Original Paper

Root Resorption Diagnostic: Role of Digital Panoramic Radiography

IULIA ROXANA MARINESCU[1], ALEXANDRA CARINA BĂNICĂ[2], VERONICA MERCUŢ[3], ANCA GABRIELA GHEORGHE[4], EMMA CRISTINA DRĂGHICI[1], MELANIA OLIMPIA COJOCARU[1], MONICA SCRIECIU[3], SANDA MIHAELA POPESCU[1]

[1]*Department of Oral Rehabilitation, Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Romania*

[2]*PhD Student, Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Romania*

[3]*Department of Prosthetic Dentistry, Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Romania*

[4]*Department of Endodontics, Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Romania*

ABSTRACT: Introduction: Root resorption is a pathological process characterized by loss of dental root substance, caused by bacterial infections, traumatic injuries or chemical irritation. Root resorption might be accidentally observed on digital panoramic radiography. Objective: The objective of the study was to identify characteristic radiological aspects for the different types of root resorption that could be observed on digital panoramic radiography, to make an easier diagnostic of root resorption. Material and Method: The retrospective study used the X-ray base from the Oral Rehabilitation and Dental Prosthetics Clinic of UMF Craiova to identify the most representative images for different types of root resorption. Digital panoramic radiographies were analysed by two investigators, of which the most suggestive images were selected and described. Results: Digital panoramic radiographies and dental charts of 240 patients were analyzed. 113 cases of root resorption were identified. External inflammatory root resorption (EIRR) was present in 27.07% of studied cases, external cervical root resorption (ECRR) was identified in 10.83% of all studied cases, external replacement root resorption (ERRR) was diagnosed in 7.08% of studied cases and internal root resorption (IRR) was the most rare type of root resorption, with only 2.08% from all studied cases. 16 cases were selected to describe the radiologic features of different types of root resorption, featuring the most interesting images of root resorption evident on digital panoramic radiographies. Discussion: Comparative analyses have been made between our results and the results of other specific studies, with both similar and different values. The radiological features which lead to the diagnostic of each type of RR were highlighted, assessing the causes that caused the lesions, as well as the treatment recommendations. Conclusions: Digital panoramic radiography is a useful tool to identify root resorption, since it has become the most common radiological investigation for diagnostic in dentistry. Description of radiological aspects of different types of root resorption on panoramic digital radiography allows faster diagnosis. Still, the CBCT may be recommended in some cases to confirm the diagnosis.

KEYWORDS: *Root resorption, diagnostic, digital panoramic radiography*

Introduction

Root resorption (RR) is a pathological process characterized by the loss of dental root substance as a result of inflammation caused by bacterial infections, traumatic injury, physical or chemical irritation [1,2,3].

Root resorption is often randomly diagnosed on dental radiographs and it is considered a less understood phenomenon, difficult to treat [4].

Radicular resorption is a pathological and undesirable process for the permanent teeth, but for the temporary dentition, it is a physiological phenomenon that leads to exfoliation and facilitates the appearance of successors [5].

Over time, several classifications have been made.

In 1970, Andreasen [6] divided root resorptions into internal (replacement and inflammatory) and external (superficial, replacement, and inflammatory).

This classification is largely used until today. In 2002, Benítez et al. [7] classified root resorptions according to their localization and etiology.

In 2003, Fuss et al. [8] also classified it with regard to treatment options.

The authors also argued that the most common stimulating factor of root resorption was pulp infection.

In 2009, Patel et al. [9] divided root resorption considering its localization on the root surface into internal and external (superficial, inflammatory, replacement, cervical and apical transitory).

10.12865/CHSJ.45.02.05

In 2011, Bruno et al. showed that there could be an idiopathic root resorption, although much less frequent [10,11].

The most recent classification of Patel and Saberi, in 2018 has been made considering the location of resorptive lesions and their pathogenesis and divided root resorption into external (external, inflammatory, cervical, surface and transitional apical breakdown) and internal (inflammatory, replacement) [4].

Root resorption diagnosis may be established using periapical radiography [12], digital panoramic radiography [13], tomosynthetic panoramic radiography [14] or cone beam computer tomography (CBCT) [15].

Digital panoramic radiography was considered a useful tool for detecting root resorption [14], while CBCT was indicated only for cases where a more precise evaluation for a surgical treatment could be necessary [13].

In our country, the panoramic radiography is a highly recommended complementary exam, therefore, the chances of finding radicular resorption injuries are very high and the situation is similar to other countries, too: Koreea [16], Sweden [17] and Belgium [18].

The objective of the study was to identify characteristic radiological aspects for the different types of root resorption that could be observed on digital panoramic radiography, which could allow an easier diagnostic and treatment of root resorption.

Material and Method

The retrospective study used the X-ray base from the Oral Rehabilitation and Dental Prosthetics Clinic of U.M.F. of Craiova to identify the most representative images for different types of root resorption.

240 digital panoramic radiographies and dental charts of patients treated between January 2017 and January 2019 were analysed by two investigators, in order to detect and diagnose root resorption.

Digital panoramic radiographic images were taken with Kodak 9000, with exposure parameters of 14.3 seconds, 70kV, 10mA and with Soredex Cranex D (15 seconds, 65kV, and 15mA).

Age, gender, and the number and type of teeth with internal or external radicular resorption were collected.

Last classification of root resorption was used [4].

The most representative cases were selected.

Radiological aspects of root resorption were described according to morphological features identified on the digital image and correlated with possible causes.

Intra-operator (Kappa score=0.879, P<0.001) and inter-operator (Kappa score=0.871, P<0.001) agreements were statistically significant.

The study was approved by the Ethics Commission of the University of Medicine and Pharmacy of Craiova.

Dental chart of each patient utilized in the study included the informed consent for dental research (a standardized form of informed consent used in the clinic).

Results

240 dental charts and digital panoramic radiographies of a group formed by 132 women and 108 men, with a mean age of 41.32±11.21 years, were analyzed. 113 cases of root resorption were identified (Table 1), accounting for 47.08% frequency in the group studied. 49.07% of men had root resorption compared to 53.09% women in the study group.

Table 1. Root resorption distribution to gender groups

Gender	EIRR	ECRR	ERRR	IRR	Total
Male	28 (11.66%)	11 (4.58%)	12 (5%)	2 (0.83%)	53 (49.07%)
Female	37* (15.41%)	15 (6.25%)	5 (2.08%)	3 (1,25%)	60 (53.09%)
Total	65 (27.07%)	26 (10.83%)	17 (7.08%)	5 (2.08%)	113 (47.08%)

External inflammatory root resorption (EIRR) was the most encountered type of root resorption, 27.07% of studied cases having this type of root resorption (Table 1).

External cervical root resorption (ECRR) was identified in 10.83% of all studied cases, while external replacement root resorption (ERRR) was diagnosed in 7.08% of studied cases. Internal root resorption (IRR) was the rarest type

of root resorption, with only 5 cases, representing 2.08% from all studied cases (Table 1).

Most frequent type of root resorption in women was EIRR, 15.41% from all studied cases, significant more than in men (15.41%) (Table 1).

ECRR was the less frequent, 4.58% in men and 6.25% in women.

The results about ERRR show that it was diagnosed in 2.08% from the studied cases in women and had double value (5%) in men.

Age in the study group varied from 18 to 81 years old, with repartition of root resorption cases on age groups as following: in age group 18-30 years old RR cases accounted 10% from all analyzed cases, in age group 31-65 years old RR cases accounted for 35% from all study group and the people over 65 years old had the fewest cases of root resorption, accounting for 2.08% from all study group (Table 2).

Table 2. Root resorption distribution to age groups

Age (years)	EIRR	ECRR	ERRR	IRR	Total
18-30	10 (4.16%)	2 (0.83%)	11 (4.58%)	1 (0.41%)	24 (10%)
31-65	53 (22.08%)	23 (9.58%)	6 (2.5%)	2 (0.83%)	84* (35%)
> 65	2 (0.83%)	1 (0.41%)	0 (0%)	2 (0.83%)	5 (2.08%)
Total	65 (27.08%)	26 (10.83%)	17 (7.08%)	5 (2.08%)	113 (47.08%)

Sixteen (6.67%) digital panoramic radiographies were selected, featuring the most interesting images of root resorption.

From these particular cases, EIRR was present in 10 cases (Fig.1a,c,d; 2a,c,d; 3a,b,c; and 4c), ERRR in 9 cases (Fig.1b; 2a,b,c,d; 3d; and 4a,b,d), IRR in two cases (4a,c), and ECRR in only one case (Fig.3b).

Figure 1 included 4 OPGs with the two most encountered types of root resorption: EIRR and ERRR.

The first image (Fig.1a) presented the right mandibular premolar (4.4) and the left inferior canine (3.3) with external inflammatory root resorption lesions.

None of the two teeth had endodontic treatment.

The premolar certainly was necrotic, because although it was covered with a metal crown, a coronary destruction stretching to the cervical area could be seen.

Radicular apex had a funnel shape due to the resorption process; the alveolar bone showed a diffuse radiotransparency which appeared to be the image of a chronic diffuse apical periodontitis.

In these cases, the roots appear shorter than normal, sometimes irregularly-shaped and surrounded by a radiotransparent area.

The root canal was visible, suggesting that resorption occurs from the outside towards the inside of the root [4].

The following OPG image (Fig.1b) presented a right mandibular premolar (4.4) with a resorption lesion, without endodontic treatment: external replacement root resorption, a possible consequence of the tooth overloading.

There was a radiotransparency area which coated the resorption lesion, which could be interpreted as the root resorption phenomenon occurred at a faster rate than the repair rate of the bone.

The classic radiological examination provided data only of the lesion located on the proximal sides of the root.

The following two OPGs (Fig.1c,d) showed two teeth (the left mandibular premolar and the right mandibular molar) with external inflammatory resorption lesions and incorrect endodontic treatment.

On both of the OPGs, an apical radiotransparency image specific to chronic apical periodontitis could be seen, so, in these cases, root resorption was associated with chronic apical periodontitis.

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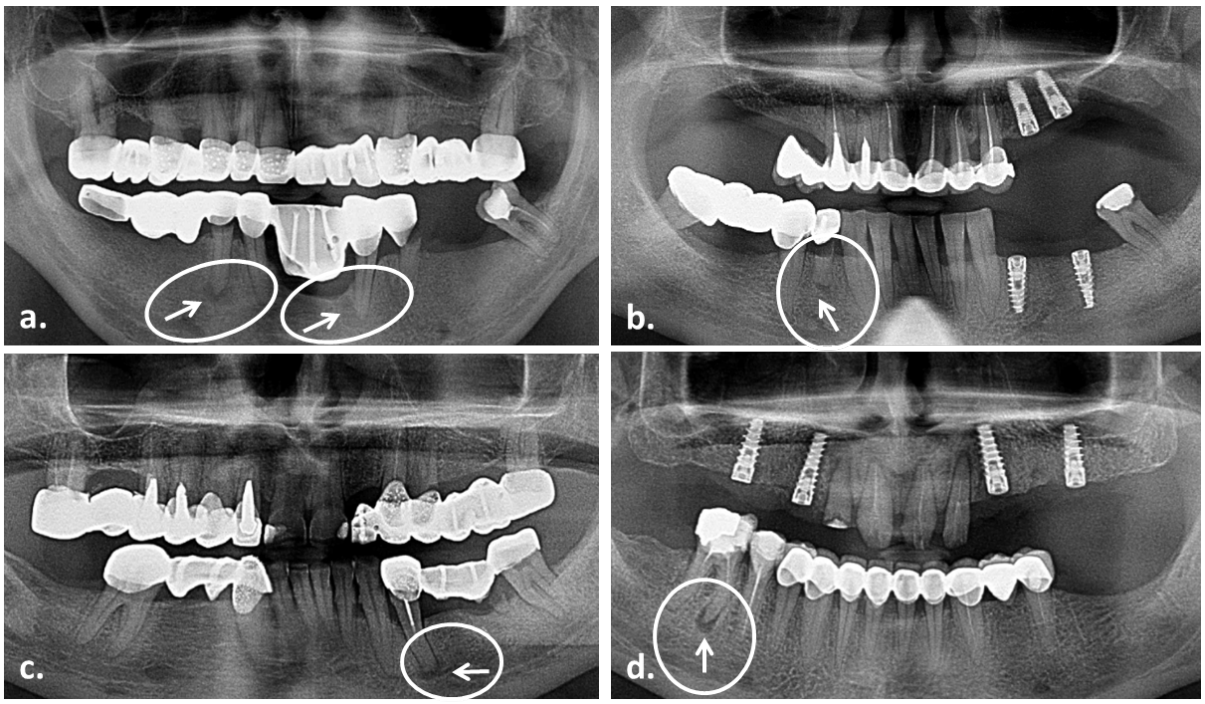

Fig.1. External radicular resorption (ERR) lesions: a) 3.3, 4.4 external inflammatory root resorption; b) 4.4 external replacement root resorption; c) and d) 3.4, 4.6. external inflammatory root resorption

Figure 2 also included cases with EIRR and ERRR.

Figure 2a showed the two right maxillary incisors 1.1, 1.2 with external replacement root resorption lesions, consequent to orthodontic treatment.

Teeth 1.5 and 1.6, with incorrect root canal fillings and coronal-radicular restorations, part of a mesial cantilever bridge showed two external inflammatory root resorption lesions.

On the second image of the figure (Fig.2b) a replacement root resorption on the two mandibles secondary molars (3.7, 4.7) could be seen, as a consequence of the two wisdom teeth in horizontal inclusion, with the crowns pushing towards the roots of the second molars.

The third image of this figure (Fig.2c) showed a right mandibular central incisor (4.1) with external replacement root resorption.

The tooth had no root treatment, the root canal was not radiological detectable and had a hard tissue resorption of about two-thirds of the root.

No radicular radiotransparent area or other signs of apical periodontitis could be observed.

The radiological image also showed a second maxillary right premolar (1.5) with external inflammatory resorption, most likely a tooth with pulp necrosis, without endodontic treatment.

Figure 2d revealed an external inflammatory root resorption lesion on the mesial root of 3.6 and an external replacement resorption aspect on 4.7 molar, due to the presence of the third molar which was bone impacted in an oblique position.

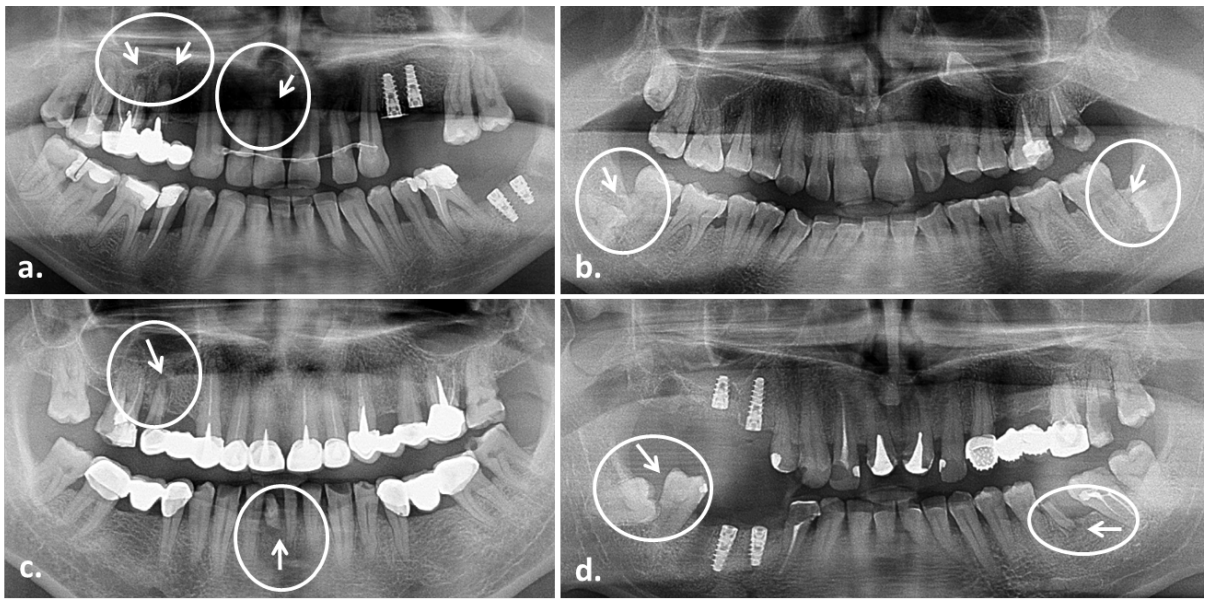

Fig.2. External root resorption lesions: a) 1.1, 1.2 external replacement root resorption and 1.5, 1.6 external inflammatory root resorption; b) 3.7, 4.7 external replacement radicular resorption; c) 4.1 external replacement root resorption, 1.5 external inflammatory root resorption; d) 3.6 external inflammatory root resorption; 4.7. external replacement root resorption

Figure 3 included cases with EIRR, ERRR and also ECRR.

The first image (Fig.3a) showed a right inferior first molar (4.6) with an external inflammatory resorption (EIR) lesion.

The tooth without endodontic treatment had a radioopacity in the pulp chamber, suggesting a partial pulpotomy.

The distal root was surrounded by a radiotransparent area, corresponding to a chronic marginal periodontitis.

Interesting fact was that this patient had several teeth with incomplete endodontic treatment, but without signs of apical periodontitis or root resorption.

Orthopantomographies from figure 3b and 3c revealed several external root resorption lesions: figure 3b showed two external inflammatory resorption lesions: the lateral upper incisor without root canal treatment but with pulp necrosis, and the right inferior first premolar with incorrect endodontic treatment.

The left mandibular first premolar (3.4), a root canal treatment, had a cervical resorption, possibly by replacement of a part of the tooth root by bone tissue.

Figure 3.c presented two external inflammatory root resorption lesions: first left mandibular premolar (3.4) and first right mandibular molar (4.6) with incomplete root canal treatments.

The last image of this figure (Fig.3d) showed two external replacement resorption lesions located on the second upper two premolars (1.5 and 2.5), overloaded by a bridge with distal extensions.

The teeth showed no endodontic treatment and apparently, they seemed vital.

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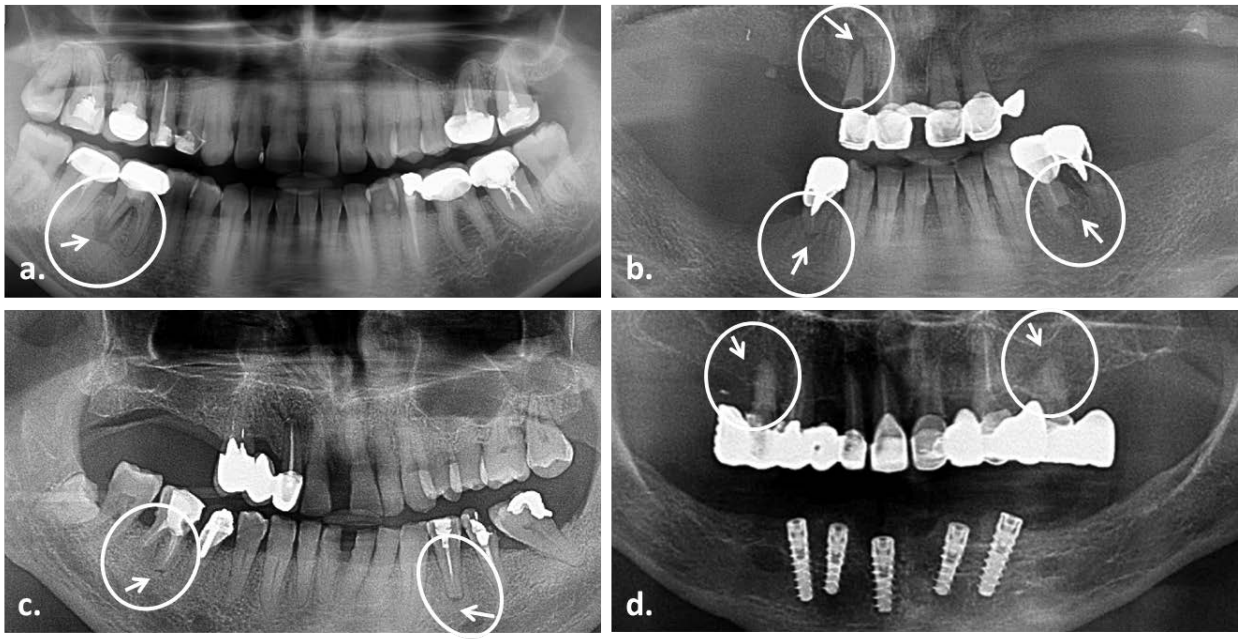

Fig.3. External radicular resorption lesions: a) 4.6 external inflammatory root resorption; b) 1.2, 4.4 external inflammatory root resorption; 3.4 cervical root resorption; c) 3.4, 4.6 external inflammatory root resorption; d) 1.5, 2.5.external replacement root resorption

Figure 4 included cases with EIRR, ERRR and also IRR.

Figure 4a showed the radiological image of the four maxillary incisors with external replacement resorptive injuries, as a consequence of the orthodontic treatment.

Their apexes had an amputated look and the central incisors also showed some irregularities of the root canals, suggesting the association with internal inflammatory resorption lesions.

The image from figure 4b showed an external replacement root resorption of the tooth 3.6, more obvious on the distal root, which has been replaced more than a half by alveolar bone.

The tooth had a large coronary filling and no endodontic treatment.

The OPG from figure 4c showed a combination of internal inflammatory radicular resorption with external inflammatory root resorption of a right second mandible molar (4.7) without endodontic treatment.

Radiological, it could be noticed: a tooth with an occlusal carious process and traces of filling material on the bottom of the cavity, without being able to tell if the pulp chamber was open, an increased volume of the pulp chamber and of the root canals, the apical third root resorption and a significant area of periapical bone lysis (radiotransparency).

Clinically, this radiological image could be interpreted as of a molar with pulp necrosis, internal and external inflammatory root resorption injuries, associated with a well-defined chronic apical periodontitis.

The first left mandibular molar could not be considered as having resorptive lesions, but rather could be seen as a tooth with massive destruction of the hard tissue, which in the future would be removed from its socket, as a consequence of the slow extrusion mechanism, associated with progressive destruction of the tooth.

Figure 4d presented the radiographic image of a 3.8 molar with external replacement resorption, so advanced that the molar appeared to be completely amputated and replaced by alveolar bone, as a result of the osteoblasts repair attempt.

The tooth was the distal pillar of a five elements dental bridge, which probably constituted an overloading of the molar, in time.

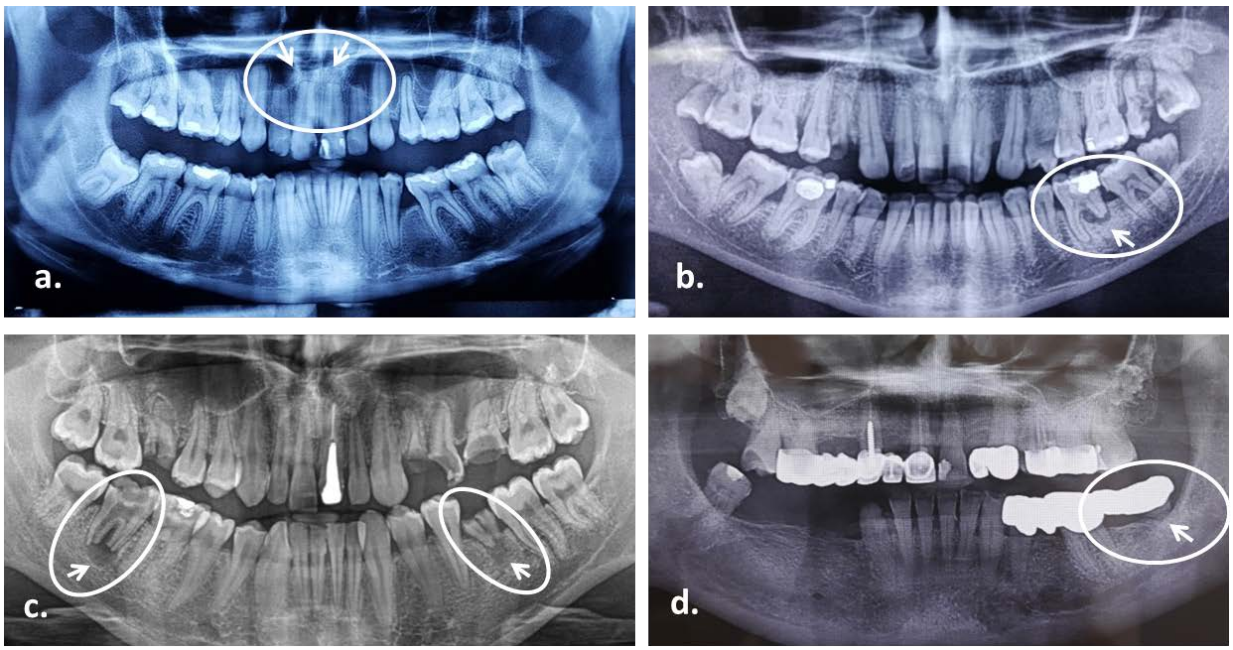

Fig.4. External and internal radicular resorption lesions: a) 1.2, 1.1, 2.1, 2.2 external replacement root resorption and internal inflammatory root resorption; b) 3.6 external replacement root resorption; c) 4.7 internal inflammatory root resorption, associated with external inflammatory root resorption; d) 3.8 external replacement root resorption

Discussions

The resorption process may be self-limiting and may go clinically undetected but, once initiated, if it is supported by infection and/or pressure, the destruction of the hard dental tissues will continue and the tooth may become irrecoverable [4].

The largest number of teeth with root resorption was diagnosed in the age group of 31-65 years, 35%, followed by 10% cases in the group of young people under 30 and by 2% in the elderly over 65 years of age.

The percentage was less than reported by a study [19] in the Indian population (46.8%), but greater than 1.7-27.1 reported by others authors [20,21,22,1].

EIRR was the most encountered type of root resorption found, 57.52% from the cases with RR, similar to another study published before by our group, over 50%, most prevalent in the middle age adults group [1].

Most authors [23] found no relationship between gender and RR, although Brezniak and Wasserstein [24,25] considered that women were more prone to idiopathic RR.

Our research indicated that root resorption was predominant in women (53.09%) than in males (49.07%).

Many of the teeth with RR from this study showed an apical radiotransparency image specific to chronic apical periodontitis, so, in these cases, root resorption was associated with chronic apical periodontitis.

Other studies [26,5,27,11] also confirmed that external inflammatory RR was commonly found in teeth with pulp necrosis and appeared in almost all teeth with chronic apical periodontitis.

Due to the bi-dimensional aspect of conventional radiographs, EIR could be detected only if it was located on the approximate sides of the root; resorptive lesions on the vestibular or oral sides of the roots could only be detected by a CT scan [4].

According to Patel and Saberi [4], there was no classical radiological appearance for external inflammatory resorption lesion, the aspect depending on the age of the lesion: recent resorptions were radio transparent, and the oldest appeared marbled, suggesting the attempt to repair the root structure [9,28].

The EIRR treatment consists of debridement and preparation of the root canal, accompanied by abundant irrigation with EDTA and sodium hypochlorite, given that it is an infection induced resorption [29] and in some cases, therapeutic pastes can also be used, such as Ledermix, inside the root canal, whose corticosteroids and antibiotics act on clastic cells [30].

10.12865/CHSJ.45.02.05

The cervical resorption diagnosed on the left mandibular first premolar (3.4), from figure 3b respected the pathognomonic aspect of the cervical resorption, visibility of the shape of the root canal through the lesion, indicating that it originated from the outside of the root [4].

The treatment depends on the location of the lesion on the tooth root and consists in curettage of the resorptive tissue in the cavity and filling it with restorative material, when it is accessible, or surgical treatment with periodontal flap, curettage, filling of the defect and repositioning of the flap. [29,31].

External replacement root resorption occurs usually in teeth with severe luxation or abnormal trauma injuries [5,32,33]; this could explain the situation of the central mandibular incisor in figure 2c, which, most likely has been mobilized in the past, but has remained in its socket.

Subsequently, in the remodeling process, osteoblastic activity could replace absent root dentine with alveolar bone [26,5,34].

External replacement root resorption seen in figures 2a, 2b, 2d occurred due to included teeth, tumours, orthodontic treatments [35,5,31]; it ceased with the removal of the cause (in this situation, after the extraction of the third included molar) and the root surface have been repaired with radicular cementum [5,6].

The treatment of this type of RR is based on the tooth's response to vitality tests, which is usually delayed; even if absent, is not an indication for endodontic treatment in the absence of other clinical seeds. If the tooth is in a favorable position, it should not intervene immediately because the replacement resorption proceeds at a slow rate, although the possibility of tooth ankylosis should be monitored in time [29].

The internal RR lesions described in figures 4a, located on the maxillary central incisors and in figure 4c, on the lower right second molar were similar with Patel and Saberi's [4] description of the internal inflammatory root resorption appearance, as a symmetrical, round or oval radiolucency, located on the root surface. In practice, images deviated frequently from this pattern.

An X-ray performed by parallax technique could bring clarification about these injuries which often could be confused with external cervical root resorption, in teeth with more than one root.

CBCT was the most appropriate exam in this situation.

Regarding the internal replacement root resorption, the root surface had a "cloudy" or spotted look, because of the hard tissue radiopaque inclusions and the root canal looked distorted and expanded. [4].

The treatment of this type of resorption consists in the preparation of the root canal either up to the resorption level and expectation for hard tissue repair or root preparation including the area with resorption and root canal filling [29,36].

RR control and hard tissue formation stimulation could be achieved by using anti-clastic therapeutic agents (Ledermix) and calcium hydroxide or ProRoot MTA. [37].

Patel and Saberi [4] also described the „apical transient breakdown", which radiological showed an enlargement of the periapical space with apical discontinuity of the lamina dura.

This form occurred in teeth suffering from mild or moderate trauma, and returned to normal radiological appearance within one year.

In fact, this lesion was an inflammatory external resorption and included a short resorption phase followed by a short repair phase.

Root resorption is usually diagnosed on orthopantomographies, with advantages such as low radiation exposure, entire dental arch view, but also disadvantages caused by magnification errors or overlapping of the dental structures, which could lead to an underestimation of the extent of root resorption lesions.

The OPG exam is largely used in Romania, as a routine radiography and it is based on the ALARA radiation protection principles: it uses an acceptable radiation dose compared to a series of periapical radiographies and less than CBCT exam. Gavala et al. [38,39] stated that the risk of radiation associated with panoramic radiography was still uncertain, although the absorbed doses were low.

In our country, the panoramic radiography is a highly recommended complementary exam and the situation is similar to other countries, too: Koreea [16], Sweden [17] and Belgium [18], therefore, the chances of finding radicular resorption injuries are very high.

In Koreea, panoramic radiography was included in the national health check-up program and it was an effective complementary exam to oral examinations [16].

It has enough diagnostic accuracy in dental caries, periodontal diseases and other lesions and the radiation dose is lower than traditional full-mouth periapical radiography [40].

In Sweden, 61% of the dentists had access to panoramic radiology techniques, especially with a direct digital sensor, compared to around 8% who had access to CBCT [17] and in Belgium, 76% of the dentists had access to a panoramic unit and one in five to a CBCT, almost all panoramic units having digital detectors. [18].

It is clear that digital panoramic radiography is more used than CBCT, therefore, the chances of finding radicular resorption injuries are obviously higher.

OPGs, however, show a 20% overestimation of external radicular resorption lesions, compared to periapical radiographies [19,41,42].

A study [14] on the accuracy of external RR detection using panoramic radiographs compared to tomosynthetically reconstructed panoramic radiography (TPAN) diagnosis, which is "a form of limited angle tomography that produces section, or 'slice,' images from a series of projection images acquired as the x-ray tube moves over a prescribed path" [43], concluded that TPAN is slightly more accurate for the root resorption detection than regular digital panoramic radiography.

The same study quoted another [12] saying that panoramic radiography was not a useful investigation in RR diagnosis.

Ahuja [44] and Saccomanno [12] concluded that periapical radiographs were more efficient in assessing RR, compared to panoramic radiographs, where the root resorption seemed more pronounced and the difference in magnification was responsible for.

In 2014, Patel and Durak [27] set out several aspects regarding the role of CBCT examination in the assessment of resorption lesions, which means that the root resorption diagnosis was established based on conventional radiography, but the CBCT exam was the one that could bring clear data on the extent and location of the lesions.

CBCT should not be used for routine screening and it should only be indicated when conventional radiographs offered a limitation of information and additional details needed to be identified [45].

CBCT exam is also recommended for monitoring these lesions, but only after a proper clinical and radiological assessment. CBCT indications were stipulated by the recommendations of the European Endodontic Society [27].

A CBCT scan could be considered only after a complete clinical examination has been performed and conventional X-rays have been taken and evaluated [9,46].

As for any device emitting ionizing radiation, the benefits of CBCT scanning must outweigh the risks [47].

This is especially important in children and adolescents who are more sensitive to the potential effects of the ionizing radiation [48].

The ALARA principle (as low as reasonably achievable) should be considered in all cases.

A CBCT recommendation should be considered only if the additional information from the reconstituted three-dimensional images will contribute to the diagnosis and/or improvement of the management of a tooth with an endodontic problem.

The CBCT exam can assess the nature of the lesion, including root perforations and whether the lesion can be surgically or non-surgically treated [29].

CBCT with FOV (limited field of view) could be considered in situations such as: diagnosis of the radiographic features of the periapical pathology when there are contradictory signs and/or symptoms (non-specific), confirmation of the local pathology which is not related to the teeth, assessment and/or management of complex dento-alveolar trauma, complications of the endodontic treatment (for example, root perforations) and, of course, in the evaluation and/or management of root resorption injuries.

Conclusions

Root resorption is commonly diagnosed with OPGs, having low cost advantages, visualization of the entire dental arch, but also disadvantages caused by magnification errors or overlapping of the dental structures, which can lead to an underestimation of the extent of root resorption lesions.

Digital panoramic radiography could be a useful tool for accidentally detecting root resorption and knowing about the radiological appearance of different types of root resorption could allow a faster diagnosis.

Still, the CBCT may be recommended in some cases to confirm the diagnosis.

Acknowledgment

Iulia Roxana Marinescu, Veronica Mercuț and Sanda Mihaela Popescu equally contributed to the manuscript.

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Corresponding Author: Alexandra Carina Bănică, Faculty of Dentistry, University of Medicine and Pharmacy of Craiova, Petru Rares str, no 2-4, e-mail: karinabanica@yahoo.com