Evaluation of the periapical condition of endodontically treated teeth by cone beam computed tomography

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ABSTRACT

Cone Beam Computed Tomography has become an important part of endodontic practice as it allows the visualization and manipulation of three-dimensional images. The present study aimed to evaluate the periapical condition of endodontically treated teeth through the analysis of computed tomography scans. This is a retrospective cross-sectional study in which 707 teeth were analyzed. The different dental groups, the presence of an intraradicular retainer, coronary restoration, root fracture, and root resorption, as well as the apical and lateral limits of the filling and the quality of the filling, were evaluated. The data were tabulated and then statistically treated through descriptive analyses and associations. The Kolmogorov-Smirnov and chi-square tests were used, and the significance level was 95% ($p \leq 0.05$). Of the total number of teeth analyzed, the maxillary incisors were the most prevalent (27.7%), followed by the maxillary premolars (18.8%) and the mandibular molars (15.1%). Significant associations were observed between the presence of alterations in the periapex and the apical limit ($p=0.001$), the lateral limit of the filling ($p=0.000$), the quality of the filling ($p=0.030$) and the presence of root resorption (0.000). It is concluded that unsatisfactory filling of root canals is a relevant factor for the presence of periapical diseases.

Keywords: Root Canal Filling, Cone Beam Computed Tomography, Endodontics, Periapical Periodontitis.

1 INTRODUCTION

Endodontic treatment aims to clean, disinfect and seal all root canals and their ramifications (Ørstavik, 1998) to prevent the formation of apical periodontitis or to create conditions for its reversal (Eriksen, 1991). Periapical radiolucency, characterized by bone resorption, is a consequence of inflammation around the root canal endings in response to a bacterial infection (Gomes et al., 2018), and is considered one of the criteria to determine the success of endodontic treatment (Alfouzan et al., 2016; Sarıyılmaz et al., 2016; Nascimento et al., 2018). Pulp and periapical diagnosis, residual pulp infection, apical limit of filling, complications during the procedure, and the presence and quality of the restoration are some of the factors that influence the success of endodontic treatment (Chugal et al., 2003). In addition, the filling of lateral canals (Yamaguchi et al., 2018), the presence of untreated canals (Hoen & Pink, 2002; Costa et al., 2019) and the homogeneity of the filling (Asgary et al., 2010) are some of the variables that are related to the success of the treatment performed.

Cone beam computed tomography (CBCT) has been widely used in the field of Endodontics for clinical planning, diagnosis of pathologies and follow-up of cases after procedures. The great advantage of this examination is that it allows the visualization of the oral cavity and its structures in a three-dimensional aspect instead of the two-dimensional aspect common to conventional radiographs (Beacham et al., 2018). In addition, it is a tool of great diagnostic value, especially in cases of failure of the endodontic treatment where there is a need to investigate possible causes. Due to its three-dimensional imaging configuration, it is easier to visualize root canal anatomy, identify root canals, and diagnose and manage root resorption (Patel et al., 2015).

Given the ability of CBCT to analyze the periapical condition and endodontic treatment, this study aimed to evaluate the periapical condition of endodontically treated teeth through the analysis of computed tomography scans.

2 MATERIAL AND METHODS

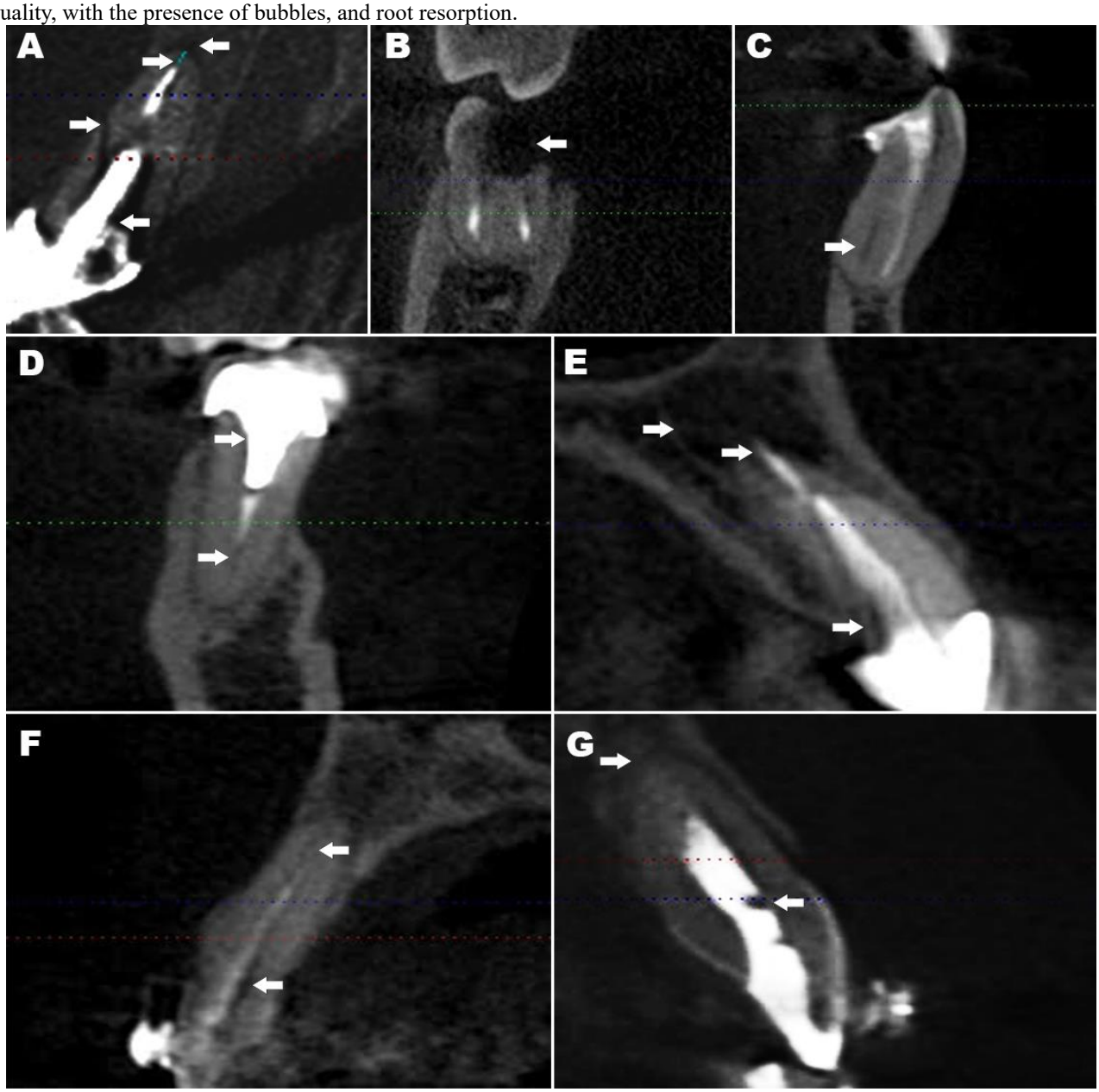
This retrospective cross-sectional study included the analysis of 707 teeth from CBCT exams filed at the Imaging Laboratory of the School of Dentistry of the Federal University of Paraná (LABIM-UFPR), dated from November 2014 to September 2018. The CT scans were performed to plan dental procedures, complementary diagnosis of dental and oral pathologies, implant placement, and surgical and endodontic treatments. The tomographic images were performed using the i-Cat (Imaging SciencesvInternational, Hatfield, PA) tomograph operated at 120kV and 7mA. All images were performed according to the protocol determined by the equipment manufacturer. The present study was approved by the Research Ethics Committee of the Health Sciences Sector of the Federal University of Paraná (Protocol no. 2,362,156).

Thei-CAT software (3.1.62, i-CAT Xoran Technologies, Ann Arbor, MI) was used for image analysis and a thickness of 0.25 mm was defined as standard for the observation of the CT scans. The images were analyzed in axial, sagittal and coronal sections. The contrast and brightness of the images have been adjusted with the aid of the software's image processing tool to ensure optimal viewing.

The inclusion criteria for the study were: CBCT images of endodontically treated permanent teeth with well-processed images, with no problems in the acquisition and visualization of the sections. The exclusion criteria established for the analysis of CT scans were: CT scans that contained artifacts that made it impossible to analyze the tooth.

The CT scans were analyzed by two trained examiners and previously calibrated (kappa 0.8). Information related to endodontic treatment, coronary restorations, periapical conditions, and root integrity was collected. The appropriate apical limit of filling was established as one at which the filling-apex distance was between 0 and 2 mm, and inadequate in case of subfillings greater than 2 mm (Sjögren et al., 1990; Farzaneh et al., 2004; Heling et al., 2001; İlgüy et al., 2013; Lee et al., 2012; Liang, Li, Wesselink, Wu 2011; Peak et al., 2001; Ridell et al., 2006; Smith, Setchell, Harty, 1993; Tani-Ishii, Teranaka, 2003), overfillings or untreated root canals. In the case of the lateral limit of filling, it was considered inadequate when it was greater or much lower than the proportion of one third of the width of the root evaluated, or even in the case of untreated root canals. As for the quality of the filling, it was considered inadequate when it was not homogeneous, with empty spaces between the filling and the prepared canal, or porosities within the obturator mass and also in untreated canals (Venskutonis et al., 2015). For the periapical condition, roots with periapical or lateral radiolucency or increased periodontal ligament space with thickening between 0.5 and 1 mm in at least one of the cutting planes were considered to have an altered periapex (Estrela et al., 2008). In patients with more than one root canal, the root canal with the worst condition was used for analysis (Venskutonis et al., 2015). Coronary restorations, intraradicular retainers, root resorptions, and tooth fractures were classified as present or absent (Figure 1).

Figure 1. (A) Presence of root retainer, root fracture, and thickening of the root periapex. Filling with apical limit of 0.90 mm, considered adequate. (B) Tooth with absence of coronary restoration. (C) Canine with the presence of two root canals and absence of lingual canal fillings. (D) Tooth with presence of intraradicular retainer and inadequate apical limit (subfilling). (E) Tooth with presence of intraradicular retainer, inadequate apical limit (overfilling), and presence of periapical lesion. (F) Tooth with inadequate apical (underfilling) and lateral limits. (G) Tooth with inadequate filling quality, with the presence of bubbles, and root resorption.



The data were tabulated using the SPSS® 17.0 software and then statistically treated using descriptive analyses of distribution and frequencies and associations. The Kolmogorov-Smirnov test was applied to verify the normality of the data and the chi-square test was used to analyze the associations. A significance level of 95% ($p \leq 0.05$) was adopted to interpret the results.

3 RESULTS

A total of 707 teeth from 280 CT scans were analyzed. The mean age of the patients evaluated was 49.36 years (median 52 years), 68.9% were female, and 31.1% were male. Table 1 presents the descriptive data of the study.

Of the teeth evaluated, 34.1% were maxillary anterior, 33.1% maxillary posterior, 27.6% mandibular posterior, and 5.2% mandibular anterior, with a higher prevalence for incisors between maxillary teeth (n=196) and molars between mandibular teeth (n=107).

Regarding the periapical condition, 62.5% of the teeth had an altered periapical condition, while 37.5% had a healthy periapical condition. Regarding the apical limit of filling, 67.9% of the teeth were adequate, and 32.1% were inadequate.

Table 1. Descriptive analysis of the data evaluated.

Variable	***N***	***%***
Sex		
Male	87	31,1
Female	193	68,9
Dental group		
Maxillary anterior	241	34,1
Maxillary posterior	234	33,1
Mandibular anterior	37	5,2
Mandibular posteiror	195	27,6
Apical limit of filling		
Adequate	480	67,9
Inadequate	227	32,1
Lateral Shutter Limit		
Adequate	528	74,7
Inadequate	179	25,3
Fill quality		
Proper	551	77,9
Inadequate	156	22,1
Periapical condition		
Healthy	265	37,5
Sick	442	62,5
Intraradicular retainer		
Present	231	32,7
Absent	476	67,3
Coronary restoration		
Present	658	93,1
Absent	49	6,9
Root resorption		
Present	106	15,0
Absent	601	85,0
Tooth fracture		
Present	13	1,8
Absent	694	98,2

The analysis of the association between the variables studied (Table 2) showed that there is no significant association between the presence of changes in the periapex and the different dental groups (maxillary teeth p=0.522; mandibular teeth p=0.525), presence of intraradicular retainers (p=0.305),

coronary restoration (0.400) and cases of root fracture (0.424). On the other hand, significant associations were observed between changes in the periapex and the apical limit of the filling (p=0.001), lateral limit of the filling (p=0.000), quality of the filling (p=0.030) and presence of root resorption.

Table 2. Association between the independent variables and the presence of alterations in the periapex.

Variable	Healthy n (%)	Sick n (%)	P Value*	Confidence interval
Dental group				
Maxillary anterior	89 (12.6)	152 (21.5)	0.522	1.004 (0.835-1.206)
Maxillary posterior	86 (12.2)	148 (20.9)		0.996 (0.824-1.204)
Mandibular anterior	14 (1.98)	76 (10.7)	0.525	0.960 (0.522-1.767)
Mandibular posterior	23 (3.25)	119 (16.9)		1.008 (0.899-1.130)
Apical limit of the filling			0.001	
Adequate	199 (75.1)	281 (63.6)		0.684 (0.536-0.872)
Inadequate	66 (24.9)	161 (36.4)		1.181 (1.070-1.304)
Lateral limit of the filling			0.000	
Adequate	217 (81.9)	311 (70.4)		0.611 (0.456-0.820)
Inadequate	48 (18.1)	131 (29.6)		1.164 (1.071-1.264)
Quality of the filling			0.030	
Adequate	217 (81.9)	334 (75.6)		1.084 (1.003-1.171)
Inadequate	48 (18.1)	108 (24.4)		0.741 (0547-1.005)
Intraradicular retainer			0.305	
Present	83 (31.3)	148 (33.5)		0.935 (0.750-1.167)
Absent	182 (68.7)	294 (66.5)		1.033 (0.930-1.147)
Coronary restoration			0.400	
Present	248 (93.6)	410 (92.8)		1.009 (0.968-1.051)
Absent	17 (6.4)	32 (7.2)		0.886 (0.502-1564)
Root resorption			0.000	
Present	24 (9.1)	82 (18.6)		1.117 (1.053-1.184)
Absent	241 (90.9)	360 (81.4)		0.488 (0.318-0.749)
Root fracture			0.424	
Present	4 (1.5)	9 (2.0)		0.741 (0.231-2.383)
Absent	261 (98.5)	433 (98)		1.005 (0.985-1.026)

* Chi-square test

4 DISCUSSION

Cone-beam computed tomography has high diagnostic accuracy in detecting changes in periapical bone tissue (Patel et al., 2010). The present study demonstrated that the presence of periapicopathy was associated with the apical limit of the filling, the lateral limit of the filling, the quality of the filling, and the presence of root resorption.

The apical limit is one of the major concerns regarding the treatment of the root canal system (Michelle et al., 2005). When there is an overinstrumentation, in other words, the radiographic apex is exceeded, the pulp stump and the periapical tissues are affected, resulting in tissue aggression (Holland et al., 1979) and, consequently, the tissue repair in this region is slowed down by the inflammatory process (Star et al., 2014). Thus, the literature suggests that the instrumentation and filling of the root canal system should be limited to the apex (Kojima et al., 2004; Swartz et al., 1983; Michelle et al., 2005). In addition, there is evidence that, in cases of overfilling, tissue repair of the periapical region after treatment may be delayed (Star et al., 2014).

On the other hand, when there is pulp necrosis, microorganisms and their by-products can persist in the most apical region of the canal, which promotes local inflammation and hinders tissue healing (Nair, 2006). These persistent inflammatory disorders of the periradicular tissues, caused by persistent microbial infection within the root canal system, are the etiology of apical periodontitis(Kakehashi*et al.*1965,1976 Sundqvist). Therefore, in relation to the apical extension of the filling, several studies in the literature show that the best results occur when the chemical-mechanical preparation and the filling of the root canal system are between 0-2 mm below the radiographic root apex (Gomes et al., 2015; Azim et al., 2016; Van der Veken et al., 2017; Nascimento et al., 2018; Kojima et al., 2004; Schaeffer et al., 2005). Some results show that there are up to 4.68 times more chances of finding a healthy periapex when the apical extension of the filling respects these limits, compared to cases of overfilling (Gomes et al., 2015).

Other important aspects are those involved with the three-dimensional filling of root canals: the lateral limit and the quality of the filling. When there is no adequate filling of the canal and, therefore, bacterial dissemination, an inflammatory process is installed, hindering apical healing (Nair, 2006) or causing apical periodontitis (Kakehashi*et al.*1965,1976 Sundqvist). Voids in the filling material provide residual bacteria with an ideal environment for the growth and transport of toxins to the periapex (Fernandez et al (2017). Therefore, eliminating voids that may harbour microorganisms during cleaning and enlarging/shaping, combined with the optimal lateral boundary and fill density, is essential for antimicrobial control (Estrela et al., 2014).

The association between root resorption and apical periodontitis was expected. Its occurrence is due to cementum resorption associated with the periradicular inflammatory response to bacteria or bacterial products that come out of the apical or lateral foramen. When the apical dentin is exposed,

the dentin tubules may allow bacteria and their products to have another established pathway to come into contact with the inflamed periradicular tissues, perpetuating inflammation and leading to ongoing resorption of dentin and cementum (Huang et al., 2019; Ricucci et al., 2014; Delzangles, 1988).

In addition to the quality of the endodontic treatment, studies have shown that coronary restoration in endodontically treated teeth is also associated with the periapical conditions (Cakici et al., 2016; Van der Veken et al., 2017; Vengerfeldt et al., 2017; Gambarini et al., 2018). Aa in vitro study suggested that unsatisfactory coronary restoration generates exposure of the root canal filling to microorganisms and their products, with reinfection of the root canal system in a relatively short period (Craveiro et al., 2015).

CBCT is superior to intraoral radiographs when it comes to detecting periapical lesions (Davies et al., 2015; Weissman et al., 2015; Sakhdari et al, 2016; Kanagasingam et al., 2017; Torabinejad et al., 2018; Ramis-Alario et al., 2019). When comparing the methods of simple periapical radiography, parallax radiographs, and CBCT, the prevalence of periapical lesions found in endodontically treated teeth was 41%, 38%, and 68%, respectively (Davies et al., 2015). When diagnosing a periapical region as healthy using two-dimensional radiography, there is a 56-61% chance that periapical disease is present (Kanagasingam et al., 2017). The present study showed that 62.5% of the periapex had alterations. This high rate corroborates studies that found prevalences of 51% to 78% (Davies et al., 2015; Gomes et al., 2015; Lemagner et al., 2015), in which the accuracy of cone beam CT scans was evidenced in showing apical periodontitis in early stages, such as increased periodontal ligament spaces and radiolucencies of smaller diameters.

Despite the high diagnostic accuracy of CBCT for most of the conditions evaluated, it is known that it is not indicated to evaluate the quality of dental restorations due to the high density of the filling material, and clinical and radiographic evaluations are more indicated for this purpose (Gomes et al., 2015; Nascimento et al., 2018). In addition, the non-association between fracture and periapical changes can be explained by the low number of teeth diagnosed with root fracture. CBCT has a lower sensitivity for detecting root fractures in the presence of radiopaque materials and metallic artefacts such as intraradicular retainers, as they can obscure the fracture line (Abdinian et al., 2016; Rabelo et al., 2017).

As this is a retrospective cross-sectional study, the question remains whether the periapical condition of the studied teeth is in the process of repair or progression, since the imaging exam provides static information on these dynamic processes.

5 CONCLUSION

It is concluded that unsatisfactory filling of root canals is a relevant factor for the presence of periapicopathies.

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