Hypercementosis and increased cementum thickness over the age: Clinical implications and meanings

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Abstract

A very common alteration that raises many questions about its etiopathogenesis and meaning is the hypercementosis. The pertinent literature is reduced and cementum represents the less studied dental tissue, and even its reactivity level under stimulation and aggression is ignored. Cementum thickness and structure change overtime. It must be noticed the difference between cementum thickness increase and hypercementosis. In hypercementosis there is an excessive formation of cementum beyond the limit necessary to allow its regular functions, with macroscopic root shape alteration, specially regarding to its diameter. Each hypercementosis type has different meanings: How to understand them when planning and/or on treatment follow-up? From a biological point of view, must a special care be taken while setting an implant in the neighborhood of a tooth with hypercementosis? To help answering these questions and at once collaborate to more secure hypercementosis diagnoses, appreciating its clinical and biological meaning, we have set ourselves out to reanalyze the literature and a sample studied over the years in papers, dissertations and thesis.

Keywords: Cementum. Hypercementosis. Dental root.

How to cite this paper: Consolaro A, Consolaro RB, Francischone LA. Hypercementosis and increased cementum thickness over the age: Clinical implications and meanings. Dental Press Implantol. 2012 Jan-Mar;6(1):20-32.

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Sent on: 01/10/2012
Reviewed and accepted: 01/28/2012

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Introduction

Implantology cares predominantly adults, and rehabilitation planning involves the remaining teeth. Some questions are inevitably asked on the condition of the remaining natural teeth, on the clinical and functional significance of changes that may present, and also on the prognosis of imaginologically diagnosed changes.

A very common dental change, which raises many questions on its etiopathogenesis and meaning, is the hypercementosis (Fig. 1-8), even because there are few studies in the literature about it. At the same time, the cementum is the least studied of all dental tissues, being ignored, for example, its reactivity level to certain stimuli and/or aggressions

There are three well-formulated questions about the cementum and hypercementosis:

1st Do cementum thickness and structure change over the age? When does a natural increase, meeting an increased functional demand, becomes hypercementosis?

2nd Each form of hypercementosis has a different meaning: How to interpret them in planning and/or treatment follow-up, even after its completion?

3rd Should it be taken any special care, from biological point of view, while placing a implant right beside a tooth with hypercementosis?

In order to collaborate in searching answers for these questions, we decided to present this work.

Dental Cementum: Characteristics and functions

Deposition of delicate and new layers of dental cementum, by the cementoblasts, continuously covers the root surface among periodontal fibers which insert or merge with cementum collagen, known as Sharpey's fibers. In this interface with the root surface, cementoblasts deposite organic cementum matrix in lamellar layers and mineralize them alternately,determining in tissue sections stained with hematoxylin and eosin, gross basophilic incremental lines (Fig. 6).

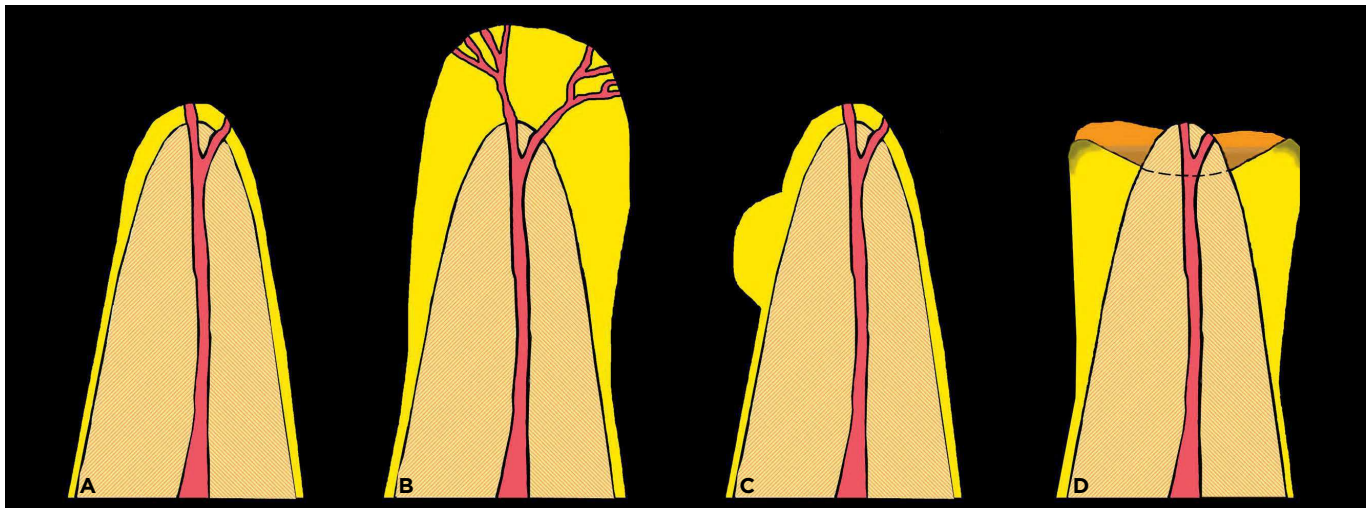

Figure 1 - Morphological types of hypercementosis: **A** = normal root; **B** = club-shaped diffuse hypercementosis; **C** = focal or localized hypercementosis; **D** = hypercementosis in the shape of "shirt sleeve cuff", does not involve the most apical portion and occurs on the periphery as response to a chronic periapical lesion (Source: Pinheiro[16]).

Cementum thickening occurs by a rhythmic process: each new layer of cementum deposited, the former one is mineralized. The last non-mineralized layer can also be called pre-cementum. When deposited before tooth eruption, the cementum can be classified as primary; after this, the deposited dental cementum can be defined as secondary and is formed in response to functional demands.[13,18,19,20]

Cementoblasts interact directly with the root surface (Fig. 6), on one face of its cell body; other faces are related to the extracellular matrix of the periodontal ligament,consists of collagen fibers. Externally the membrane proteins of cementoblasts are related to extracellular matrix components, such as fibronectin. The transmembrane proteins, known as integrins, are connected internally to the cytoskeleton proteins, providing stable form and cell mobility.

Cementum covers the root surface,and "hides" or isolates the dentin of the periodontal ligament and, at the same time, allows the insertion of periodontal collagen fibers for dental support and articulation of the gomphosis type with the periodontal ligament along the alveolar wall.[8,21] The term cementum comes from the Latin caementum or "cementum": Stone particles used to make mortar. Cementum is an organic portion which predominantly consists of type I collagen in a medium of proteoglycans and water. Its mineral part comprises 45-50% of its volume, mostly calcium and phosphate in the form of hydroxyapatite.

The periodontal activity of absorbing, directing and distributing forces applied to the tooth may move the periodontal fibers and other extracellular matrix components, as well as deforming the cytoskeleton of the cementoblasts by means of integrins. Cytoskeleton deformation may represent necessary stimulus for the cellular stress, resulting in increased release of mediators and cementum matrix synthesis on the root surface.

In other words, thicker cementum - and, ultimately, hypercementosis - may be an adaptive response to an increased periodontal functional demand. This may result from an acceleration in the deposition, or an increase in the amount of cementum matrix, as a way to insert more time and in largest area the periodontal fibers more functionally required. The collagen of the cementum forms a

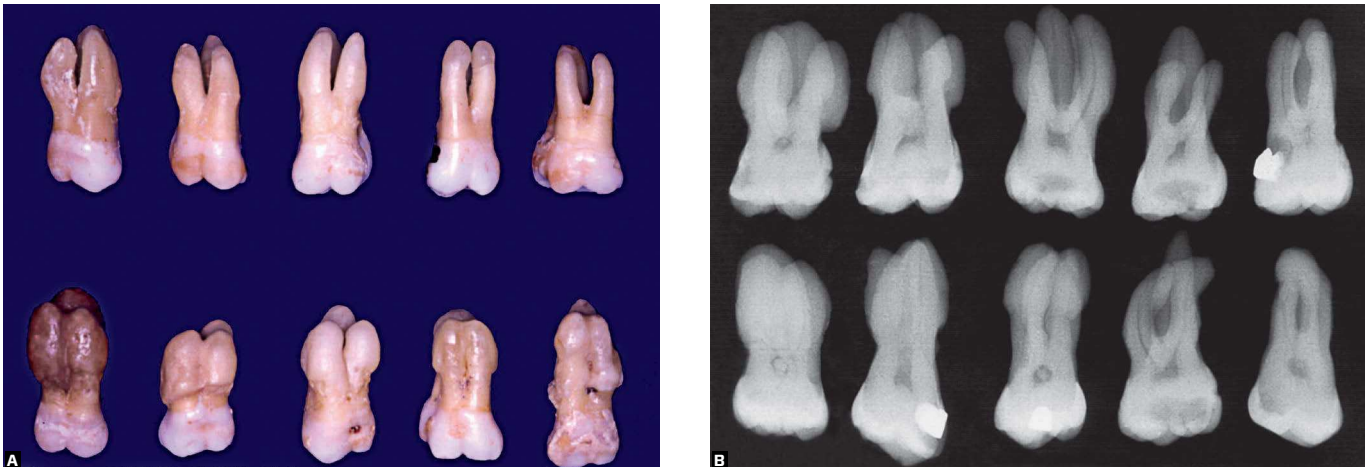

Figure 2 - Upper molars are the most affected teeth by hypercementosis, in different intensity levels, as these specimens of a sample extracted from 21,573 teeth.[5]

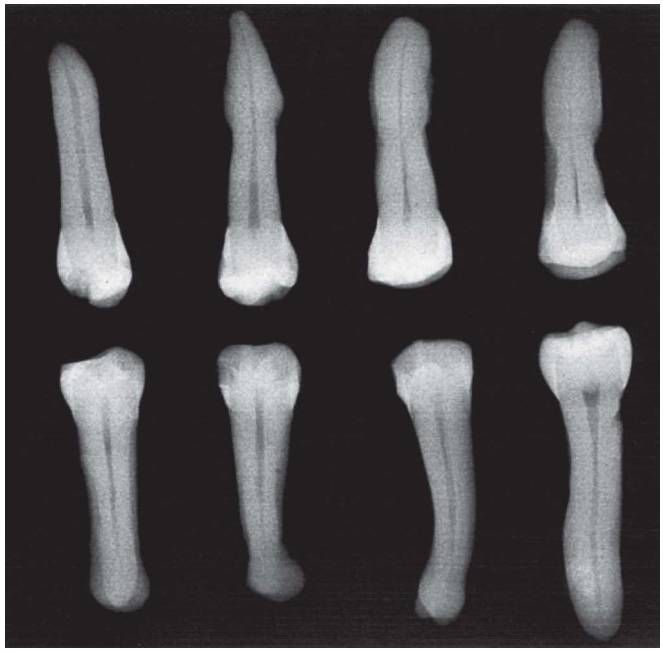

Figure 3 - Upper and lower premolars with several grades of impairment by diffuse or club-shaped hypercementosis for a sample extracted from 21,573 teeth.[5]

fibrillar network, which is sometimes parallel to the surface, sometimes irregularly distributed[19,20] and related to insertions of Sharpey's fibers, a real system of transmission and diffusion of forces applied to the tooth.

The dental cementum has some intriguing characteristics when compared to the bone tissue: It does not undergo remodeling and it is continuously deposited over the life.[1,2,7,9,22] Cementoblasts are formed throughout life from progenitor cells located in the periodontal ligament and two non-collagenic proteins may be related to chemical attraction, adhesion and differentiation of pre-cementoblasts on the root surface: Bone sialoprotein and osteopontin.[4,17]

Cementum cellularity and its reactive capacity

Cementum matrix deposition by cementoblasts at cervical and middle thirds of the root does not include cells inside, and the cementum generally becomes classified as acellular (Fig. 7). Among the layers of the deposited cementum, there are no gaps with cementocytes inside them.

At the end of the middle third, and throughout the apical third, the cellular cementum presents itself with gaps filled by cementocytes and with numerous interconnecting extensions of "spider web" type (Fig. 6, 7, 8). The cementocytes are also in large numbers in furcation areas. Their gaps, called cementoplasts, intercommunicate cementocytes and make the metabolic exchanges with the odontoblastic extensions of the closest dentin.

In the bone, a osteocyte network is formed through contact with approximately twenty cells. This interconnecting network exchanges fluids and mediators, keeping the mineralized bone matrix metabolically active and connected to the internal and external bone surfaces. Probably this communicating network captures structural deformations by applying compression forces and bone stretching with cytoskeleton deformation and mediators release which promote adaptive cellular activities on the surfaces of the cortical and medullary spaces. It will probably help understanding why the cementum must have half of its structure formed by organic components: It must be more flexible or deformable than other dental tissues.

In the cementum, it may be that the interconnecting network of cementocytes helps to control the apical root shape (Fig. 5). The cementum is not as hard as dentin.[10,15] Compression and stretching forces to the root, especially in the apical third (thinner and more delicate), can cause a deformation on the interconnecting network of cementocytes and the respective cytoskeletons. On the surface, cementoblast layer may receive stimuli from cementocytes to slow down or accelerate cementum deposition and respond appropriately to the perceived stimulus.

In conceptual and hypothetical terms, we may infer that the increased cementum thickness and the consequent hypercementosis represent an adaptive response of periodontal tissues to increase the area of support and distribution of occlusal forces. This way of increasing its surface relationship with the adjacent bone can be important in response to excessive occlusal loads[5] and even in the absence of antagonist, when occlusal forces are hardly noted[5]: Increased cementum thickness and the consequent hypercementosis may represent a way of increasing the retention or dental insertion in the alveolar bone.

These aspects discussed may explain why there are two types of cementum in term of cellularity: Acellular and cellular, the latter almost exclusively of apical thirds and furcation regions, two regions mechanically very required in periodontal physiology. The cementum represents the deposition of subsequently mineralized organic matrix , and the adaptive responses are directly related to the depositing cells: cementoblasts (Fig. 6). The cementum, as a dental tissue, represents the insertion structure of periodontal fibers almost passively; the active and reactive part of the tissue is represented by cementoblasts and cementocytes.

The term acellular is not perfectly appropriate to the cementum because despite of the absence of cementocytes inside its already mineralized matrix, it contains numerous cementoblasts on its surface. In a new situation, cellular cementum can be deposited in new matrix layers deposited on the cellular cementum.

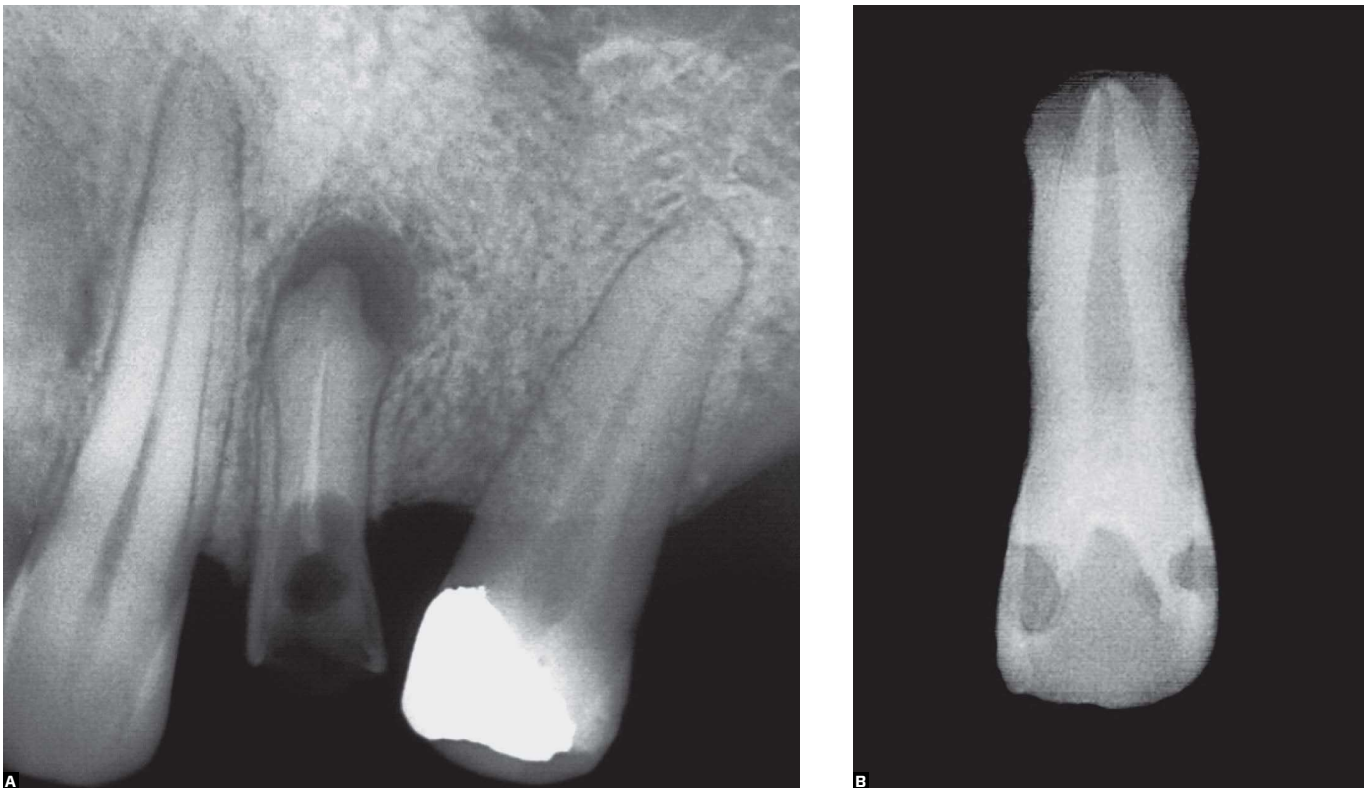

Figure 4 - Upper premolar and incisor with hypercementosis in shape of "shirt sleeve cuff". This aspect is provided by the presence of chronic periapical lesion and increased formation of reactive nature in the periodontal periphery of the lesion.

Hypercementosis: concept and types

Hypercementosis represents an adaptive dental change of the periodontal ligament, characterized by increased cementum thickness on the root surface, besides the limit required to fulfill its normal functions, resulting in abnormal thickening and change in the macroscopic shape of the root.[3,5,16]

There are no criteria defined to differentiate, even microscopically, what represents an increased cementum thickness due to aging and/or functional demand and what can be diagnosed as a hypercementosis. More bulging or rounded root shape and the root apex may be due to an increased cementum thickness which would represent a variability in root morphology, but within the normal range.

Hypercementosis has an excessive cementum formation, besides the limit required to fulfill its normal functions, resulting in abnormal thickening and macroscopic change in the root; and this may require applying forces in different intensity, direction and distribution of a conventional mechanics.

Based on the macroscopic and imaginologic point of view, the hypercementosis was classified 5 in:

- Diffuse hypercementosis: rounded apical third of the root with a diameter equal to or greater than the middle third, involving all root surfaces. This shape is the most frequent and it was found in 96.72% of the 228 teeth examined[5] (Fig. 1 – 5).
- Focal hypercementosis: cementum nodule located in one of the root faces or superimposed

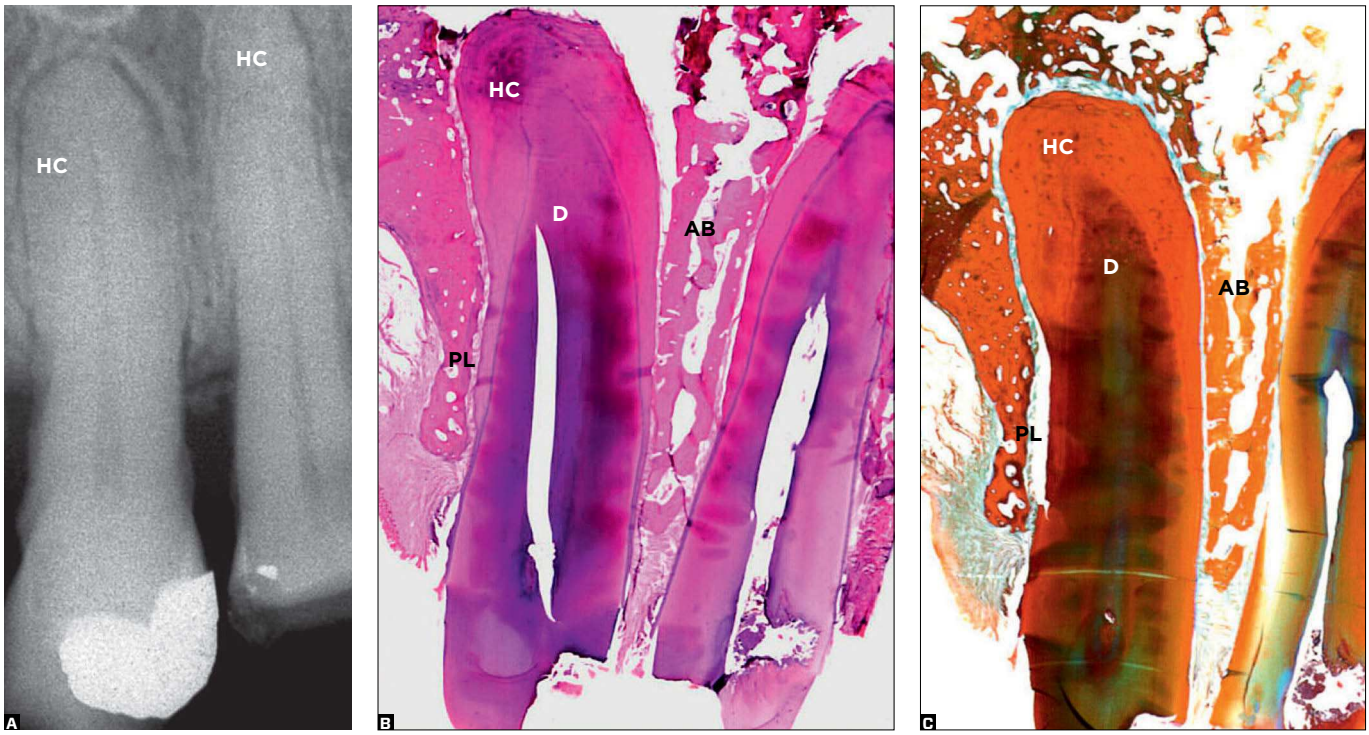

Figure 5 - Radiographic and microscopic aspects of hypercementosis. New cementum layers (HC) is deposited continuously on the root surface by changing the apical morphology which tends to become rhomboidal. The limits of dentin (D) and cementum remain preserved in tissue sections. The periodontal ligament (PL) remain present, with normal structure and organization, binding the tooth to the alveolar bone (AB).
(**B**= HE, 2.5x; **C**= polychrome, 2.5x).

on the tooth apex. It was found in only 2.07% of 228 examined teeth with hypercementosis.[5]

- Hypercementosis in shape of "shirt sleeve cuff": cementum thickening in the lateral areas of the apical third, such as a collar or shirt sleeve around the apex surrounded by a chronic periapical lesion.[5] It represents a reaction of the peripheral periodontal tissues to chronic periapical lesion by depositing more rapidly the cementum in this region. This type is only occasionally described probably due to the unawareness of the terminology used for changes with these characteristics (Fig. 1, 4).

Causes, characteristics and clinical implications

The excessive cementum formation, beyond the limit required to fulfill its normal functions, resulting in abnormal thickening and macroscopic change in the root,[16] or in hypercementosis. Once hypercementosis is formed it modifies the morphology of roots, both internally and externally, especially in the apical third (Fig. 1-8). Its incidence has not been determined yet, but its prevalence ranges from 1.05 to 5.67% in brazilians.[5,12]

In three studies, the morphological aspects of hypercementosis were studied.[3,5,16] Based on the analysis of

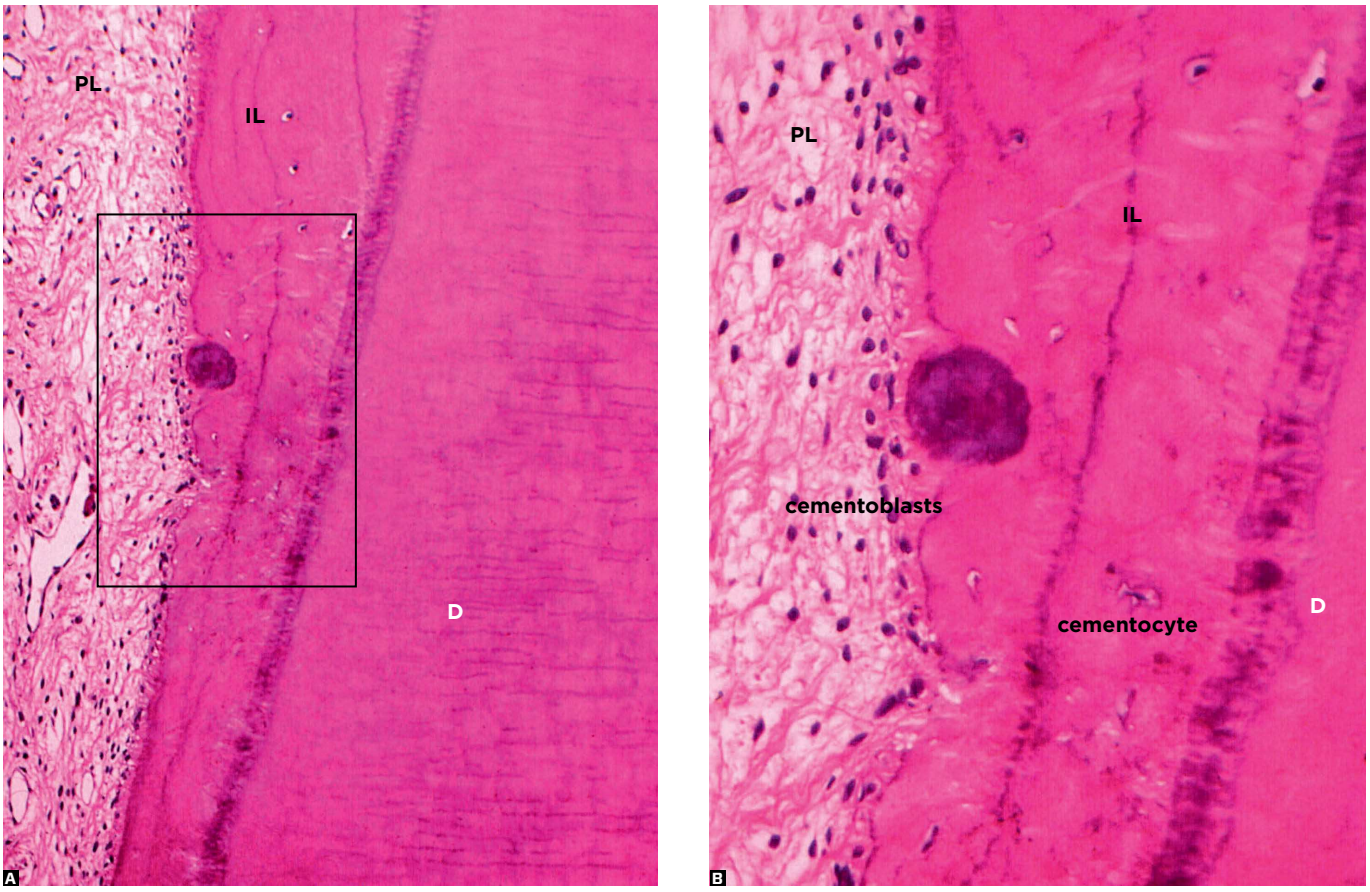

Figure 6 - Hypercementosis in tissue sections obtained by demineralization and stained with HE. Periodontal ligament (PL), cementoblasts and cementocytes within their gaps, or cementoplasts are highlighted. In cementum, with increasing thickness from bottom to top, basophilic incremental lines (IL) from the dentin (D) are observed. More basophilic spherical area corresponds to cementicle included by continuous and accelerated deposition of the cementum. (HE, **A**=10x and **B**=25x).

21,573 isolated teeth, it was found[5] that the teeth most compromised by hypercementosis were the superior molars (5%) (Fig. 2), followed by the superior and inferior premolars (0.88%) and inferior molars (0.86%) (Fig. 3), and (0.74%). The canines showed very little impairment, the upper incisors were rarely affected and there were no hypercementosis cases among lower incisors. More detailed data are provided in Table 1.

The functional stress represents the most commonly cause related to hypercementosis. In patients with bruxism, teeth clenching and occlusal trauma, the hypercementosis is usually present in higher or lower extension. However, many teeth with hypercementosis have no antagonists or would be teeth with largely destroyed crowns, but without records to prove their previous existence or not.

There are still no absolute evidences on the adaptive and/or reactive nature of increased cementum thickness and hypercementosis, although it seems to be very logical.

Another cause often related to hypercementosis are chronic periapical lesions, such as periapical granulomas (Fig. 4). At the peripheral portion of granulomas, the root cementum increases its thickness as a response to inflammatory stimuli originating from the largely present cellular and tissue mediators. On extracted teeth and with this type of hypercementosis, when removing the chronic periapical lesion, the apex surrounded laterally by increased cementum promotes a shape of "shirt sleeve cuff"[5] (Fig. 4).

In 110 randomly selected human teeth and cut serially from the apex to the cementoenamel junction,

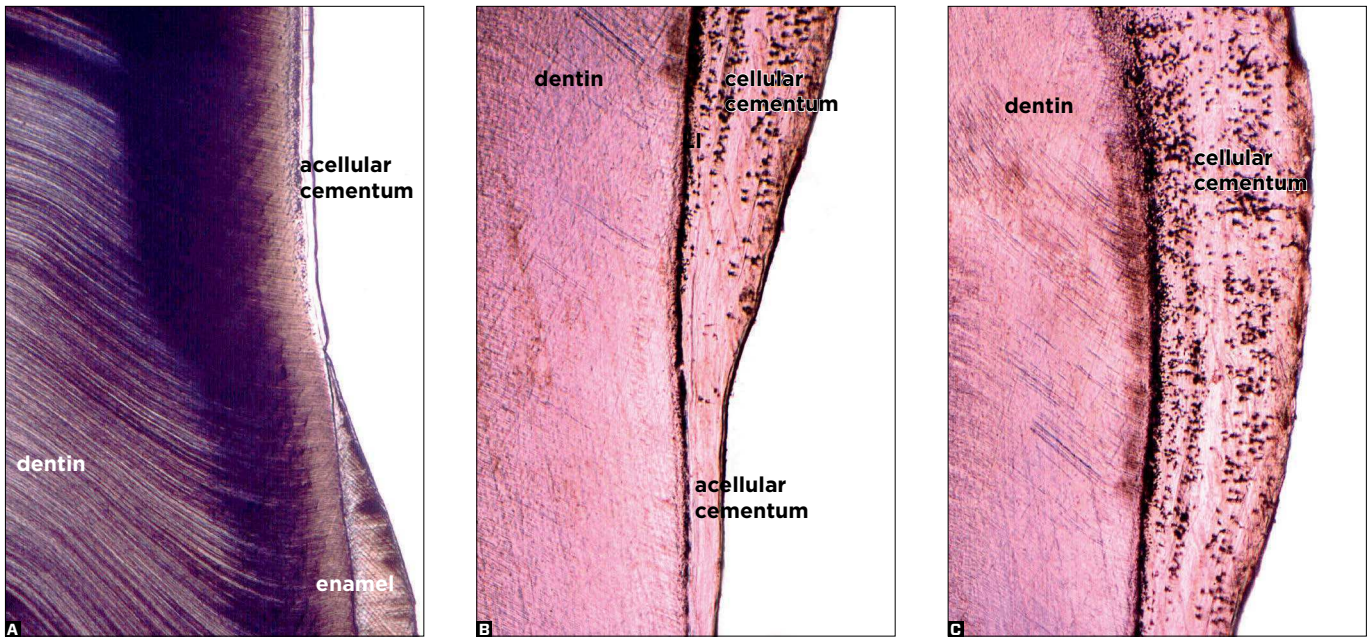

Figure 7 - Hypercementosis in tissue sections obtained by detrition without demineralization and staining. Uniform thickness of acellular cementum in the cervical and middle thirds is highlighted. Gaps, or cementoplasts, are in large quantities in the cellular cementum of the apical third. Increasing thickness of the cementum from bottom (cervical) to top (apical) is noted. (**A**=4x, **B**=10x and **C**=25x).

Table 1 - Prevalence of hypercementosis in dental groups from the sample with 21,573 isolated teeth examined macroscopically and radiographically by Consolaro et al,[5] in 1987.

Dental group	Analyzed teeth		Teeth with hypercementosis		Prevalence (%)	
	Upper	Lower	Upper	Lower	Upper	Lower
Incisors	3.658	3.412	2	-	0.05	-
Canines	1.658	1.680	6	3	0.36	0.18
Premolars	3.884	2.202	34	19	0.88	0.86
Molars	2.931	2.148	148	16	5.00	0.74
Subtotal	12.131	9.442	190	38	1.56	0.40
Total	21.573		228		1.05%	

Hurzeler and Zander[9] measured the cementum thickness in single-rooted teeth. In teeth of subjects with mean age of 17 years, the cementum thickness was 0.076 mm; while the teeth of individuals with mean age of 59 years, the cementum was three times thicker, with an average of 0.206 mm.

In another study, Zander and Hurzeler[22] analyzed the cementum thickness of 233 single-rooted teeth of subjects between 11 and 76 years old. There was a gradual increase, due to aging, in the apical cementum. In patients aged 20 years, the apical cementum was 0.095 mm thickness on average; in those with 30 years old, the average was of 0.125 mm; in 40 years old, 0.155 mm; in 50 years old, 0.185 mm; and in 60 years old, average thickness of 0.215 mm (Table 2).

In order to compare the cementum in different ethnic groups, Muller and Zander[14] studied[61] single-rooted teeth from Indians and, in several age groups , found a slightly cementum thickness smaller than in North Americans in Minnesota.

In Implantology, information about the planning of clinical cases with remaining teeth with hypercementosis is scarce in literature. If the cementum is deposited continuously, then the root and apical shape should change throughout life, but this has not been demonstrated in a methodologically indisputable manner yet.

Table 2 - Mean thickness of apical cementum, according to age group, in 223 single-rooted teeth analyzed by Zander and Hurzeler,[22] in 1958. It is noted the thickness increasing with age.

Zander and Hurzeler,[22] 1958 223 single-rooted teeth	
11 to 76 years	**Mean thickness of apical cementum**
20 years	0.095 mm
30 years	0.125 mm
40 years	0.155 mm
50 years	0.185 mm
60 years	0.215 mm

In teeth with hypercementosis or a slightly more bulging shape, such as an incipient hypercementosis, would it be more provident to let the implants a little farther or wouldn't it have any consequences if, in a near future, the hypercementosis increased and approached the osseointegrated implant?[6]

Although it is probably reduced, the mobility of teeth with hypercementosis still persists indefinitely. The contact of hypercementosis with the implant could cause localized root resorption, through the mechanical trauma represented by the movements of the tooth in the alveolus, "rubbing" with the neighboring implant — an inflammation induced by physical/mechanical causes would set in the site. Therefore, a proximity ratio between teeth with hypercementosis and osseointegrated implants is not convenient.

Root and apical shapes have not been related to the age of patients. For example: Is the triangular shape of the tooth root and apex more prevalent in young, adult or elderly people? Should not the rhomboidal or quadrangular shape of tooth apex be more prevalent in older subjects? Even in two samples of 60 and 72 unerupted canines, Azaz et al[1,2] found with the course of aging, an increased cementum thickness and prevalence of unerupted teeth with hypercementosis.

Considering these questions and particularities of the cementum, both conceptually and in practice, it should accurately distinguish between increased cementum thickness due to aging and/or functional demand and diagnosis of hypercementosis. The bulging or more rounded shape of the root and root apex may be due to an increased cementum thickness representative of variability in root morphology, but within the normal range.

In hypercementosis there is an excessive cementum formation, in addition to the limit required to fulfill its normal functions, resulting in abnormal thickening and macroscopic form change in the root; this may require applying forces with different intensity, direction and distribution of a conventional mechanics. These particularities and specificities of teeth with hypercementosis should complicate orthodontic movement, but in only one published case[11] it was shown difficulties for an effective displacement of the compromised teeth. In such cases, the functional and esthetic solutions for edentulous spaces may necessarily have to appeal to the placement of osseointegrated implants.

The relationship of hypercementosis with the occurrence of alveolo-dental ankylosis or with loss or delay in the rash was not reviewed in the relevant literature, although they eventually may be noted as a possibility which does not seem to be logical from a biological point of view.

Likewise, the effects over the time on the root and apex shape, of continuous cementum deposition or whether the moved teeth with hypercementosis would present a higher or lower rate of root resorption were not analyzed yet.

In 1999, Barros[3] analyzed — from the macroscopic, stereomicroscopic with and without diaphanization points of view,, as well as optical microscopy in tissue sections — the external and internal anatomy of dozens of teeth with hypercementosis. He noted that hypercementosis increased the number of lateral and accessory canals, as well as apical deltas, besides narrowing the main channel in the apical third, with directional change of the foramen. From the organizational and structural points of view, the cementum in the teeth with hypercementosis was normal under optical microscopy.

In turn, in 2005, Pinheiro[16] analyzed 576 permanent teeth with hypercementosis from the macroscopic, stereomicroscopic, radiographic and scanning electron microscopy points of view-. In 85.24% of the examined teeth, the roots assumed the shape of club; 8.16% of the teeth had the localized form; and 6.6% in the shape of "shirt sleeve cuff" (Tab. 3)

Contemporary Implantology requires more detailed studies on the significance of increased cementum thickness over the the age and hypercementosis in the

Table 3 - Prevalence of hypercementosis types, in their shape and distribution, detected in 576 teeth analyzed by Pinheiro.[16]

Pinheiro,[16] 2005 576 teeth with hypercementosis	
Types	**Prevalence**
Diffuse or club	85.24%
Localized or focal	8.16%
Shirt sleeve cuff	6.60%

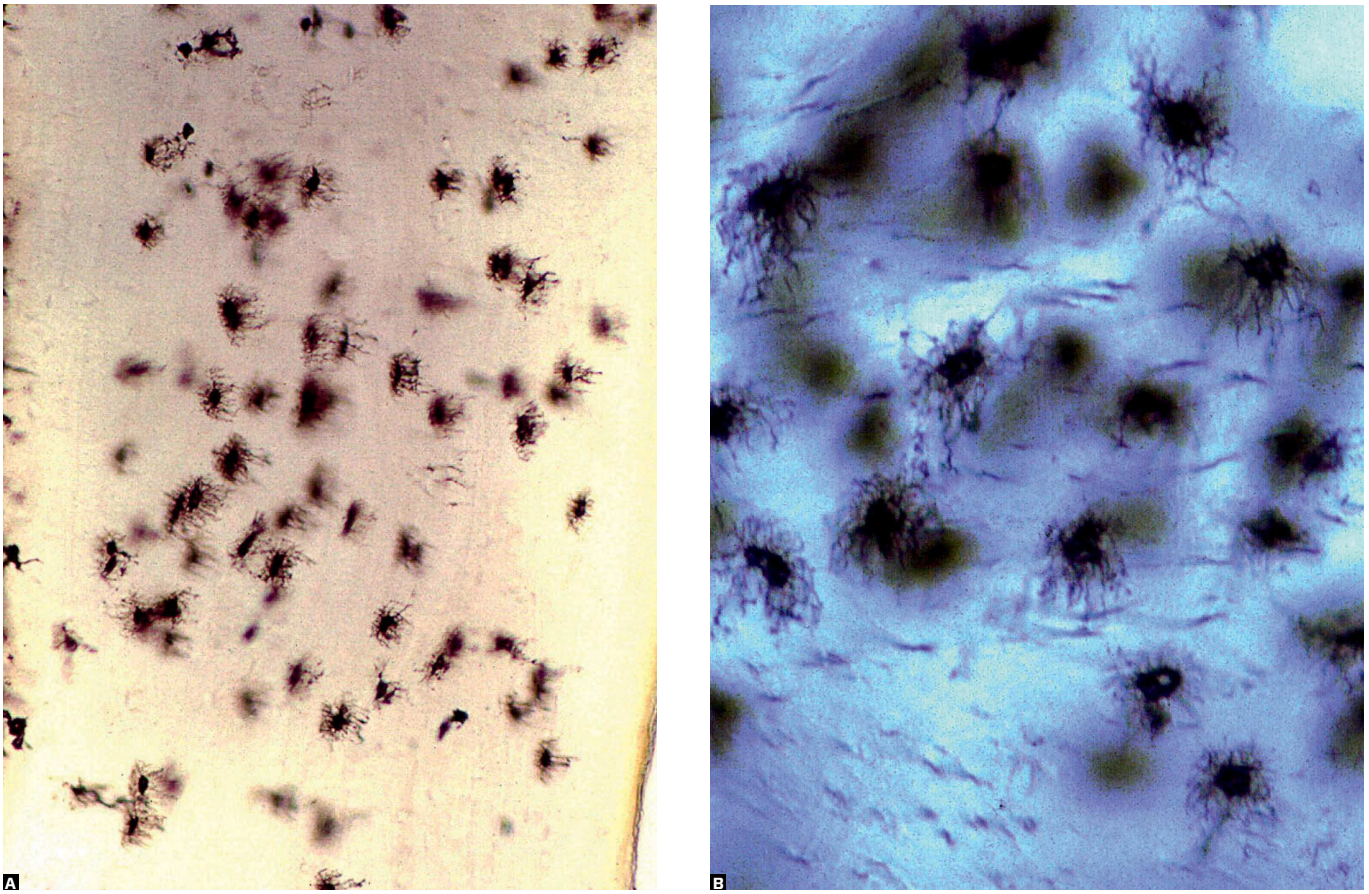

Figure 8 - Cementocytes gaps, or cementoplasts, in area with hypercementosis in tissue sections obtained by grinding without demineralization and staining. It should be noted the numerous canaliculi where they were stay the numerous cytoplasmic irregularly distributed and communicating with other cementocytes providing a communicating signals and stimuli network (**A**=40x, **B**=100x).

setting of an oral rehabilitative treatment, especially with significant clinical case reports.

Final Considerations

1st The cementum, being continuously deposited, should change the root and apical shape over the age, although these changes have not been studied yet. Consolaro et al,5 in a study which analyzed 228 teeth with hypercementosis selected from 21,573 isolated specimens, used the diameter of the middle third of the root as limit to consider increased cementum as hypercementosis. If equal or higher than this diameter, the diagnosis of diffuse hypercementosis was considered.

2nd The bulging roots may represent an increased cementum thickness or incipient hypercementosis, and club-shaped root must have the imaging diagnosis of diffuse hypercementosis. These morphological changes may represent an occlusal overload, a higher masticatory

demand related to bruxism or not. It can indicate even the lack of antagonism. Teeth with hypercementosis tend to have an accelerated aging of the pulp, reducing its reparatory capacity. Other implications or specific meanings of hypercementosis in oral rehabilitation treatment with osseointegrated implants have been described in literature.

3rd Distance between a tooth with hypercementosis and osseointegrated implant should probably be evaluated, but there are no criteria defined for this in literature, as well as the consequences of hypercementosis-implant proximity.

4th The most common causes related to hypercementosis are increased occlusal demand; lack of antagonist followed by continued passive tooth eruption with extrusion for edentulous spaces; and chronic periapical lesions. Focal hypercementosis will be hardly diagnosed for its frequency and difficulty of generating images due to the reduced size and lower cementum mineralization.

5th The most common causes associated with hypercementosis are increased occlusal demand; lack of antagonist followed by continued passive tooth eruption with extrusion for edentulous spaces; and periapical lesions. Focal hypercementosis hardly will be diagnosed for its frequency and difficulty of generating images due to the reduced size and low grade of cementum mineralization.

REFERENCES

1. Azaz B, Ulmansky M, Moshev R, Sela J. Correlation between age and thickness of cementum in impacted teeth.Oral Surg Oral Med Oral Pathol. 1974;38(5):691-4.
2. Azaz B, Michaeli Y, Nitzan D. Aging of tissues of the roots of nonfunctional human teeth (impacted canines). Oral Surg Oral Med Oral Pathol. 1977;43(4):572-8.
3. Barros LAP. Estudos macro e microscópico da morfologia do terço dentário apical na hipercementose [tese]. Bauru (SP): Universidade de São Paulo; 1999.
4. Bosshardt DD, Selvig KA.Dental cementum: the dynamic tissue covering of the root. Periodontol 2000. 1997 Feb;13:41-75.
5. Consolaro A, Oliveira LU, Vasconcelos MHF. Determinação da prevalência da hipercementose e suas implicações etiopatogênicas. Odontol Mod. 1987;14(3):6-14.
6. Consolaro A. Reabsorções dentárias nas especialidades clínicas. 2ª ed. Maringá: DentalPress; 2005.
7. Gootlieb B. Continuous deposition of cementum.J Am Dent Assoc. 1943;30(11):842-7.
8. Hammarstrom L, Alatli I, Fong CD. Origins of cementum. Oral Dis. 1996;2(1):63-9.
9. Hurzeler B, Zander A. Determination of cementum thickness. J Dent Res. 1958;37(6):44.
10. Kerr DA. The cementum; its role in periodontal health and disease. J Periodontol. 1931;32:183-9. Orban, B. Oral histologyandembryology. 3.ed. St.Louis, Mosby, 1953, p.154
11. Mattar Neto A, Vedovello Filho M, Vedovello S, Chiarini P, Alciara Alice de Aguiar Young, AAA. Tratamentoortodôntico em pacienteportador de hipercementose. RGO: Rev Gaucha Odontol. 2005;53(2):120-3.
12. Matos ASRC. Levantamento das condições dentárias dos pacientes atendidos nas clínicas da Faculdade de Odontologia de Bauru-USP, através de exames clínico e radiográfico [tese]. Bauru (SP): Universidade de São Paulo; 1985.
13. Mjor IA, Fejerskov O. O periodonto. In: Mjor IA. Embriologia e histologia oral humana. São Paulo: Panamericana; 1990. p. 131-76.
14. Muller G, Zander A. Cementum thickness of teeth from India. J Dent Res. 1959;38(4):668.
15. Orban B. Oral histology and embryology. 3th ed. St.Louis: Osby; 1953. p.154.
16. Pinheiro BC. Hipercementose: estudo macroscópico, esteromicroscópico, radiográfico e à microscopia eletrônica de varredura [dissertação]. Bauru (SP): Universidade de São Paulo; 2005.
17. Saygin NE, Giannobile WV, Somerman M. Molecular and cell biology of cementum. Periodontol 2000. 2000;24:73-98.
18. Schroeder HE, Page RC. The normal periodontotium: In: Schluger S. Periodontal Disease: basic phenomena, clinical management, and occlusal and restorative interrelationships. 2th ed. Philadelphia: Lea &Febiger; 1990. p.3-52.
19. Selvig KA. An ultra structural study of cementum formation. Acta Odontol Scand. 1964;22:105-20.
20. Selvig KA. The fine structure of human cementum. Acta Odontol Scand. 1965;23:423-41.
21. Ten Cate AR. Oral histology: development, structure and function. 5th ed. St. Louis: Mosby; 1998.
22. Zander A, Hurzeler B. Continuous cementum apposition. J Dent Res. 1958;37(6):1035-44.