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Radiological and optical coherence tomography aspects in external root resorption

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Abstract

Pathological external root resorption is a process by which the hard tooth substance is lost because of action of different local irritative or systemic factors. Six forms of external root resorption are described: surface external root resorption, inflammatory external root resorption, replacement external root resorption, invasive external cervical root resorption, ankylosis and transient apical breakdown. The objective of the study was to establish the prevalence of the pathological root resorption in a retrospective radiological study, to highlight radiological aspects of external root resorption and to describe optical coherence tomography (OCT) aspects in pathological root resorption. External root resorption prevalence in our study was 17%. Radiological exam was very useful to detect the form of root resorption but also to establish possible etiological factors. The study presents the radiological aspects of some forms of pathological external root resorption highlighted on radiography accompanied by radiolucency of the adjacent bone to resorption lesion (as in inflammatory external root resorption and in invasive cervical root resorption) or as changes of the root form, in which the missing part of the root is replaced by the bone tissue, without radiolucency (as in replacement root resorption). The comparison of the OCT aspects of the physiological root resorption in primary teeth with the OCT aspects of pathological root resorption in permanent teeth showed an obvious difference between the images of the OCT signal of the two types of resorption. The OCT signal from the cement is stronger in pathological root resorption, and the OCT signal from the dentin in teeth with inflammatory external root resorption showed a demineralized dentin with multiple heterogeneities, anfractuosities corresponding to resorption craters, with craze lines in subjacent layers of dentin.

Keywords: inflammatory external root resorption, replacement external root resorption, cervical extensive root resorption, radiography, OCT.

Introduction

External root resorption is a physiological or pathological process by which the hard root tissues are lost. The physiological process is characteristic for primary teeth, enabling their replacement with permanent teeth. The process is considered as pathological when it is encountered in permanent teeth. This process appears in pathological situations, but there is also an idiopathic root resorption form [1]. The pathological external root resorption is correlated with a series of local pathologies (periodontal and periapical inflammatory processes [2], excessive occlusal forces, incorrect orthodontic treatments [3–5], crowded teeth [6], impacted teeth [7], tumors, replantation of teeth [8]), and also a series of systemic diseases (hormonal disturbances, Paget's disease). A genetic predisposition was incriminated [1, 9].

Pathological root resorption was described for the first time by Mueller & Rony, in 1930 [10]. According to *World Health Organization* (WHO) classification of diseases (2016 – ICD 10) [11], external root resorption together with internal root resorption represent a separate pathology, category K03.3. Nevertheless, this pathology was described as a tooth wear form, for the first time by Imfeld, in 1996 [12] and then by Paesani, in 2010 [13]. Neville *et al.* [14] classified it separately, apart to tooth wear, as a different form of non-carious tooth lesion. Neville stated that external root resorption was very common and all patients could have a root resorption detectable through a thorough radiographic exam [14]. According to Tsesis *et al.* [15], external root resorption prevalence is 28.8%. Prevalence of the external root resorption determined by orthodontic movement varies between 2.9% [16] and 96% [3].

Clinically, the tooth with root resorption could be asymptomatic, discovered by chance through a radiographic examination, but sometimes the tooth could present pain, mobility, pulpal complications, root fracture, even tooth exfoliation from the dental arch.

Main clinical forms of root resorption are: (1) surface external root resorption, usually self-limiting, which appears after occlusal trauma; (2) inflammatory external root resorption, which appears usually after a trauma (treatment) or periodontal infection, which initiates an inflammatory response in periodontal ligament [17, 18]; (3) external replacement root resorption, which is usually associated with orthodontic movement through biological factors (genetic disorders, metabolic disorders, medication) and mechanical factors; (4) external cervical resorption (invasive external cervical root resorption – Patel 2016 [19–21])

is a complex pathological state because of its infiltrative nature in advanced evolution stages, which could be initiated by factors as dental trauma, orthodontic movement, periodontal treatment, internal crown bleaching; (5) root ankylosis, which appears usually after tooth replantation; (6) transient apical breakdown, which is a temporary phenomenon in which after a trauma tooth apex appears on radiography as being resorbed and returns to normal after a period of a year [18].

The objective of the study was to highlight radiographic external root resorption, to describe each radiographic form, to correlate the radiographic lesion with visible radiographic etiological and to describe the optical coherence tomography (OCT) aspect of the root resorption on extracted teeth, because this aspect was not described in literature until now, to our knowledge.

Materials and Methods

One hundred panoramic radiographs of 100 patients from the Clinic of Prosthetic Dentistry and Oral Rehabilitation, Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Romania, were randomly selected from the archive. These radiographs were analyzed on negatoscope by two investigators dentists, separately, watching root resorption lesions presence and radiological aspect of these, the existence of local irritative factors or periodontal or periapical pathological processes.

For OCT evaluation, we selected five extracted teeth in clinic with a well-contoured form of external root resorption and a control group of five primary teeth with physiological root resorption. OCT analysis could be used to study soft tissues but also hard tissues like enamel, dentin and cement [22, 23].

Optical measurements

In the study, we used extracted teeth disinfected with 10% H_2O_2 for 10 minutes and after that rinsed with water. Until the OCT analysis, teeth stayed in sterile deionized water to avoid desiccation. To maintain teeth in a stable position, they were fixed in dental silicone with lesion in an optimal position so light beam would fall perpendicular. Teeth were pictured with a Canon DSLR 600EOS.

Before the OCT evaluation, the teeth were removed from the solution and dried with paper. Characteristics for the OCT system manufactured by Thorlabs (OCS1300SS), with a power swept laser source with central wavelength of 1310 nm, with spectral bandwidth of 100 nm, and average power of 12 mW. Axial resolutions of this system were 12 μm, and lateral resolutions were 15 μm. The apparatus investigated samples with dimensions of 10×10×3 mm (length, width, depth) or 1024×1024×512 pixels in about 30 seconds using a charge-coupled device (CCD)-type detector.

Images processing

The obtained images were processed using Image J, an open access program. The study was approved by the Ethical Committee of the University of Medicine and Pharmacy of Craiova.

Results

Radiological aspects of root resorption

After the evaluation of the 100 radiographs, we counted a number of 2115 teeth. Between them, in 17 radiographs we observed a number of 23 external root resorption: 21 were inflammatory external root resorption (Figure 1, a and b), associated with periapical inflammations or with impacted teeth, one was a replacement root resorption (Figure 1c), one was an invasive external cervical root resorption (Figure 1d).

The prevalence of the root resorption observed on radiographs was 17%, and the frequency of the inflammatory root resorption was greatest, determined by periapical pathological processes.

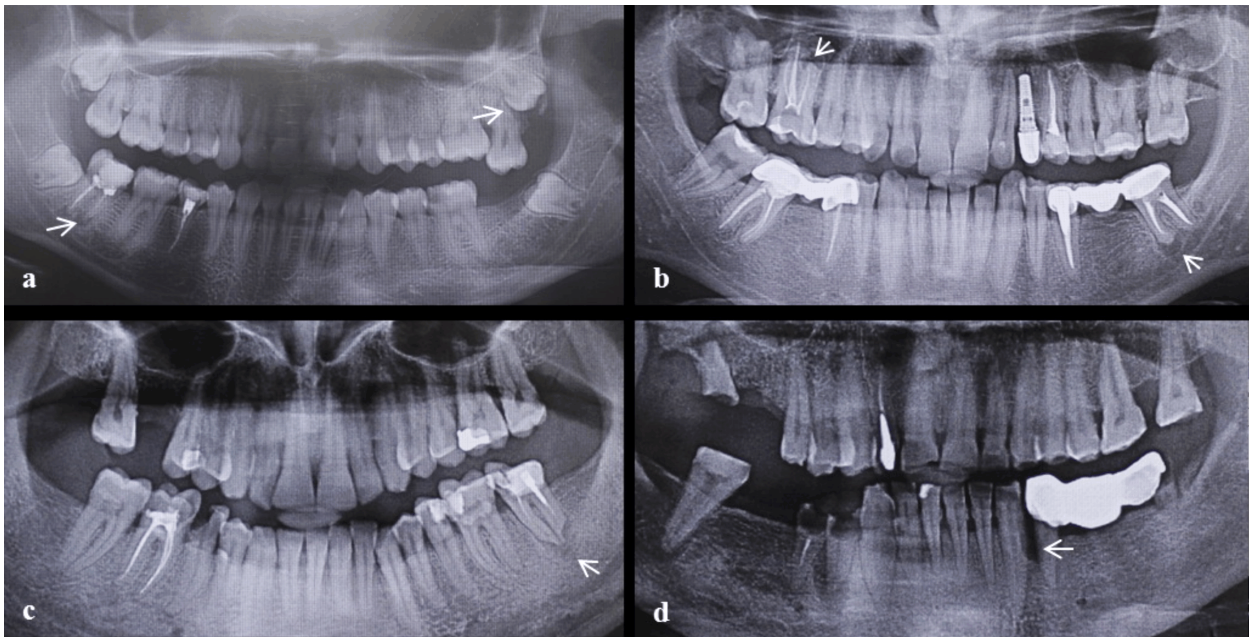

Figure 1 – ***Radiological aspects of pathological root resorption. Inflammatory external root resorption of a left second superior molar and right second inferior molar (a), inflammatory external root resorption of a right first superior molar and left third inferior molar (b), replacement root resorption of a left second inferior molar (c), invasive external cervical root resorption of a left inferior canine (d).***

For the inflammatory external root resorption, the presence of the local irritative factor that determined the lesion, and the shortening of the affected root tooth were visible on the radiographs. In the first radiograph (Figure 1a), an impacted third superior molar determined through the exerted pressure an external root resorption of left second superior molar. Radiolucency was not evident on the radiography. On this radiography, an inflammatory root resorption lesion on the second inferior right molar at the apex linked with a chronic periapical inflammation associated with a potentially incorrect endodontic treatment. Radiolucency was present in root apex and the adjacent bone.

The second image (Figure 1b) presents multiple teeth periapical inflammatory disease (periapical granuloma): right superior first molar, left inferior third molar, right inferior second molar. The radiograph shows potentially correct endodontic treatment in teeth with external root resorption and periapical chronic inflammatory processes. Radiography exhibits radiolucency in external root surface and in surrounding bone.

The third image (Figure 1c) presents a replacement root resorption in a left inferior molar with a potentially incorrect endodontic treatment. Radiographic image of root apex amputation with a new atypical form, and the presence of periodontal space with an intact lamina dura, has no radiolucency in adjacent bone.

The last radiographic image (Figure 1d) is an invasive external cervical root resorption in a left mandibular canine. A prosthetic restoration with an incorrect cervical border, considered as an irritative periodontal factor, is visible on the radiography. A loss of the root contour, with radiolucency on this level, and in inter-root bone septum could be observed.

OCT evaluation

To have a landmark in results interpretation, we first examined the primary teeth with physiological resorption. For exemplification, we chose an inferior incisive with incomplete root resorption positioned on the lingual aspect of the root in the median third, with a form of oval plate (borders and bottom) (Figure 2a). The borders of the root resorption area are smooth and well contoured. Root resorption process has opened pulp chamber in the center.

On OCT analysis (Figure 2b), a well contoured OCT signal on exterior and diffuse in interior could be observed in root cement. As the root resorption advances in profoundness, the exterior contour is diffused (Figure 2c), and the dentin exposure determines a stronger OCT signal, well contoured in exterior and diffused in profoundness (Figure 2, d and e). A concave form of the root resorption is evident. In the next images, the pulp chamber with the loss of the OCT signal next to the root channel could be observed (Figure 2, f–h). The bottom of the resorption process, located in the interior wall of root channel, presents an OCT signal well contoured at the surface, without diffusion in profoundness. The next images (Figure 2, i and j) present the next wall of the root resorption process with a stronger signal in root dentin.

For illustration of the external root resorption process, we chose a superior third molar, which presents an external root resorption lesion in median third of the buccal root on the buccal aspect (Figure 3a). Comparative with physiological root resorption, the borders of the pathological lesion are irregular, anfractuous, with dentin arranged in visible layers in exterior, and with the bottom of the lesion exhibiting dentin bridges with irregular forms, and an apical cervical direction, especially. On the same tooth, more incipient lacunar lesions of external root resorption were evident in cervical area.

On the OCT image of the core lesion, a signal less contoured in exterior, going diffuse in interior, compared with the signal in physiological root resorption was characteristic for the sound cement (Figure 3b). The external root surface of the cement has a wavy form. In the next images, the root resorption lesion becomes obvious, as a crater (Figure 3c), which is then widening (Figure 3, d and e). The OCT signal has a stronger intensity comparative with physiological root resorption. The signal trail is very irregular because of the multiple heterogeneities that are characteristic for the lesion, with craters going in the profoundness of the hard dental tissues (Figure 3, c–g) and also with the prominence of the structures/ lesions in profoundness, the apex extremity showing the presence of a root fissure in this area. The other wall of the resorption lesion (Figure 3, g and h) has an irregular aspect with craters and peaks.

Discussion

The prevalence of the external root resorption in our study was lower compared with other studies [3, 14, 15]. Nevertheless, in this study, we did not include cases with orthodontic treatments. In their book, Neville *et al.* [14] referred to a review that mentioned 86.4% from 13263 teeth examined as teeth with external root resorption, from which 10% presented an unusual form of root resorption. The author motivated the high prevalence considering the external root resorption as a possible phenomenon for every patient, the individual resorption susceptibility being the most important factor of the root resorption produced as result of a stimulus.

Patel [19] classified pathological root resorption according to localization, etiology and form of the root resorption process into internal and external root resorption. Different authors classified external root resorption in external surface resorption, invasive cervical root resorption, inflammatory root resorption, ankylosis, replacement resorption, transient apical breakdown [19–21].

Between the forms of external root resorptions encountered in this study, the external inflammatory root resorption had the highest frequency. This kind of root resorption appeared after a trauma, periodontal or peri-apical infection that initiated an inflammatory response in periodontal ligament [17, 18]. A tumor, a tooth eruption, a tooth intrusion [24] or orthodontic movement [17, 18] could induce the inflammatory response. If tooth eruption determines this form of root resorption, like in the situation described in the study, the process could be initially asymptomatic. Sometimes pressure applied by the tooth eruption on the apical blood vessels and nerves produces trophicity disturbances, going towards pulp

necrosis. The inflammatory external root resorption because of an apical pathological process could also evolve without clinical signs as a part of periapical pathology [18, 25].

Fuss *et al.* [26] described external root resorption determined by impacted tooth on radiography localized adjacent to the causative factor, without signs of radiolucency or infection, an image found also in our study. For the inflammatory external root resorption determined by periapical pathology, radiographic exam could highlight radiolucency with a bowl form in tooth and in adjacent bone. This type of external radicular resorption is visible on radiographs as a periapical extended radiolucency associated with an inflammatory response extended from endodontic pathology [18, 26].

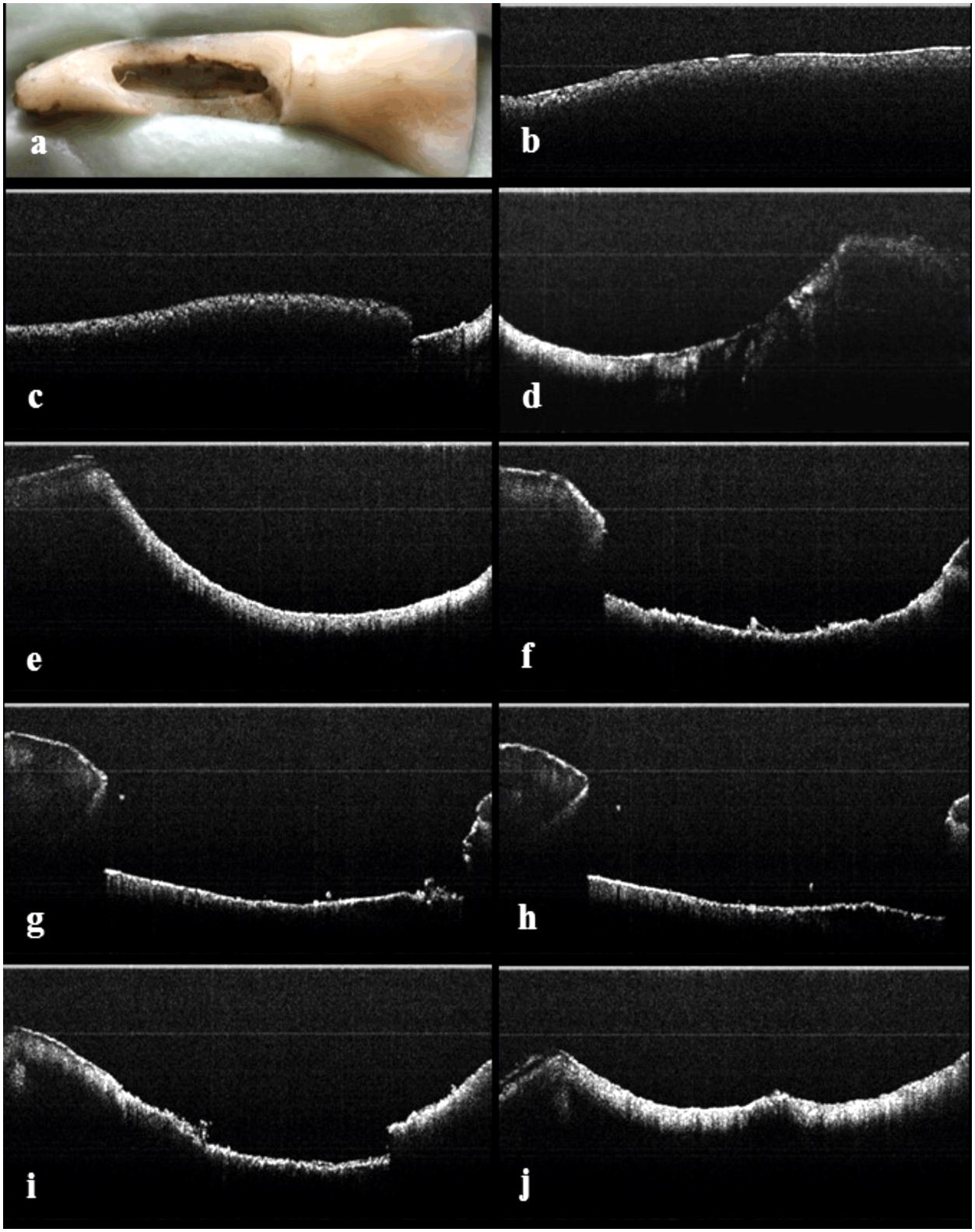

Figure 2 – ***Macroscopic image of a primary incisor with physiological root resorption (a). OCT imaging of the root resorption of the same tooth: intact root cement (b and c), root dentin exposed (d and e), root channel (f–h) and root dentin (i and j).***

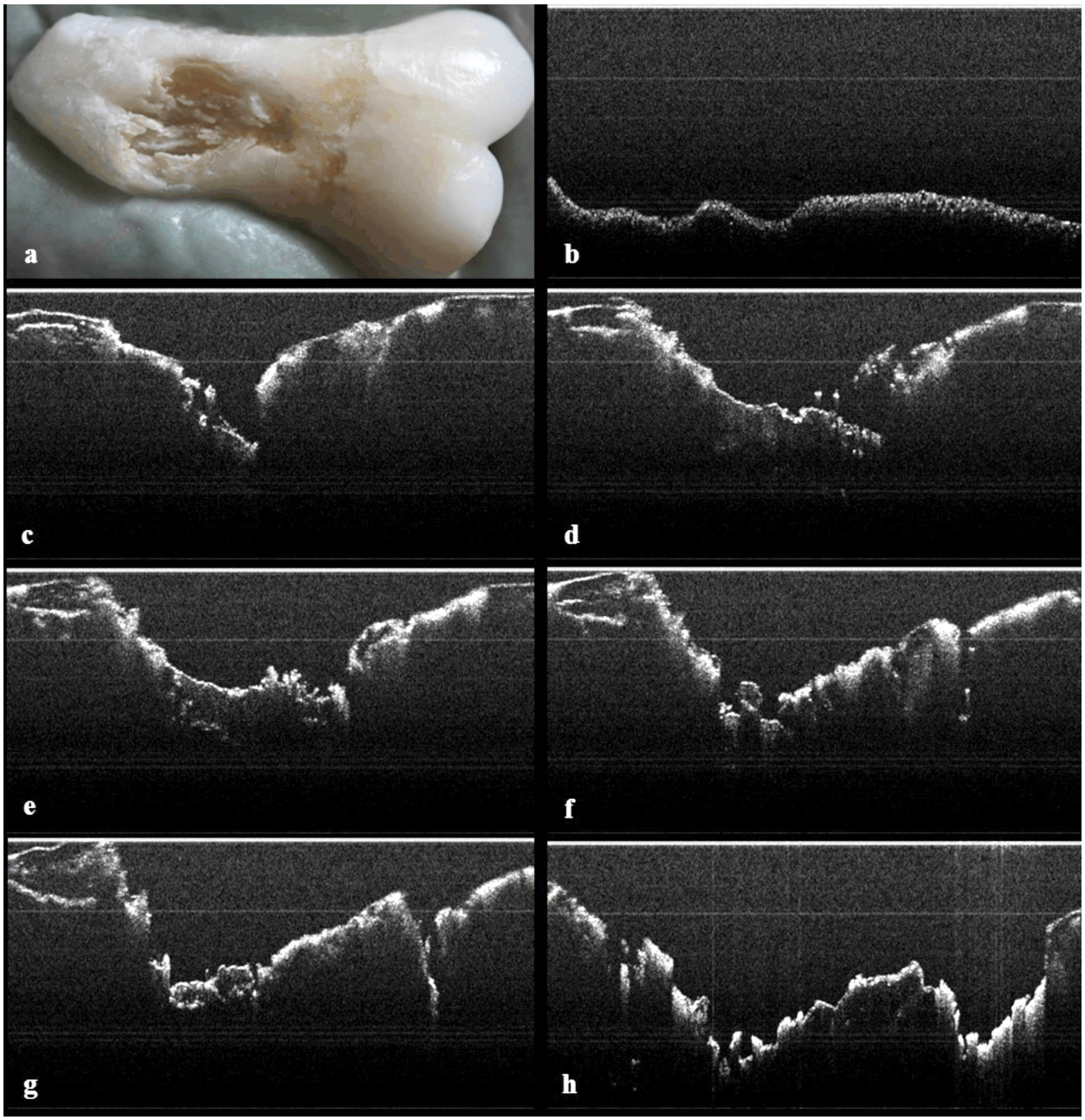

Figure 3 – ***Macroscopic image of a permanent molar with pathological root resorption (a). OCT imaging of the root resorption of the same tooth: cement (b), dentin, with fissures towards root apex (c–h).***

Patel [19] described the mechanism of this type of resorption as the result of the destruction of the periodontal ligament cells, which determines a denuded root surface, in which dentin and cement loss realizes a direct communication between periodontal space and root channel. All the compounds resulted from inflammation and necrosis of pulp impede deposition of reparative cement, sustaining the resorptive process through the free passage from root channel and could determine resorption extension on root surface [27].

Replacement root resorption is usually associated with orthodontic movement and some biological factors (genetic disorders, metabolic disorders, medicines) and mechanical factors. Replacement root resorption is a continuing process across the tooth, bone gradually replacing the tooth. The tooth with this kind of resorption is asymptomatic but could present a metallic noise at percussion [18, 28, 29].

Radiographic, root form is uncommon, bone structure replacing tooth structure, without areas of radiolucency in bone or root [18, 26]. The mechanism of this form of resorption relies on the action of resorptive cells from apical area of the root, cells that are stimulated by causative factor.

Invasive external cervical root resorption [19] represented a complex pathological condition because of its infiltrative nature in advanced evolution stages. This type of resorption has etiological factors like dental trauma, orthodontic movement, periodontal therapy, internal dental crown bleaching, but also could be idiopathic [18]. Periodontal pathology that determined the lesion dominates the symptomatology. If the resorptive process could reach the supragingival area of crown, the vascularized granulated tissue from the resorption lacuna appears through crown enamel as a pink area.

Radiographic, infective periodontal resorption could appear as a single resorption lacuna in dentin, many times at the level of crestal bone, extending towards the apical and crown direction. Together with the resorptive process progression, radiolucency in alveolar bone adjacent to the resorptive lacunae from the dentin area is evident [26].

Fuss *et al.* [26] described the mechanism of this type of resorption through the action of bacteria from periodontal space that enter through the dentinal tubule coronal opened towards attachment epithelium and get out apical towards attachment epithelium without entering the pulp space. Resorptive cells colonize denuded dentin area with exposed dentin, enter in dentin and determine resorption inside the root. In the first stage, the resorptive process does not enter in the pulp because of the protective layer of predentin, but on the contrary, it spreads on the root in an irregular fashion. In time, the process could reach the root channel. Periodontal infective resorption would include also the alveolar bone adjacent to the tooth resorptive lacuna [26].

To our knowledge, the OCT signal of the root external physiological or pathological resorption was never described until now. Hard tooth structures visible on OCT are root cement and root dentin. The aspect of the OCT signal is different in the cement comparative with dentin, being stronger in teeth with pathological resorption than physiological resorption. The morphology of OCT signal is also different between the two types of resorption, pathological resorption having a wavy form compared with smooth form in physiological resorption. In dentin, the OCT signal is stronger also at the surface and in profoundness, being homogeneous in physiological root resorption, but heterogeneous and anfractuous in pathological root resorption. Sinescu *et al.* [30] and Shimada *et al.* [31] described a similar aspect of dentin.

The OCT analysis confirms the macroscopic aspect of the resorption lesion and distinguishes the pathological resorption lesion from physiological resorption lesion. This technique shows a profound visualization of hard tooth structures from the resorption area and gives supplemental data about diverse other lesions of hard tooth structures, as root fissures. Keeping the examined assay intact is the advantage of OCT toward other techniques. Nowadays, for this type of lesion, the method applicability is for *in vitro* studies.

Conclusions

Pathological external root resorption is a dental lesion with a relative high prevalence, determined by a variety of factors among which periapical pathological processes, teeth eruption, and periodontal pathological processes. Multiple external root resorption lesions in the same patient are orienting towards an individual pre-disposition. Radiographic exam is essential in detecting this lesion and in establishing causative factors. The OCT image in external root resorption is specific, presenting uneven morphology, with many abnormalities, profound different compared with the one in physiological external root resorption.

Conflict of interests

The authors declare no conflict of interests.

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