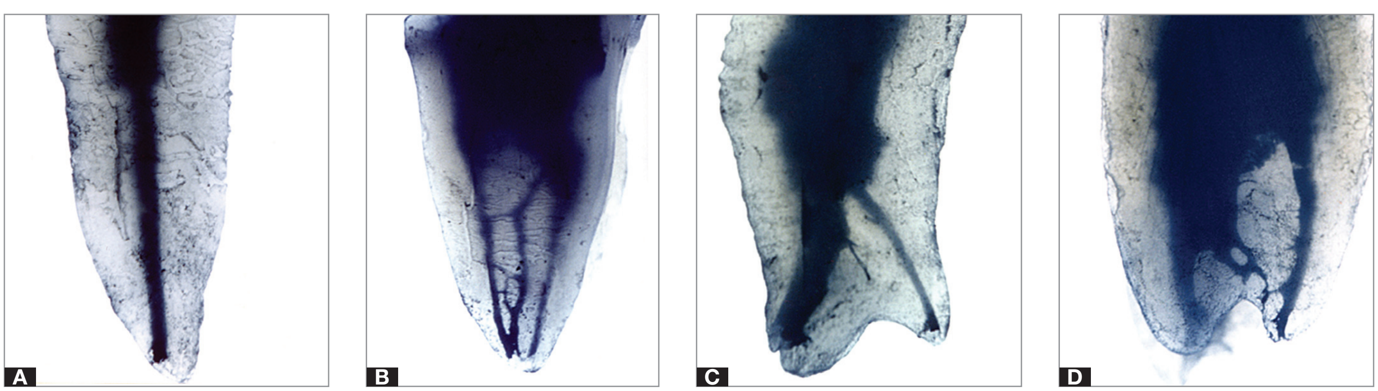

Figure 2. Differences between mandibular premolars and mandibular molars without (**A** and **B**) and with hypercementosis (**C** and **D**) observed through the clearing technique. The root canal path of the specimens without hypercementosis displays a regular trajectory. Original magnification 5X.

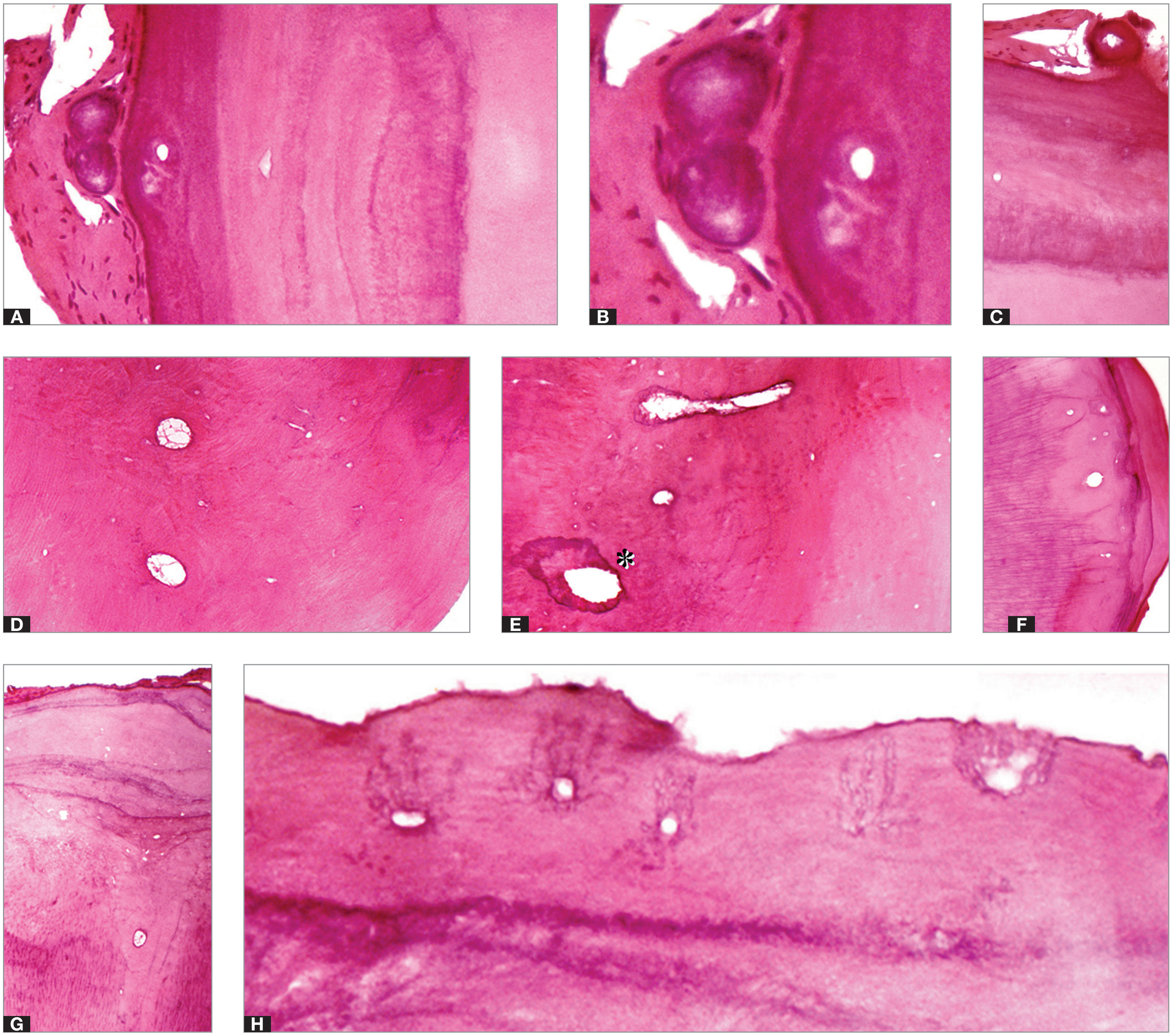

Figure 3. Microscopic aspects of hypercementosis. In **A** and **B,** the presence of cementicles closely related to cementum and included by cementum deposition, **C** shows a slight fusion between the cementum and the periodontal cementicle. Note in **D** and **E** the presence of canaliculi that might be part of apical deltas. One of the canaliculi in **E** appears partially obliterated with incremental lines of cementum deposition. The pattern of cemental deposition is highlighted in **F, G** (acellular cementum) and **H** (cellular cementum with innumerous cementoblasts). Original magnification: **A** = 16X, **B** = 400X, **C** = 160X, **D** and **E** = 40X, **F** and **G** = 16X, **H** = 160X (H.E. stain).

with the main root canal, it is reasonable to assume that these canaliculi might be part of apical deltas. In other instances, these canaliculi would appear obliterated with incremental lines of cementum deposition (Fig 3).

Discussion

The methods applied in this study intended to assess hypercementosis and its influence over root canal morphology from different points of view. The present radiographic data provided a perspective that is commonly found in endodontic practice; the method of canal staining and root clearing was found to be excellent for three dimensional evaluation of root canal morphology; and the microscopic evaluation enlightened the morphological aspects of cementum deposition and its relationship with root canal formation.

Radiographs alone have shown limited value when certain aspects of the root canal system are under study.[14,16]

The interaction between the different methods applied in the present study aimed at minimizing that limitation. The only feature, strictly related to hypercementosis, that achieved substantial concordance between the radiographic and tooth clearing techniques was the one regarding the type of hypercementosis ($\kappa = 0.6$).

The presence of deformations on the longitudinal axis of the root canal ($\kappa = 0.9$ with hypercementosis and 0.9 without it) also presented substantial agreement between tooth clearing and radiography, but similarly to the findings on root surface, very similar results were present when comparing teeth with and without hypercementosis. Therefore, it is reasonable to conclude that other factors probably influence the formation of the apical third of the root canal and promote deformations of the root canal longitudinal axis.[17]

Although the clearing technique is useful only as a teaching/research tool, with little or no clinical applicability, it was only by means of this technique that the high frequency of apical deltas could be detected. In addition to that, other interesting morphological findings were also considered in this study: the alterations in root canal breadth at the apical third and the changes in the original root canal path due to hypercementosis. Therefore, a clinical inference can be drawn from these findings: instrumentation of teeth with hypercementosis should take into account the possibility of a complex root canal anatomy at the apical third, even if it cannot be radiographically identified.

Other radiographic methods could provide more information to this study. The methodological impact of X-ray microtomography with high quality reconstructions of the external and internal morphology of teeth with hypercementosis could be applied as a different observational technique. This method could be an alternative, a non-destructive 3D research and educational tool.[18]

This study draws attention to an interesting clinical fact regarding the influence of hypercementosis over electronic apex location. Previous studies have shown that as the width of the major foramen increases, the discrepancy between the electronic probe tip length induction and the actual position of the major foramen also increases.[19] There is a current thinking that apex locators are only capable of detecting the major diameter of the root canal terminus, in other words, the major foramen.[20] The present study found that hypercementosis usually increases the presence of apical deltas, what may reduce the presence of a major foramen. Further studies may address this issue by properly evaluating the possibility of hypercementosis affecting the accuracy of electronic apex locators.

The results observed in this study lead to future correlations established between the presence of hypercementosis and the type of root canal. It is worth noting that most classifications were made without observing the presence or absence of hypercementosis.[21-25]

The morphological characteristics of the influence of hypercementosis over the formation of the root apical third, observed by means of stereomicroscopy, radiographic and tooth clearing techniques, were coherent with the microscopic evaluation. Continuous cementum deposition, observed in teeth with hypercementosis, was associated with the presence of numerous canaliculi, probably part of apical deltas, and so were the constrictions in the cemental canal due to incremental lines of cementum deposition surrounding the root canal compartment. These findings can be relevant when used in studies regarding the cemento-dentino-canal junction, the apical foramen and apical constriction.[26]

The microscopic evaluation of the root and root canal morphology of teeth with hypercementosis performed in this study was similar to that reported by other studies.[1,9] The influence of hypercementosis over root external surface constitutes the major limitation of the methods proposed herein. How and where the apical and accessory foramina are displaced due to hypercementosis, and the possible variations related to their morphotype have already been shown by means of scanning electron microscopy, by comparing teeth with and without hypercementosis.[14]

Conclusions

This study found that hypercementosis can cause higher frequency of apical deltas, constriction in root canal breadth, and changes in the original root canal path at the apical third of affected teeth. These findings point out the possible existence of a complex root canal anatomy at the apical third in teeth with hypercementosis, which is sometimes undetectable by common radiographic examination.

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