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ORIGINAL ARTICLE

Prevalence of Lateral Radiolucency, Apical Root Resorption and Periapical Lesions in Portuguese Patients: A CBCT Cross-Sectional Study with a Worldwide Overview

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ABSTRACT

Objective: Apical periodontitis develops when bacteria, or their by products, migrate from the infected root canal system space to the surrounding apical tissues. The objective of the present multi-center cross-sectional study was to analyze the prevalence of lateral radiolucency, apical root resorption and periapical lesions in 7 districts of Portugal using cone-beam computed tomographic (CBCT) assessment.

Methods: A total of 1,249 CBCT scans, from 11 dental clinics, were screened. Data regarding 22,899 teeth was included. For each tooth the recorded data was the presence of lateral radiolucency, apical root resorption, periapical lesions, previous root canal treatment, missed root canals, length of root canal filling (short, good or overfilling) and type of coronal restoration (intact tooth, non-restored, filling or crown). Differences between districts were tested using chi-squared. A $P<0.05$ was considered significant.

Results: The proportion of lateral radiolucency ranged between 0.0% (Aveiro, Braga and Coimbra) and 0.9% (Lisbon), while the prevalence of apical root resorption ranged from 0.0% (Braga and Coimbra) to 3.0% in Setubal. The nationwide proportion of lateral radiolucency was 0.4%, while for apical root resorption was 1.1%. The prevalence of periapical lesions varied from 4.1% (Braga) and 13.0% (Lisbon) with a nationwide proportion of 10.0%. Significant differences were noted between districts ($P<0.05$).

Conclusion: The prevalence of lateral radiolucency and apical root resorption were low in all districts. Root canal filled teeth were associated with higher periapical lesions proportions than non-treated teeth. Independently of the assessed district, the periapical status may be influenced by both quality of the endodontic treatment and coronal restoration.

Keywords: Apical periodontitis, cone-beam computed tomography, cross-sectional study, diagnostic imaging, endodontically treated teeth, periapical disease

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HIGHLIGHTS

- A nationwide multi-center lateral radiolucency, apical root resorption and periapical lesions assessment was conducted in Portuguese patients.
- A global sample of 22,889 teeth from 1,249 patients were screened.
- The proportion of lateral radiolucency and apical root resorption was low at a regional and global level.
- The percentage of periapical lesions varied from 4.1% in Braga and 13.0% in Lisbon, with a nationwide proportion of 10.0%.
- The comparison between regions showed significant differences regarding proportions of lateral radiolucency, apical root resorption and periapical lesions.

INTRODUCTION

Apical periodontitis develops as a consequence of root canal system infection (1-3). Bacteria and their toxins are capable of reaching the pulp space originally coming from dental caries or following trauma or operative procedures and ultimately may lead to changes in the periapical bone structure which may be visible as radiolucency in radiographs (4-6).

Due to its importance in public health, several studies have assessed the periapical status in different populations (7-10). Ineffective elimination of microbial infection (4), quality of the root obturation (11) and adequate coronal restoration (12, 13) are the main reasons for developing periapical lesions. A systematic review (14) reported that preoperative absence of periapical radiolucency, root filling extending within 2 mm to radiographic apex,

root canal obturation without voids, and a satisfactory coronal restoration were associated with a superior root canal treatment outcome. Other studies (10, 15, 16) have documented the higher proportions of apical periodontitis on root canal treated teeth when compared to non-treated cases, while treated teeth presenting missed canals (17, 18) were associated with a higher percentage of periapical lesions.

Imaging examinations in endodontics play an important role in the process of disease diagnosis, evaluation of procedure quality and assessment of healing progress (10, 19). Currently, several periapical periodontitis prevalence studies based on imaging assessments have been conducted. The overall reported pathology proportions ranges from 1.1% in Norway (20) to 15.1% in Palestine (21), and from 15.3% in Finland to (22) to 73.9% in Turkey (23) for root canal filled teeth, with all four studies relying on panoramic radiograph assessments.

The vast majority of periapical periodontitis prevalence studies are based on the evaluation and assessment of 2-dimensional imaging modalities such as periapical radiographs (8, 15), panoramic radiographs (7, 24) or a combination of both (23). There are few studies that rely on 3-dimensional imaging assessment with cone-beam computed tomography (CBCT) examinations (25, 26) and even less studies that reported data regarding lateral radiolucency or apical root resorption (26). CBCT provides high resolution images with a superior capacity, whan compared to radiographs, in the detection of anatomic variations, missed canals, internal and external resorptions, perforations and other pathologies in periapical tissues (18, 24, 27). According to Patel et al. (28) the 3-dimensional view helps to minimise the superimposition of anatomic structures which overcomes one of the most relevant limitation of conventional radiograph providing the clinicians with a superior diagnostic tool.

Considering the limited information available using 3-dimensional imaging, the aim of the present study was to determine the regional and nationwide prevalence of lateral radiolucency, root resorption and periapical lesions in Portuguese patients based on CBCT.

MATERIALS AND METHODS

The present study followed the "strengthening the reporting of observational studies in epidemiology" (STROBE statement). This study received an approval by an ethics commission on April 23rd 2018 and followed previous published studies (17, 26, 29).

Sample selection

The sample was a convenience sample in which all the CBCT datasets available in the source locations were assessed following a pre-established protocol.

Data acquisition

In order to standardise the characteristics of the CBCT examinations to be assessed, only large size field-of-view volumes with voxel sizes equal or lower than 200 µm were included. All the examinations were already available at the time of the data assessment, and were performed for several reasons such as endodontic or surgical diagnostic procedures and treatment planning. No volume acquisition was performed for the sole purpose of the present study which adheres to the position of statement guidelines of the European Society of Endodontology regarding the use of CBCT (30). The CBCT brand and voxel size according to each region were the following: Hyperion X5 with 80 µm (My Ray, Imola, Italy) (Aveiro, Coimbra, Faro); NewTom Giano with 75 µm (NewTom, Verona, Italy) (Braga, Setúbal); RCT700 with 100 µm (Rayscan, Gyeonggi-do, Korea) (Lisbon), R100 with 125 µm (Morita, Kyoto, Japan) (Lisbon), I-Max Touch with 92 µm (Owandy, Croissy-Beaubourg, France) (Lisbon), Promax 3D with 200 µm (Planmeca, Helsinki, Finland) (Lisbon), Orthophos Xg 3D with 160 µm (Sirona, Bensheim, Germany) (Oporto); and Vistavox with 120 µm (Durr Dental, Gechinge, Germany) (Oporto). All examinations ranged from 84 kV to 94 kV and from 9.0 mA and 14.0 mA.

Data assessment

The data assessment was performed by 5 examiners (all endodontists) with experience working with CBCT visualisation software and instructed to follow the same assessment protocol as described below. The dataset screening considered the tooth as a whole. In multi-rooted teeth, all roots were considered and the most problematic condition/finding was recorded for the particular tooth. All examiners followed a strict standard pre-defined screening methodology which included the assessment of each root in the axial, coronal and sagittal planes after a proper 3-dimensional alignment of the visualisation software reference lines with the long axis of the root being assessed. All assessments were analysed with a proper visualisation software as recommended by the scanner manufacturer. The visualisation software used were: iRYS (Imola, Italy) for Hyperion X5; NNT (Verona, Italy) for NewTom Giano; Xelis 3D (Gyeonggi-do, Korea) for RCT700; One Volume Viewer (Kyoto, Japan) for R100; Quickvision (Croissy-Beaubourg, France) for I-Max Touch; Romexis (Helsinki, Finland) for Planmea; Galileos (Bensheim, Germany) for Orthophos; and DBSWin (Gechinge, Germany) for Vistavox. Although the visualisation software were different amongst some regions, all displayed similar functions which allowed an equal methodology of assessment for all CBCT datasets. The examiners were allowed to change the software settings such as applying filters or using noise reduction tools in order to aid the evaluation process. Unfilled roots, primary dentition, impacted teeth, third molars or teeth that could not be correctly screened due to CBCT artefacts, and which could be seen as a possible source of bias, were excluded.

For each tooth the following information was recorded: (a) tooth number; (b) presence/absence of lateral radiolucency; (c) presence/absence of apical root resorption; (d) presence/absence of periapical lesions (classified according to Estrela et al. (6) where intact periapical bone structures (absence) was scored 0 and its presence from 1 to 5 (radiolucency showing a diameter of more than 0.5 mm); (e) presence/absence of previous root canal treatment; (f) presence of missed root canals; (g) length of root canal filling according to Ng et al. (14) (classified as: "short" when filled at least 2 mm short of the radiographic apex; "good or flush" when root canal material was place between 0 to 2 mm of the radiographic apex; or "overfilling or long" when the filling material is beyond the radio-

graphic apex); and (h) type of coronal restoration (intact tooth, non-restored, filling or crown).

Intra- and inter-rater reliability

In order to determine the intra- and inter-rater reliability, 10 CBCT datasets (containing 319 teeth) were screened by the 5 examiners independently. The first screening was used to determine the inter-rater score by running an interclass correlation coefficient (ICC). One month later a second screening of the same 10 volumes were conducted and the individual results compared to the first assessment in order to determine the inter-rater score by running the Cohen's kappa test. The variables to be considered were the periapical status, presence/absence of previous root canal treatment and coronal restoration. The group scores for the three previously mentioned variables were 0.92, 0.94 and 0.94, respectively, while the individual scores for the 5 examiners were 0.61, 0.82, 0.77, 0.95 and 0.74, and 1.00, 1.00, 1.00, 0.98 and 1.00, and 1.00, 0.68, 1.00, 0.84 and 0.73, respectively.

Statistical analysis

The primary outcomes were lateral radiolucency, root resorption and periapical lesions, and their proportions, at a nationwide and regional level, were expressed in means with 95% confidence interval (CI). Chi-square test was used to analyse primary outcome differences between regions (SPSS software version 24; IBM SPSS Statistics, Chicago, IL, USA). A P value of <0.05 was to be considered significant.

RESULTS

A total of 1,249 CBCT examinations (Portuguese patients, 528 males and 721 females with a mean age of 47 years) performed between 2012 and 2020, were collected from 11 private dental clinics from 7 districts of Portugal and assessed from January 2018 to March 2020.

The exclusions represented less than 3% of the initial available sample. An overall sample of 22,899 teeth were screened (11.450 anterior, 6.355 premolars and 5.094 molars).

The prevalence of lateral radiolucency ranged from 0.0% in Aveiro, Braga and Coimbra to 0.9% [0.7%-1.1% CI 95%] in Lisbon, while the percentages of root resorption varied from 0.0% in Braga and Coimbra to 3.0% [2.6%-3.4% CI 95%] in Setúbal (Table 1). Both variables presented low proportions in all the studied locations independently of the tooth being assessed (Table 2, 3, 4 and 5). The nationwide prevalence of periapical lesions was 10.0% [9.6%-10.4% CI 95%]. Braga presented the lowest percentages of periapical lesions, while Lisbon was the location with the highest (4.1% [2.6%-5.6% CI 95%] and 13.0% [12.2%-13.8% CI 95%], respectively) (Table 1 and Figure 1 and 2). Regions presented differences regarding the proportions of lateral radiolucency, root resorption and periapical lesions (P<0.05). Additionally, 54.0% [52.0%-56.0% CI 95%] of all root canal filled teeth were associated with periapical lesions at a nationwide level, while the district presenting higher proportion was Lisbon (65.4% [62.1%-68.7% CI 95%]) (Table 1 and Figure 2) with the mandibular lateral incisor being the one presenting the highest prevalence on that region (Table 3). Moreover, 79.0% [74.5%-83.5% CI 95%] of all root canal filled teeth presenting a missed root canal showed periapical

TABLE 1. Overall results of lateral radiolucency, root resorption and periapical lesions prevalence according to geographic region

Factors evaluated				Prevalence of periapical lesions									
					Previous root canal treatment (RCT)			Length of root canal obturation			Type of coronal restoration		
Location	n	Lateral radiolucency*	Root resorption*	Periapical lesions* (Overall)	With RCT	Without RCT	With a missed root canal	Short	Good	Overfilling	Intact tooth	Non-restored	Filling	Crown
Aveiro	933	0.0% (0/933)	0.1% (1/933)	7.4% (69/933)	53.9% (55/102)	1.7% (14/831)	85.7% (12/14)	78.0% (32/41)	38.8% (19/49)	33.3% (4/12)	1.0% (6/572)	28.6% (6/21)	10.6% (30/283)	47.4% (27/57)
Braga	691	0.0% (0/691)	0.0% (0/691)	4.1% (28/691)	36.1% (26/72)	0.3% (2/619)	90.0% (9/10)	66.7% (20/30)	17.1% (6/35)	0.0% (0/7)	0.0% (0/437)	40.0% (4/10)	8.9% (18/202)	14.3% (6/42)
Coimbra	726	0.0% (0/726)	0.0% (0/726)	4.3% (31/726)	46.3% (31/67)	0.0% (0/659)	75.0% (6/8)	79.3% (23/29)	21.2% (7/33)	16.7% (1/6)	0.0% (0/435)	8.3% (1/12)	8.2% (21/257)	40.9% (9/22)
Faro	652	0.2% (1/652)	1.8% (12/652)	10.1% (66/652)	52.7% (29/55)	6.2% (37/597)	75.0% (9/12)	61.1% (11/18)	50.0% (17/34)	33.3% (1/3)	5.0% (23/457)	57.1% (4/7)	10.2% (15/147)	58.5% (24/41)
Lisbon	6902	0.9% (61/6902)	0.7% (49/6902)	13.0% (900/6902)	65.4% (536/819)	6.0% (364/6083)	90.5% (76/84)	83.6% (225/269)	53.5% (230/430)	67.5% (81/120)	2.2% (98/4499)	62.5% (90/144)	26.6% (504/1892)	56.7% (208/367)
Oporto	7469	0.1% (8/7469)	0.3% (22/7469)	7.4% (553/7469)	54.2% (409/754)	2.1% (144/6715)	80.2% (77/96)	68.2% (257/377)	42.2% (130/308)	31.9% (22/69)	0.5% (18/3967)	9.6% (49/511)	11.1% (279/2505)	42.6% (207/486)
Setubal	5526	0.5% (29/5526)	3.0% (166/5526)	11.5% (635/5526)	41.7% (262/628)	7.6% (373/4898)	65.1% (56/86)	55.4% (77/139)	39.6% (132/333)	34.0% (53/156)	6.5% (238/3670)	38.7% (36/93)	16.7% (241/1439)	37.0% (120/324)
Overall	22899	0.4% (99/22899)	1.1% (250/22899)	10.0% (2282/22899)	54.0% (1348/2497)	4.6% (934/20402)	79.0% (245/310)	71.4% (645/903)	44.3% (541/1222)	43.4% (162/373)	2.7% (383/14037)	23.8% (190/798)	16.5% (1108/6725)	44.9% (601/1339)

*Significant differences between regions (P<0.05)

TABLE 2. Prevalence of lateral radiolucency, root resorption and periapical lesions on maxillary anterior teeth

Factors evaluated Location	n	Lateral radiolucency	Root resorption	Prevalence of periapical lesions										
				Periapical lesions (Overall)	Previous root canal treatment (RCT)		With a missed root canal	Length of root canal obturation			Type of coronal restoration			
					With RCT	Without RCT		Short	Good	Overfilling	Intact tooth	Non-restored	Filling	Crown
Maxillary central incisor														
Aveiro	74	0.0% (0/74)	0.0% (0/74)	8.1% (6/74)	33.3% (3/9)	4.6% (3/65)	-	-	42.9% (3/7)	0.0% (0/2)	4.3% (2/47)	0.0% (0/2)	5.9% (1/17)	37.5% (3/8)
Braga	55	0.0% (0/55)	0.0% (0/55)	0.0% (0/55)	-	-	-	-	-	-	-	-	-	-
Coimbra	55	0.0% (0/55)	0.0% (0/55)	5.5% (3/55)	42.9% (3/7)	0.0% (0/48)	100% (1/1)	100% (2/2)	20.0% (1/5)	-	0.0% (0/37)	0.0% (0/2)	16.7% (2/12)	25.0% (1/4)
Faro	51	0.0% (0/51)	3.9% (2/51)	19.6% (10/51)	57.1% (4/7)	13.6% (6/44)	-	-	57.1% (4/7)	-	11.1% (4/36)	-	20.0% (1/5)	50.0% (5/10)
Lisbon	590	1.0% (6/590)	2.2% (13/590)	14.2% (84/590)	63.1% (53/84)	6.1% (31/506)	-	81.0% (17/21)	50.0% (25/50)	84.6% (11/13)	2.6% (10/389)	50.0% (4/8)	26.2% (37/141)	63.5% (33/52)
Oporto	585	0.0% (0/585)	1.5% (9/585)	5.8% (34/585)	44.3% (31/70)	0.6% (3/515)	-	46.2% (6/13)	44.9% (22/49)	37.5% (3/8)	0.7% (2/303)	3.5% (2/57)	3.7% (6/163)	38.7% (24/62)
Setubal	444	0.0% (0/444)	4.3% (19/444)	15.1% (67/444)	40.3% (29/72)	10.2% (38/372)	-	25.0% (1/4)	46.2% (24/52)	25.0% (4/16)	10.4% (30/288)	33.3% (1/3)	20.4% (21/103)	30.0% (15/50)
Overall	1854	0.3 % (6/1854)	2.3% (43/1854)	11.0% (204/1854)	48.8% (123/252)	5.1% (81/1602)	100% (1/1)	65.0% (26/40)	45.7% (79/173)	46.2% (18/39)	4.2% (48/1142)	9.7% (7/72)	15.1% (68/451)	42.9% (81/189)
Maxillary lateral incisor														
Aveiro	70	0.0% (0/70)	0.0% (0/70)	5.7% (4/70)	25.0% (2/8)	3.2% (2/62)	-	0.0% (0/1)	28.6% (2/7)	-	2.5% (1/40)	25.0% (1/4)	4.8% (1/21)	20.0% (1/5)
Braga	52	0.0% (0/52)	0.0% (0/52)	3.8% (2/52)	28.6% (2/7)	0.0% (0/45)	-	50.0% (1/2)	25.0% (1/4)	0.0% (0/1)	0.0% (0/40)	-	12.5% (1/8)	25.0% (1/4)
Coimbra	53	0.0% (0/53)	0.0% (0/52)	1.9% (1/53)	20.0% (1/5)	0.0% (0/48)	-	100% (1/1)	0.0% (0/3)	0.0% (0/1)	0.0% (0/39)	0.0% (0/1)	9.1% (1/11)	0.0% (0/2)
Faro	50	0.0% (0/50)	6.0% (3/50)	6.0% (3/50)	33.3% (1/3)	4.3% (2/47)	-	-	33.3% (1/3)	-	0.0% (0/38)	-	0.0% (0/5)	42.9% (3/7)
Lisbon	565	0.4% (2/565)	1.6% (9/565)	11.7% (66/565)	67.1% (47/70)	3.8% (19/495)	100% (1/1)	86.7% (13/15)	56.4% (22/39)	75.0% (12/16)	2.3% (9/399)	40.0% (2/5)	25.2% (31/123)	63.2% (24/38)
Oporto	577	0.0% (0/577)	1.7% (10/577)	5.9% (34/577)	47.4% (27/57)	1.3% (7/520)	-	66.7% (10/15)	40.0% (14/35)	42.9% (3/7)	0.3% (1/301)	6.6% (5/76)	5.9% (9/152)	39.6% (19/48)
Setubal	425	0.7% (3/425)	5.6% (24/425)	10.8% (46/425)	39.2% (20/51)	7.0% (26/374)	-	71.4% (5/7)	31.3% (10/32)	41.7% (5/12)	6.3% (17/270)	20.0% (1/5)	8.6% (9/105)	42.2% (19/45)
Overall	1792	0.3% (5/1792)	2.6% (46/1792)	8.7% (156/1792)	49.8% (100/201)	3.5% (56/1591)	100% (1/1)	73.2% (30/41)	40.7% (50/123)	54.1% (20/37)	2.5% (28/1127)	9.9% (9/91)	12.2% (52/425)	45.0% (67/149)
Maxillary canine														
Aveiro	74	0.0% (0/74)	1.4% (1/74)	10.8% (8/74)	58.3% (7/12)	1.6% (1/62)	-	83.3% (5/6)	40.0% (2/5)	0.0% (0/1)	2.4% (1/42)	0.0% (0/3)	5.0% (1/20)	66.7% (6/9)
Braga	57	0.0% (0/57)	0.0% (0/57)	0.0% (0/57)	-	-	-	-	-	-	-	-	-	-
Coimbra	57	0.0% (0/57)	0.0% (0/57)	0.0% (0/57)	-	-	-	-	-	-	-	-	-	-
Faro	50	0.0% (0/50)	0.0% (0/50)	4.0% (2/50)	50.0% (2/4)	0.0% (0/46)	-	-	50.0% (2/4)	-	0.0% (0/42)	0.0% (0/1)	0.0% (0/4)	66.7% (2/3)
Lisbon	578	1.0% (6/578)	0.7% (4/578)	10.0% (58/578)	48.4% (31/64)	5.3% (27/514)	-	63.6% (7/11)	46.3% (19/41)	41.7% (5/12)	1.2% (5/413)	72.7% (8/11)	28.8% (34/118)	30.6% (11/36)
Oporto	592	0.2% (1/592)	0.0% (0/592)	5.1% (30/592)	35.3% (18/51)	2.2% (12/541)	-	47.8% (11/23)	28.6% (6/21)	14.3% (1/7)	0.3% (1/325)	4.1% (3/74)	9.9% (14/141)	23.1% (12/52)
Setubal	442	0.0% (0/442)	1.6% (7/442)	9.0% (40/442)	23.1% (18/78)	6.0% (22/364)	-	31.3% (5/16)	24.4% (11/45)	11.8% (2/17)	4.5% (13/290)	28.6% (4/14)	13.5% (13/96)	23.8% (10/42)
Overall	1850	0.4% (7/1850)	0.6% (12/1850)	7.5% (138/1850)	35.2% (76/216)	3.8% (62/1634)	-	48.3% (28/58)	33.3% (40/120)	21.1% (8/38)	1.7% (20/1199)	14.3% (15/105)	15.7% (62/395)	27.2% (41/151)

TABLE 3. Prevalence of lateral radiolucency, root resorption and periapical lesions on mandibular anterior teeth

Factors evaluated Location	n	Lateral radiolucency	Root resorption	Prevalence of periapical lesions										
				Periapical lesions (Overall)	Previous root canal treatment (RCT)		With a missed root canal	Length of root canal obturation			Type of coronal restoration			
					With RCT	Without RCT		Short	Good	Overfilling	Intact tooth	Non-restored	Filling	Crown
Mandibular central incisor														
Aveiro	78	0.0% (0/78)	0.0% (0/78)	0.0% (0/78)	-	-	-	-	-	-	-	-	-	-
Braga	56	0.0% (0/56)	0.0% (0/56)	0.0% (0/56)	-	-	-	-	-	-	-	-	-	-
Coimbra	60	0.0% (0/60)	0.0% (0/60)	1.7% (1/60)	100% (1/1)	0.0% (0/59)	-	-	100% (1/1)	-	0.0% (0/53)	-	14.3% (1/7)	-
Faro	53	0.0% (0/53)	5.7% (3/53)	18.9% (10/53)	100% (4/4)	12.2% (6/49)	-	-	100% (4/4)	-	13.0% (6/46)	-	0.0% (0/3)	100% (4/4)
Lisbon	572	1.0% (6/572)	1.0% (6/572)	6.3% (36/572)	80.0% (12/15)	4.3% (24/557)	-	100% (4/4)	50.0% (3/6)	100% (5/5)	2.5% (13/523)	-	47.7% (21/44)	40.0% (2/5)
Oporto	635	0.0% (0/635)	0.0% (0/635)	2.7% (17/635)	57.9% (11/19)	1.0% (6/616)	100% (2/2)	50.0% (1/2)	61.5% (8/13)	50.0% (2/4)	0.6% (3/507)	0.0% (0/5)	9.6% (11/114)	33.3% (3/9)
Setubal	503	0.4% (2/503)	7.8% (39/503)	14.5% (73/503)	57.1% (4/7)	13.9% (69/496)	100% (3/3)	100% (2/2)	100% (2/2)	0.0% (0/3)	12.9% (62/480)	100% (3/3)	46.2% (6/13)	28.6% (2/7)
Overall	1957	0.4% (8/1957)	2.5% (48/1957)	7.0% (137/1957)	66.7% (32/48)	5.5% (105/1909)	100% (5/5)	87.5% (7/8)	64.3% (18/28)	58.3% (7/12)	4.9% (84/1728)	37.5% (3/8)	20.1% (39/194)	40.7% (11/27)
Mandibular lateral incisor														
Aveiro	78	0.0% (0/78)	0.0% (0/78)	0.0% (0/78)	-	-	-	-	-	-	-	-	-	-
Braga	58	0.0% (0/58)	0.0% (0/58)	3.4% (2/58)	66.7% (2/3)	0.0% (0/55)	-	100% (2/2)	0.0% (0/1)	-	0.0% (0/48)	-	12.5% (1/8)	50.0% (1/2)
Coimbra	60	0.0% (0/60)	0.0% (0/60)	0.0% (0/60)	-	-	-	-	-	-	-	-	-	-
Faro	54	0.0% (0/54)	3.7% (2/54)	9.3% (5/54)	100% (1/1)	7.5% (4/53)	-	-	100% (1/1)	-	7.5% (4/53)	-	-	100% (1/1)
Lisbon	591	0.5% (3/591)	0.8% (5/591)	6.4% (38/591)	87.5% (14/16)	4.2% (24/575)	100% (1/1)	75.0% (3/4)	75.0% (3/4)	100% (8/8)	2.2% (12/534)	75.0% (3/4)	43.8% (21/48)	40.0% (2/5)
Oporto	638	0.0% (0/638)	0.0% (0/638)	2.8% (18/638)	65.0% (13/20)	0.8% (5/618)	100% (3/3)	100% (6/6)	44.4% (4/9)	60.0% (3/5)	0.6% (3/492)	5.3% (1/19)	10.0% (12/120)	28.6% (2/7)
Setubal	504	0.4% (2/504)	5.0% (25/504)	8.5% (43/504)	60.0% (6/10)	7.5% (37/494)	100% (4/4)	100% (3/3)	50.0% (3/6)	0.0% (0/1)	6.9% (33/479)	66.7% (2/3)	29.4% (5/17)	60.0% (3/5)
Overall	1983	0.3% (5/1983)	1.6% (32/1983)	5.3% (106/1983)	72.0% (36/50)	3.6% (70/1933)	100% (8/8)	93.3% (14/15)	52.4% (11/21)	78.6% (11/14)	3.0% (52/1732)	23.1% (6/26)	19.0% (39/205)	45.0% (9/20)
Mandibular canine														
Aveiro	83	0.0% (0/83)	0.0% (0/83)	1.2% (1/83)	100% (1/1)	0.0% (0/82)	-	100% (1/1)	-	-	0.0% (0/72)	-	9.1% (1/11)	-
Braga	62	0.0% (0/62)	0.0% (0/62)	1.6% (1/62)	16.7% (1/6)	0.0% (0/56)	-	100% (1/1)	0.0% (0/5)	-	0.0% (0/48)	50.0% (1/2)	0.0% (0/11)	0.0% (0/1)
Coimbra	59	0.0% (0/59)	0.0% (0/59)	0.0% (0/59)	-	-	-	-	-	-	-	-	-	-
Faro	53	0.0% (0/53)	0.0% (0/53)	0.0% (0/53)	-	-	-	-	-	-	-	-	-	-
Lisbon	592	0.3% (2/592)	0.0% (0/592)	3.9% (23/592)	58.8% (10/17)	2.3% (13/575)	-	60.0% (3/5)	55.6% (5/9)	66.7% (2/3)	1.1% (6/525)	50.0% (3/6)	23.6% (13/55)	16.7% (1/6)
Oporto	652	0.2% (1/652)	0.0% (0/652)	2.8% (18/652)	51.6% (16/31)	0.3% (2/621)	-	52.9% (9/17)	50.0% (6/12)	50.0% (1/2)	0.2% (1/435)	1.5% (1/66)	5.7% (7/123)	32.1% (9/28)
Setubal	513	0.4% (2/513)	2.5% (13/513)	7.0% (36/513)	45.5% (5/11)	6.2% (31/502)	0.0% (0/1)	75.0% (3/4)	33.3% (2/6)	0.0% (0/1)	5.4% (25/460)	20.0% (2/10)	18.9% (7/37)	33.3% (2/6)
Overall	2014	0.2% (5/2014)	0.6% (13/2014)	3.9% (79/2014)	50.0% (33/66)	2.4% (46/1948)	0.0% (0/1)	60.7% (17/28)	40.6% (13/32)	50.0% (3/6)	2.0% (32/1641)	8.2% (7/85)	11.3% (28/247)	29.3% (12/41)

TABLE 4. Prevalence of lateral radiolucency, root resorption and periapical lesions on premolars teeth

Factors evaluated Location	n	Lateral radiolucency	Root resorption	Prevalence of periapical lesions										
				Periapical lesions (Overall)	Previous root canal treatment (RCT)		With a missed root canal	Length of root canal obturation			Type of coronal restoration			
					With RCT	Without RCT		Short	Good	Overfilling	Intact tooth	Non-restored	Filling	Crown
Maxillary first premolar														
Aveiro	56	0.0% (0/56)	0.0% (0/56)	21.4% (12/56)	91.7% (11/12)	2.3% (1/44)	-	88.9% (8/9)	100% (3/3)	-	3.8% (1/26)	60.0% (3/5)	23.8% (5/21)	75.0% (3/4)
Braga	42	0.0% (0/42)	0.0% (0/42)	7.1% (3/42)	37.5% (3/8)	0.0% (0/34)	-	50.0% (1/2)	40.0% (2/5)	0.0% (0/1)	0.0% (0/21)	0.0% (0/1)	18.8% (3/16)	0.0% (0/4)
Coimbra	49	0.0% (0/49)	0.0% (0/49)	2.0% (1/49)	25.0% (1/4)	0.0% (0/45)	-	50.0% (1/2)	0.0% (0/2)	-	0.0% (0/19)	0.0% (0/2)	3.6% (1/28)	-
Faro	44	2.3% (1/44)	0.0% (0/44)	13.6% (6/44)	44.4% (4/9)	5.7% (2/35)	0.0% (0/1)	50.0% (3/6)	33.3% (1/3)	-	7.1% (2/28)	0.0% (0/1)	11.1% (1/9)	50.0% (3/6)
Lisbon	458	0.9% (4/458)	0.4% (2/458)	21.4% (98/458)	75.3% (61/81)	9.8% (37/377)	100% (3/3)	92.6% (25/27)	63.6% (28/44)	80.0% (8/10)	2.8% (7/252)	68.8% (11/16)	37.5% (60/160)	66.7% (20/30)
Oporto	475	0.0% (0/475)	0.0% (0/475)	14.1% (67/475)	63.0% (46/73)	5.2% (21/402)	50.0% (1/2)	81.1% (30/37)	55.6% (15/27)	1.1% (1/9)	0.5% (1/205)	28.6% (8/28)	17.7% (34/192)	48.0% (24/50)
Setubal	312	0.6% (2/312)	1.0% (3/312)	12.8% (40/312)	33.8% (23/68)	7.0% (17/244)	60.0% (3/5)	37.5% (9/24)	35.5% (11/31)	23.1% (3/13)	4.8% (7/145)	28.6% (2/7)	15.4% (19/123)	32.4% (12/37)
Overall	1436	0.5% (7/1436)	0.3% (5/1436)	15.8% (227/1436)	58.4% (149/255)	6.6% (78/1181)	63.6% (7/11)	72.0% (77/107)	52.2% (60/115)	36.4% (12/33)	2.6% (18/696)	40.0% (24/60)	22.4% (123/549)	47.3% (62/131)
Maxillary second premolar														
Aveiro	54	0.0% (0/54)	0.0% (0/54)	18.5% (10/54)	57.1% (8/14)	5.0% (2/40)	-	80.0% (4/5)	28.6% (2/7)	100% (2/2)	0.0% (0/23)	0.0% (0/1)	22.7% (5/22)	62.5% (5/8)
Braga	43	0.0% (0/43)	0.0% (0/43)	0.0% (0/43)	-	-	-	-	-	-	-	-	-	-
Coimbra	44	0.0% (0/44)	0.0% (0/44)	11.4% (5/44)	41.7% (5/12)	0.0% (0/32)	-	60.0% (3/5)	40.0% (2/5)	0.0% (0/2)	0.0% (0/16)	-	12.5% (3/24)	50.0% (2/4)
Faro	47	0.0% (0/47)	2.1% (1/47)	12.8% (6/47)	33.3% (2/6)	9.8% (4/41)	-	33.3% (1/3)	33.3% (1/3)	-	8.3% (2/24)	-	14.3% (3/21)	50.0% (1/2)
Lisbon	439	1.4% (6/439)	0.2% (1/439)	18.0% (79/439)	58.2% (53/91)	7.5% (26/348)	100% (2/2)	71.4% (20/28)	50.9% (29/57)	66.7% (4/6)	1.8% (4/227)	68.4% (13/19)	25.0% (36/144)	53.1% (26/49)
Oporto	437	0.0% (0/437)	0.0% (0/437)	14.0% (61/437)	62.2% (51/82)	2.8% (10/355)	100% (1/1)	81.1% (30/37)	51.2% (21/41)	0.0% (0/4)	0.6% (1/180)	28.6% (6/21)	12.6% (24/191)	66.7% (30/45)
Setubal	311	1.3% (4/311)	0.3% (1/311)	11.6% (36/311)	36.9% (24/65)	4.9% (12/246)	100% (3/3)	58.3% (7/12)	38.9% (14/36)	17.6% (3/17)	2.7% (4/147)	60.0% (6/10)	12.0% (15/125)	37.9% (11/29)
Overall	1375	0.7% (10/1375)	0.2% (3/1375)	14.3% (197/1375)	52.2% (143/274)	4.9% (54/1101)	100% (6/6)	71.4% (65/91)	45.4% (69/152)	29.0% (9/31)	1.7% (11/639)	48.1% (25/52)	15.9% (86/541)	52.4% (75/143)
Mandibular first premolar														
Aveiro	83	0.0% (0/83)	0.0% (0/83)	0.0% (0/83)	-	-	-	-	-	-	-	-	-	-
Braga	55	0.0% (0/55)	0.0% (0/55)	5.5% (3/55)	50.0% (2/4)	2.0% (1/51)	-	100% (1/1)	33.3% (1/3)	-	0.0% (0/43)	100% (1/1)	12.5% (1/8)	33.3% (1/3)
Coimbra	58	0.0% (0/58)	0.0% (0/58)	1.7% (1/58)	50.0% (1/2)	0.0% (0/56)	-	100% (1/1)	0.0% (0/1)	-	0.0% (0/45)	0.0% (0/1)	8.3% (1/12)	-
Faro	52	0.0% (0/52)	0.0% (0/52)	1.9% (1/52)	-	1.9% (1/52)	-	-	-	-	0.0% (0/43)	100% (1/1)	0.0% (0/8)	-
Lisbon	556	0.2% (1/556)	0.2% (1/556)	7.0% (39/556)	51.2% (22/43)	3.3% (17/513)	100% (3/3)	72.7% (8/11)	40.9% (9/22)	50.0% (5/10)	1.2% (5/410)	28.6% (4/14)	14.3% (16/112)	70.0% (14/20)
Oporto	612	0.0% (0/612)	0.0% (0/612)	3.6% (22/612)	40.9% (18/44)	0.7% (4/568)	100% (1/1)	61.1% (11/18)	28.0% (7/25)	0.0% (0/1)	0.0% (0/378)	0.0% (0/66)	7.0% (10/142)	46.2% (12/26)
Setubal	464	0.4% (2/464)	2.2% (10/464)	8.2% (38/464)	37.5% (12/32)	6.0% (26/432)	50.0% (2/4)	57.1% (4/7)	31.3% (5/16)	33.3% (3/9)	4.9% (17/348)	11.1% (1/9)	17.3% (17/98)	33.3% (3/9)
Overall	1880	0.2% (3/1880)	0.6% (11/1880)	5.5% (104/1880)	42.6% (55/129)	2.8% (49/1751)	75.0% (6/8)	62.5% (25/40)	32.4% (22/68)	38.1% (8/21)	1.7% (22/1328)	7.5% (7/93)	11.3% (45/397)	48.4% (30/62)

TABLE 4. Prevalence of lateral radiolucency, root resorption and periapical lesions on premolars teeth

Factors evaluated				Prevalence of periapical lesions										
					Previous root canal treatment (RCT)			Length of root canal obturation			Type of coronal restoration			
Location	n	Lateral radiolucency	Root resorption	Periapical lesions (Overall)	With RCT	Without RCT	With a missed root canal	Short	Good	Overfilling	Intact tooth	Non-restored	Filling	Crown
Mandibular second premolar														
Aveiro	71	0.0% (0/71)	0.0% (0/71)	4.2% (3/71)	27.3% (3/11)	0.0% (0/60)	-	100% (1/1)	22.2% (2/9)	0.0% (0/1)	0.0% (0/40)	-	8.0% (2/25)	16.7% (1/6)
Braga	49	0.0% (0/49)	0.0% (0/49)	6.1% (3/49)	40.0% (2/5)	2.3% (1/44)	-	0.0% (0/2)	100% (2/2)	0.0% (0/1)	0.0% (0/35)	100% (1/1)	9.1% (1/11)	50.0% (1/2)
Coimbra	56	0.0% (0/56)	0.0% (0/56)	0.0% (0/56)	-	-	-	-	-	-	-	-	-	-
Faro	48	0.0% (0/48)	0.0% (0/48)	10.4% (5/48)	20.0% (1/5)	9.3% (4/43)	-	-	25.0% (1/4)	0.0% (0/1)	9.4% (3/32)	-	7.1% (1/14)	50.0% (1/2)
Lisbon	474	1.5% (7/474)	0.0% (0/474)	11.2% (53/474)	43.8% (35/80)	4.6% (18/394)	100% (1/1)	63.0% (17/27)	34.0% (16/47)	33.3% (2/6)	3.0% (8/266)	47.1% (8/17)	12.7% (20/158)	51.5% (17/33)
Oporto	546	0.0% (0/546)	0.0% (0/546)	6.2% (34/546)	33.3% (26/78)	1.7% (8/468)	100% (1/1)	40.5% (15/37)	31.4% (11/35)	0.0% (0/6)	0.3% (1/286)	19.4% (6/31)	7.0% (13/185)	31.8% (14/44)
Setubal	420	0.7% (3/420)	1.7% (7/420)	10.2% (43/420)	37.2% (16/43)	7.2% (27/377)	100% (2/2)	42.9% (3/7)	34.8% (8/23)	38.5% (5/13)	4.5% (12/264)	50.0% (6/12)	16.7% (21/126)	22.2% (4/18)
Overall	1664	0.6% (10/1664)	0.4% (7/1664)	8.5% (141/1664)	36.9% (83/225)	4.0% (58/1439)	100% (4/4)	48.0% (36/75)	32.5% (40/123)	25.0% (7/28)	2.5% (24/956)	33.3% (21/63)	10.7% (58/540)	36.2% (38/105)

lesion. Locally, the proportion of missed canals with lesion ranged from 65.1% [55.0%-75.2% CI 95%] in Setúbal to 90.5% [83.8%-96.4% CI 95%] in Lisbon (Table 1 and Figure 2), with the higher total counts coming from the maxillary first molar (Table 5). The length of the root canal obturation presenting higher prevalence of periapical lesions was the short filling, whose percentages ranged from 55.4% [47.1%-63.7% CI 95%] in Setúbal to 83.6% [79.2%-88.0% CI 95%] in Lisbon (Table 1). As for the type of coronal restoration, the higher proportion of periapical lesion was noted in teeth with crown, with percentages ranging from 14.3% [3.6%-25.0% CI 95%] in Braga to 58.5% [43.2%-73.8% CI 95%] in Faro (Table 1).

DISCUSSION

Although 2-dimensional radiographic analysis remains the most common method used for routine diagnosis of apical periodontitis, the CBCT has the ability to overcome the radiography limitations of an incomplete diagnosis of periapical lesions and treatment quality assessment, (27, 31, 32) due to its superior sensitivity and accuracy in bone changes detection (27). Patel et al. (33) reported that CBCT assessment was 100% successful at identifying periapical lesions while intra-oral radiographs were only 25%, concluding that routine radiographs (panoramic or periapical) underestimates the true prevalence of apical periodontitis. Despite its advantages, is not available yet in every dental office in many countries which prevents both superior clinical diagnosis and large sample sizes collection for cross-sectional research (34, 35). Additionally, it is important to notice that despite all advantages of the CBCT, conventional radiographs should remain the main imaging diagnostic tool, and CBCT should only be reserved for diagnosis challenges or high difficulty cases according to the European Society of Endodontolgy position statement (30).

With the awareness and acceptance of the superior diagnostic capacity of CBCT, a shift has been made in the last years regarding the methodology used in the assessment of periapical lesions in these observational studies. The use of CBCT tends to rectify the radiographic results for higher percentages of periapical lesions prevalence in the studied populations. A study on Turkish patients reported 15.8% of teeth with root filling and apical periodontitis using panoramic assessment (36), another study, conducted a year after based on CBCT reported and rectified the prevalence to 45.6% (37). Similarly in a study on Brazilian patients, and for teeth in the same conditions, a proportion of 16.7% was reported on periapical analysis (38) while 35.4% was documented when assessing CBCT exams (9) (Table 6). Although the studies were performed by different research groups and were based on different sub-populations from the same country, the results appear to be consistent and corroborate with the Portuguese assessment.

Two previous studies in Portuguese patients reported an overall periapical lesion prevalence of 2.0% in Oporto (39) and 4.4% in Coimbra (40), both using radiographs, while the present study, assessing CBCT, recorded 7.4% and 4.3% in those regions, respectively. As for root canal filled teeth with periapical lesions, the previous radiographic studies reported 21.7%, in Oporto, and 29.6%, in Coimbra (39, 40), while the present CBCT study found 54.2% and 46.3%, respec-

TABLE 5. Prevalence of lateral radiolucency, root resorption and periapical lesions on molars teeth

Factors evaluated Location	n	Lateral radiolucency	Root resorption	Prevalence of periapical lesions										
				Periapical lesions (Overall)	Previous root canal treatment (RCT)		With a missed root canal	Length of root canal obturation			Type of coronal restoration			
					With RCT	Without RCT		Short	Good	Overfilling	Intact tooth	Non restored	Filling	Crown
Maxillary first molar														
Aveiro	53	0.0% (0/53)	0.0% (0/53)	20.8% (11/53)	69.2% (9/13)	5.0% (2/40)	80.0% (8/10)	75.0% (6/8)	50.0% (2/4)	100% (1/1)	0.0% (0/12)	50.0% (1/2)	20.6% (7/34)	60.0% (3/5)
Braga	52	0.0% (0/52)	0.0% (0/52)	15.4% (8/52)	57.1% (8/14)	0.0% (0/38)	100% (7/7)	80.0% (8/10)	0.0% (0/2)	0.0% (0/2)	0.0% (0/12)	0.0% (0/2)	18.2% (6/33)	40.0% (2/5)
Coimbra	45	0.0% (0/45)	0.0% (0/45)	8.9% (4/45)	50.0% (4/8)	0.0% (0/37)	66.7% (4/6)	66.7% (4/6)	0.0% (0/1)	0.0% (0/1)	0.0% (0/10)	-	9.4% (3/32)	33.3% (1/3)
Faro	42	0.0% (0/42)	2.4% (1/42)	23.8% (10/42)	75.0% (6/8)	11.8% (4/34)	75.0% (6/8)	80.0% (4/5)	50.0% (1/2)	100% (1/1)	12.5% (2/16)	-	22.7% (5/22)	75.0% (3/4)
Lisbon	408	0.5% (2/408)	0.7% (3/408)	27.7% (113/408)	82.8% (72/87)	12.8% (41/321)	93.2% (41/44)	94.6% (35/37)	75.0% (27/36)	71.4% (10/14)	4.4% (6/137)	77.8% (7/9)	33.2% (79/238)	87.5% (21/24)
Oporto	441	0.2% (1/441)	0.2% (1/441)	15.6% (69/441)	65.3% (49/75)	5.5% (20/366)	76.0% (38/50)	69.4% (43/62)	45.5% (5/11)	50.0% (1/2)	0.9% (1/112)	35.0% (7/20)	16.1% (44/274)	48.6% (17/35)
Setubal	259	0.8% (2/259)	0.4% (1/259)	17.0% (44/259)	53.7% (29/54)	7.3% (15/205)	58.3% (21/36)	57.9% (11/19)	55.0% (11/20)	46.7% (7/15)	4.5% (4/88)	33.3% (1/3)	18.6% (27/145)	52.2% (12/23)
Overall	1300	0.4% (5/1300)	0.5% (6/1300)	19.9% (259/1300)	68.3% (177/259)	7.9% (82/1041)	77.6% (125/161)	75.5% (111/147)	60.5% (46/76)	55.6% (20/36)	3.4% (13/387)	44.4% (16/36)	22.0% (171/778)	59.6% (59/99)
Maxillary second molar														
Aveiro	57	0.0% (0/57)	0.0% (0/57)	7.0% (4/57)	37.5% (3/8)	2.0% (1/49)	100% (2/2)	100% (3/3)	0.0% (0/2)	0.0% (0/3)	0.0% (0/23)	33.3% (1/3)	7.1% (2/28)	33.3% (1/3)
Braga	44	0.0% (0/44)	0.0% (0/44)	6.8% (3/44)	42.9% (3/7)	0.0% (0/37)	100% (2/2)	100% (3/3)	0.0% (0/3)	0.0% (0/1)	0.0% (0/17)	100% (1/1)	8.3% (2/24)	0.0% (0/2)
Coimbra	48	0.0% (0/48)	0.0% (0/48)	6.3% (3/48)	60.0% (3/5)	0.0% (0/43)	100% (1/1)	100% (2/2)	33.3% (1/3)	-	0.0% (0/11)	100% (1/1)	2.9% (1/34)	50.0% (1/2)
Faro	45	0.0% (0/45)	0.0% (0/45)	8.9% (4/45)	100% (2/2)	4.7% (2/43)	100% (2/2)	100% (2/2)	-	-	0.0% (0/22)	50.0% (1/2)	14.3% (3/21)	-
Lisbon	450	0.7% (3/450)	0.2% (1/450)	16.4% (74/450)	65.4% (34/52)	10.1% (40/398)	83.3% (15/18)	90.0% (18/20)	50.0% (13/26)	50.0% (3/6)	4.5% (9/202)	69.2% (9/13)	21.2% (44/208)	44.4% (12/27)
Oporto	486	0.6% (3/486)	0.4% (2/486)	10.1% (49/486)	70.0% (28/40)	4.7% (21/446)	71.4% (15/21)	75.0% (21/28)	57.1% (4/7)	60.0% (3/5)	1.6% (3/182)	22.7% (5/22)	12.2% (31/254)	35.7% (10/28)
Setubal	351	0.6% (2/351)	1.7% (6/351)	17.7% (62/351)	61.8% (34/55)	9.5% (28/296)	57.1% (12/21)	66.7% (10/15)	63.6% (14/22)	55.6% (10/18)	7.4% (11/149)	66.7% (2/3)	21.9% (39/178)	47.6% (10/21)
Overall	1481	0.5% (8/1481)	0.6% (9/1481)	13.4% (199/1481)	63.3% (107/169)	7.0% (92/1312)	73.1% (49/67)	80.8% (59/73)	50.8% (32/63)	48.5% (16/33)	3.8% (23/606)	44.4% (20/45)	16.3% (122/747)	41.0% (34/83)
Mandibular first molar														
Aveiro	42	0.0% (0/42)	0.0% (0/42)	14.3% (6/42)	85.7% (6/7)	0.0% (0/35)	100% (2/2)	75.0% (3/4)	100% (3/3)	-	0.0% (0/11)	-	13.8% (4/29)	100% (2/2)
Braga	29	0.0% (0/29)	0.0% (0/29)	10.3% (3/29)	75.0% (3/4)	0.0% (0/25)	-	100% (3/3)	0.0% (0/1)	-	0.0% (0/9)	-	15.0% (3/20)	-
Coimbra	31	0.0% (0/31)	0.0% (0/31)	22.6% (7/31)	77.8% (7/9)	0.0% (0/22)	-	100% (5/5)	50.0% (1/2)	50.0% (1/2)	0.0% (0/12)	-	25.0% (4/16)	100% (3/3)
Faro	28	0.0% (0/28)	0.0% (0/28)	14.3% (4/28)	50.0% (2/4)	8.3% (2/24)	100% (1/1)	100% (1/1)	33.3% (1/3)	-	0.0% (0/11)	100% (2/2)	7.7% (1/13)	50.0% (1/2)
Lisbon	273	3.3% (9/273)	0.7% (2/273)	27.1% (74/273)	75.4% (49/65)	12.0% (25/208)	80.0% (4/5)	100% (29/29)	57.1% (16/28)	50.0% (4/8)	1.3% (1/80)	78.6% (11/14)	30.8% (49/159)	65.0% (13/20)
Oporto	349	0.3% (1/349)	0.0% (0/349)	16.3% (57/349)	72.6% (45/62)	4.2% (12/287)	100% (10/10)	86.4% (38/44)	28.6% (4/14)	75.0% (3/4)	0.0% (0/110)	23.1% (3/13)	18.3% (37/202)	70.8% (17/24)
Setubal	248	0.8% (2/248)	2.8% (7/248)	13.7% (34/248)	42.2% (19/45)	7.4% (15/203)	100% (3/3)	70.0% (7/10)	36.0% (9/25)	30.0% (3/10)	1.0% (1/105)	57.1% (4/7)	16.9% (20/118)	50.0% (9/18)
Overall	1000	1.2% (12/1000)	0.9% (9/1000)	18.5% (185/1000)	66.8% (131/196)	6.7% (54/804)	95.2% (20/21)	89.6% (86/96)	44.7% (34/76)	45.8% (11/24)	0.6% (2/338)	55.6% (20/36)	21.2% (118/557)	65.2% (45/69)

TABLE 5. Cont.

Factors evaluated					Prevalence of periapical lesions									
					Previous root canal treatment (RCT)		With a missed root canal	Length of root canal obturation			Type of coronal restoration			
Location	n	Lateral radiolucency	Root resorption	Periapical lesions (Overall)	With RCT	Without RCT		Short	Good	Overfilling	Intact tooth	Non restored	Filling	Crown
Mandibular second molar														
Aveiro	60	0.0% (0/60)	0.0% (0/60)	6.7% (4/60)	66.7% (2/3)	3.5% (2/57)	-	100% (1/1)	0.0% (0/1)	100% (1/1)	3.4% (1/29)	-	3.6% (1/28)	66.7% (2/3)
Braga	37	0.0% (0/37)	0.0% (0/37)	0.0% (0/37)	-	-	-	-	-	-	-	-	-	-
Coimbra	51	0.0% (0/51)	0.0% (0/51)	9.8% (5/51)	62.5% (5/8)	0.0% (0/43)	-	100% (4/4)	25.0% (1/4)	-	0.0% (0/11)	-	10.5% (4/38)	50.0% (1/2)
Faro	35	0.0% (0/35)	0.0% (0/35)	0.0% (0/35)	-	-	-	-	-	-	-	-	-	-
Lisbon	356	1.1% (4/356)	0.6% (2/356)	18.3% (65/356)	79.6% (43/54)	7.3% (22/302)	83.3% (5/6)	86.7% (26/30)	71.4% (15/21)	66.7% (2/3)	2.1% (3/142)	87.5% (7/8)	23.4% (43/184)	54.5% (12/22)
Oporto	444	0.2% (1/444)	0.0% (0/444)	9.7% (43/444)	57.7% (30/52)	3.3% (13/392)	100% (5/5)	68.4% (26/38)	33.3% (3/9)	20.0% (1/5)	0.0% (0/151)	15.4% (2/13)	10.7% (27/252)	50.0% (14/28)
Setubal	330	0.9% (3/330)	1.2% (4/330)	10.0% (33/330)	62.2% (23/37)	3.4% (10/293)	75.0% (3/4)	77.8% (7/9)	47.1% (8/17)	72.7% (8/11)	1.3% (2/157)	25.0% (1/4)	14.2% (22/155)	57.1% (8/14)
Overall	1313	0.6% (8/1313)	0.5% (6/1313)	11.4% (150/1313)	65.6% (103/157)	4.1% (47/1156)	81.3% (13/16)	76.2% (64/84)	51.9% (27/52)	57.1% (12/21)	1.2% (6/518)	38.5% (10/26)	13.9% (97/699)	52.9% (37/70)

tively (Table 1 and 6). Another advantage of the present research when compared to the two previous studies was the multi-center methodology allowing a more reliable nationwide understanding. From the 18 continental districts, 7 of the most populous were assessed which together represent 77.2% of the country population. The comparison between regions showed significant differences not only regarding the prevalence of periapical lesions, but also in proportions of lateral radiolucency and apical root resorption.

Several epidemiological studies have been performed in different countries by assessing periapical radiographs, panoramic images, a combination of both or CBCT examinations. According to the reported data, the Portuguese nationwide overall prevalence of periapical lesions (10.0%) corroborates with the results reported in previous studies carried out in Switzerland (8.5%) (41), Croatia (8.5%) (42), Japan (9.4%) (43), Jordan (11.6%) (44) and Belarus (11.7%) (16). However, this percentage is lower compared with the results from Mukhaimer et al. (21) in Palestine (15.1%) and Oginni et al. (45) in Nigeria (14.4.%), but higher than the proportions documented by Skudutyte-Rysstad & Eriksen (20) in Norway (1.1%) and Ureyen Kaya et al. (36) in Turkey (1.2%). Additionally, the results of the present study showed that the prevalence of periapical lesions in root canal filled teeth was 54.0%, which is a lower percentage when compared to the one from Morocco (66.8%) (46) and Spain (64.5%) (8) but considerably higher than the reported prevalence in Finland (15.3%) (22). Table 6 and Figure 3 summarize the previous literature regarding the prevalence of periapical lesions (7, 9, 10, 15, 16, 20-25, 36-88). Considering the imaging methodological differences, the comparison between studies should be made with caution.

Considering only on CBCT studies, the overall apical periodontitis prevalence ranges from 3.4% in Brazil (9) to 10.0% in Portugal (present study) (Table 6). The present research showed that 2.497 teeth (10.9%) had root canal treatment, while only one study presented a higher percentage (12.2%) (10). The present study also noticed small discrepancies between females and males with an overall prevalence of apical periodontitis of 10.1% and 9.7%, respectively. These results are in agreement with others investigations (9, 10) confirming that apical periodontitis is not gender dependent. Nur et al. (37) and Van der Veken et al. (10) found no difference in the percentage of periapical lesions between upper and lower teeth. In the present study higher percentages were observed in the upper teeth corroborating the Scottish (25) and Brazilian reports (9). Moreover, the present results, using a larger sample size, reinforces previously documented findings (17, 26), suggesting a strong association between missed canals in root canal filled teeth and periapical lesions prevalence and the strong influence of the length of root canal obturation and coronal restoration in the root canal treatment outcomes, corroborating previous observations from other countries (9, 11, 18, 88). These results show that apical periodontitis is a prevalent oral disease in the Portuguese population and at a worldwide level. Regional differences (P<0.05) are difficult to be explained considering the homogeneity of the Portuguese population. The present findings may be linked to the economic, social and educational level of the patients attending the dental practices, and also

TABLE 6. Overview of the published studies reporting periapical lesions prevalence according to country

Author	Country	Imaging technique	Teeth with periapical lesion	Root canal filled teeth	Root canal filled teeth with periapical lesion
Timmerman et al. (2017) (47)	Australia	Panoramic radiographs	1.9%	1.7%	41.5%
Kielbasa et al. (2017) (48)	Austria	Panoramic radiographs	12.9%	11.1%	44.9%
Kabak & Abbott (2005) (16)	Belarus	Panoramic radiographs)	11.7%	20.3%	45.2%
De Moor et al. (2000) (24)	Belgium	Panoramic radiographs	6.6%	6.8%	40.4%
Van der Veken et al. (2017) (10)	Belgium	CBCT	5.9%	12.2%	32.7%
Paes da Silva Ramos Fernandes et al. (2013) (9)	Brazil	CBCT	3.4%	7.4%	35.4%
Berlinck et al. (2015) (38)	Brazil	Periapical radiographs	7.9%	6.9%	16,7%
Dugas et al. (2003) (49)	Canada	Panoramic and periapical radiographs	3.1%	2.5%	45.4%
Moreno et al. (2013) (50)	Colombia	Periapical radiographs	-	-	49.0%
Matijevic et al. (2011) (42)	Croatia	Panoramic radiographs	8.5%	8.5%	54.0%
Kalender et al. (2013) (51)	Cyprus	Panoramic and periapical radiographs	7.0%	8.9%	62.0%
Kirkevang et al. (2001) (15)	Denmark	Periapical radiographs	3.4%	4.8%	52.2%
Kirkevang et al. (2006) (52)	Denmark	Periapical radiographs	3.7%	5.6%	44,3%
Vengerfeldt et al. (2017) (53)	Estonia	Panoramic radiographs	6.3%	6.9%	44.6%
Huumonen et al. (2017) (22)	Finland	Panoramic radiographs	4.4%	6.6%	15.3%
Boucher et al. (2002) (54)	France	Periapical radiographs	7.4%	19.1%	29.7%
Lupi-Pegurier et al. (2002) (7)	France	Panoramic radiographs	7.3%	18.9%	31.5%
Tavares et al. (2009) (55)	France	Periapical radiographs	-	-	33.0%
Weiger et al. (1997) (56)	Germany	Panoramic and periapical radiographs	3.0%	2.7%	61.4%
Connert et al. (2018) (57)	Germany	Panoramic and periapical radiographs	2.0%	3.6%	34.1%
Georgopoulou et al. (2005) (58)	Greece	Periapical radiographs	13.6%	9.2%	60.0%
Archana et al. (2015) (59)	India	Panoramic radiographs	5.8%	4.1%	37.4%
Asgary et al. (2010) (60)	Iran	Panoramic radiographs	-	3.6%	52.0%
Loftus et al. (2005) (61)	Ireland	Panoramic radiographs)	2.0%	2.0%	25.0%
Covello F. et al. (2010) (62)	Italy	Panoramic radiographs	-	11.4%	41.6%
Tsuneishi et al. (2005) (43)	Japan	Periapical radiographs	9.4%	20.5%	40.0%
Al-Omari et al. (2011) (44)	Jordan	Panoramic radiographs)	11.6%	5.7%	71.9%
Kamberi et al. (2011) (63)	Kosovo	Panoramic radiographs	12.3%	2.3%	46.3%
Jersa et al.. (2013) (64)	Latvia	Panoramic radiographs	7.0%	18.0%	31.0%
Sidaravicius et al. (1999) (65)	Lithuania	Panoramic radiographs	7.2%	15.0%	39.4%
El Merini et al. (2017) (46)	Morocco	Panoramic and periapical radiographs	4.0%	4.2%	66.8%
De Cleen et al. (1993) (66)	Netherlands	Panoramic radiographs	4.5%	2.3%	39.2%
Peters et al. (2011) (67)	Netherlands	Panoramic radiographs	2.5%	4.8%	24.1%
Oginni et al. (2015) (45)	Nigeria	Periapical radiographs	14.4%	12.2%	40.7%
Skudutyte-Rysstad & Eriksen (2006) (20)	Norway	Panoramic and periapical radiographs	1.1%	1.5%	43.0%
Mukhaimer et al. (2012) (21)	Palestine	Panoramic radiographs	15.1%	13.2%	59.5%
Boltacz-Rzepkowska & Laszkiewicz (2005) (68)	Poland	Periapical radiographs	6.2%	9.7%	36.4%
Marques et al. (1998) (39)	Portugal	Panoramic radiographs	2.0%	1.5%	21.7%
Diogo et al. (2014) (40)	Portugal	Panoramic and periapical radiographs	4.4%	3.0%	29.6%
Present study	Portugal	CBCT	10.0%	10.9%	54.0%
Alfouzan et al. (2016) (69)	Saudi Arabian	Panoramic radiographs	3.8%	6.6%	58.6%
Al-Nazhan et al. (2017) (70)	Saudi Arabian	Panoramic radiographs	6.2%	6.2%	40.0%
Dutta et al. (2014) (25)	Scotland	CBCT	5.8%	4.8%	47.4%
Touré et al. (2008) (71)	Senegal	Periapical radiographs	4.6%	2.6%	56.1%
Ilić et al. (2014) (72)	Serbia	Panoramic radiographs	-	12.5%	51.8%
Kim et al. (2010) (73)	South Korea	Panoramic radiographs	-	97.1%	22.8%
Song et al. (2014) (74)	South Korea	Periapical radiographs	-	-	40.9%
Jimenez-Pinzon et al. (2004) (8)	Spain	Periapical radiographs	4.2%	2.1%	64.5%
López-López et al. (2012) (75)	Spain	Panoramic radiographs	2.8%	6.4%	23.8%
Ahmed et al. (2017) (76)	Sudan	Panoramic and periapical radiographs	3.3%	1.6%	32.5%
Odesjo et al. (1990) (77)	Sweden	Periapical radiographs	2.9%	8.6%	24.5%
Hugoson et al. (2005) (78)	Sweden	Panoramic and periapical radiographs	2.1%	7.5%	18.0%
Frisk et al. (2008) (79)	Sweden	Panoramic and periapical radiographs	3.3%	8.5%	24.6%
Dawson et al. (2016) (80)	Sweden	Panoramic and periapical radiographs	-	5.6%	32.8%
Imfeld et al. (1991) (41)	Switzerland	Periapical radiographs	8.5%	20.3%	31.0%
Thampibul et al. (2018) (81)	Thailand	Periapical radiographs	-	-	35.0%
Sunay et al. (2007) (82)	Turkey	Panoramic radiographs	4.2%	5.3%	53.5%

TABLE 6. Cont.

Author	Country	Imaging technique	Teeth with periapical lesion	Root canal filled teeth	Root canal filled teeth with periapical lesion
Gulsahi et al. (2008) (83)	Turkey	Panoramic radiographs	1.4%	3.3%	18.2%
Gencoglu et al. (2010) (23)	Turkey	Panoramic radiographs	-	9.4%	73.9%
Gumru et al. (2011) (84)	Turkey	Panoramic radiographs	2.2%	1.6%	42.0%
Özbaş et al. (2011) (85)	Turkey	Periapical radiographs	1.6%	1.6%	37.9%
Ureyen Kaya et al. (2013) (36)	Turkey	Panoramic radiographs	1.2%	2.6%	15.8%
Nur et al. (2014) (37)	Turkey	CBCT	-	-	45.6%
Di Filippo et al. (2014) (86)	United Kingdom	Panoramic radiographs	4.1%	3.4%	38.3%
Chen et al. (2007) (87)	USA	Periapical radiographs	5.1%	4.8%	35.5%

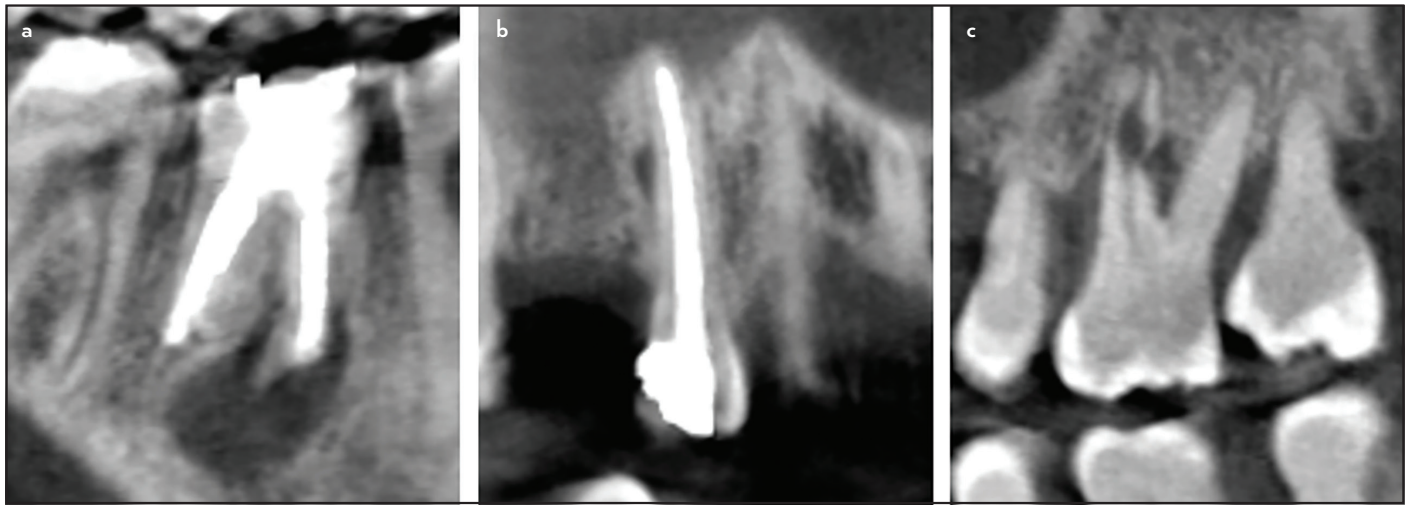

Figure 1. Examples of the main assessed variables: periapical lesion (a); lateral radiolucency (b); root resorption (c)

to differences in health, dental and endodontic care services provided by the clinics. These factors may partially justify the regional differences but also the wide range of results present at a worldwide level (Table 6 and Figure 3) (89). Since the impact and importance of each of one of these factors was not assessed in each region, the analytic analyses aimed to check for differences between regions, without necessarily identifying them in order to avoid incorrect interpretations.

Despite the high success rate of the root canal therapy, some failures can still occur. In the present study, 1.1% of all teeth presented with apical root resorption (Table 1). Additionally, 2.3% and 2.6% of maxillary central and lateral incisors, respectively, and 2.5% and 1.6% mandibular central and lateral incisors, respectively, showed apical root resorption (Table 2 and 3). Several causes may have led to this condition such as dental trauma, internal bleaching, periodontal treatment, and idiopathic events (90). Another explanation can be related to orthodontic pressure applied to the roots during teeth movement (91). Moreover, CBCT scan has been proposed as a valid tool to conduct differential diagnosis of resorptive lesions increasing the effectiveness of root canal therapy (90). Regarding the presence of lateral radiolucency, to the best of the author's knowledge, this finding has not been reported in the endodontic literature yet. A global prevalence of 0.4% was observed (Table 1), with the higher percentage being noted in mandibular first molars (1.2%) (Table 5). The literature shows that lateral canals can harbor bacteria that can reach the periodontal ligament and cause disease (92), and may be difficult to access, clean, disinfect, and fill during root canal treatment.

One limitation of the present study is related to its cross-sectional nature providing information about a group of participants at a specific point in time and not being possible to determine if a periapical lesion is healing or increasing after root canal treatment. Therefore, a treatment failure cannot be diagnosed alone by the evaluation of presence/absence of a periapical lesions (88). Additionally, the imaging methods provide limited information which does not allow a perfect understand and judgement of the quality of the previous treatment (9). Another limitation of the present study was the fact that the length of the root canal filling, although following a previously reported criteria (14), did not take into consideration the position of the apical constriction, but the radiographic apex only, since the latter is more precisely identified in the CBCT examinations. In clinical practice the determination of the working and filling length should be assisted by the use of an electronic apex locator and not only based on a radiographic 2 mm window. The strengths of the present study are related with the

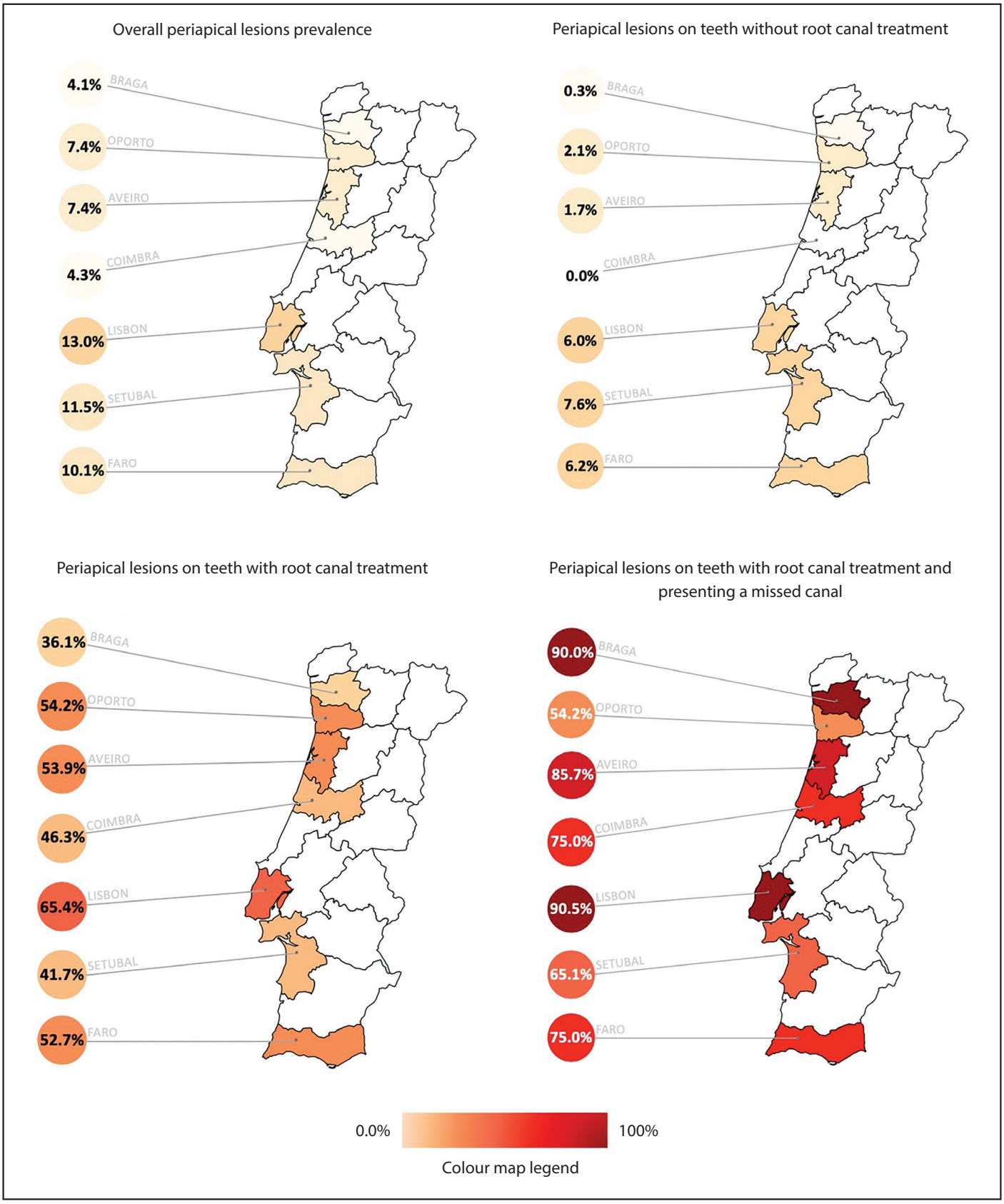

Figure 2. Periapical lesions prevalence according to different clinical conditions in the 7 assessed districts. The presence of previous root canal treatment had higher lesion proportions for all 7 regions, especially if missed canals were present

3-dimensional screening methodology, and the assessment of pathological conditions, such as apical root resorption and lateral radiolucency, with limited previous knowledge. Although, caution should be taken when extrapolating these results to the general population, mainly in the comparisons with other countries due to the methodological differences as well as

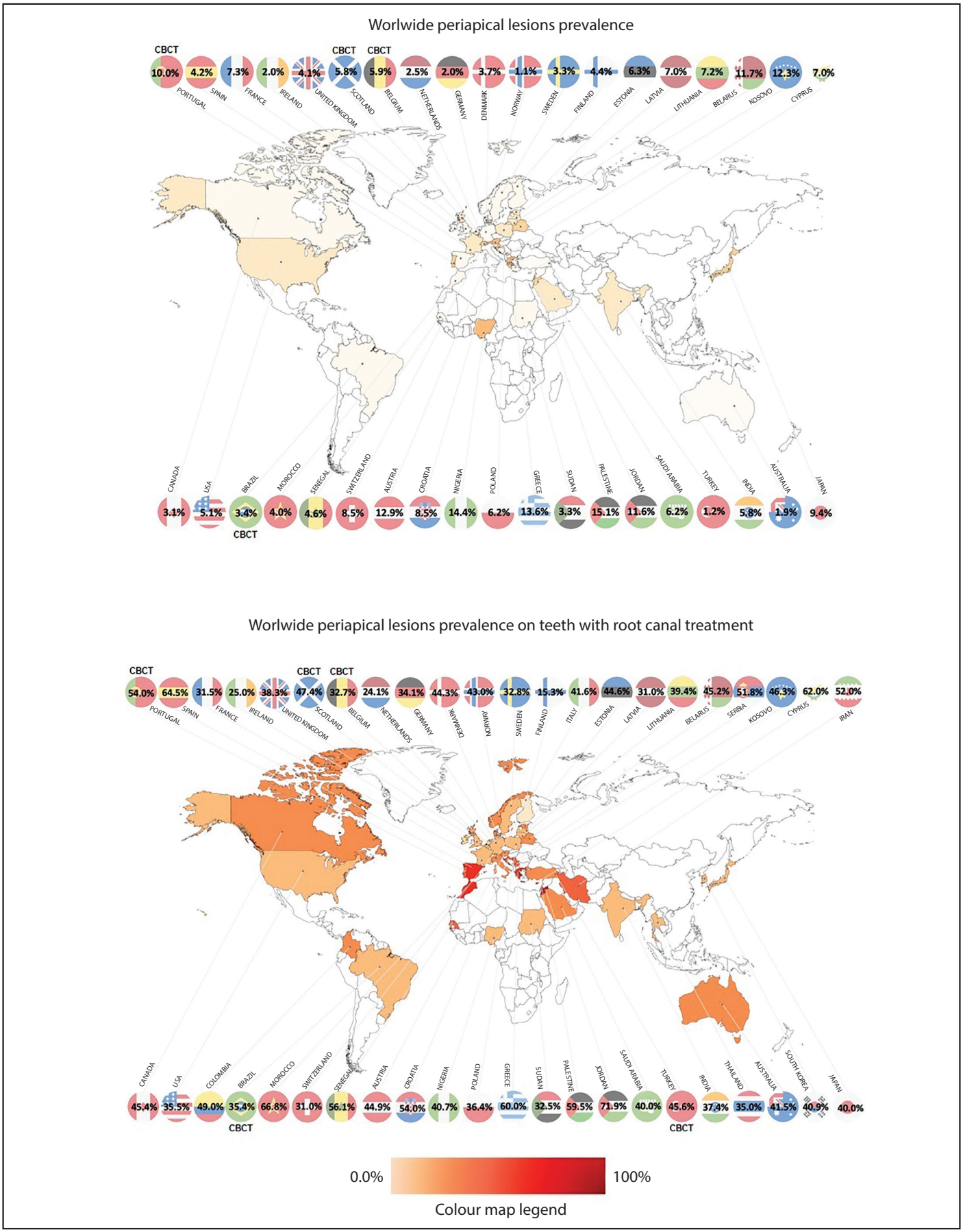

Figure 3. Worldwide overview of the periapical lesions prevalence. Teeth with previous root canal therapy tend to present higher proportions independently of the country being assessed

in healthcare services and socioeconomic factors, one major advantage of the study is the large sample size that has been collected under a multi-center assessment, which tends to increase the external validity of the results.

Future research in other countries, using 3-dimentional methodologies are recommended in order to better understand the differences between regions. That awareness may help to identify areas in need of intervention. Further longitudinal studies combining clinical and radiographic examination on this topic would also be beneficial in order to identify the incidence of periapical lesions (emergence of new cases).

CONCLUSION

Considering the present study findings the prevalence of lateral radiolucency and apical root resorption were low. The proportion of periapical lesions ranged from 4.1% and 13.0% in Braga and Lisbon, respectively, with a nationwide prevalence of 10.0%. Differences were observed among districts. The individual districts results confirmed that factors such as previous root canal treatment, missed canals, length of root canal obturation and type of coronal filling may influence the lesions prevalence.

Disclosures

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