Radiological Assessment of Prevalence and Quality of Periapical Status of Endodontic Treatments

Background: The aim of this study was to determine the current prevalence and quality of endodontic treatments and investigate the relationship of various factors with posttreatment endodontic disease (PTED) in a Turkish subpopulation.

Material/Methods: The cone beam computed tomography (CBCT) images of 1069 patients (male, 50.9%; female, 49.1%; mean age, 45.32±13.50 years) were retrospectively analyzed. A total of 20,646 teeth were examined; 1604 had undergone root canal. Periapical status was assessed using a modified CBCT periapical index. The relationship between periapical status and quality of root canal fillings (RCFs) was analyzed statistically using the chi-square test. Multivariate logistic regression was performed to evaluate the effect of individual parameters by adjusting them for other variables.

Results: A total of 7.8% of all teeth had RCF. The prevalence of poor filling (having at least 1 procedural error) was 54.1%; the prevalence of PTED was 56.8%. The prevalence of PTED was 44.3% in teeth with short RCF, 10.8% with overextended RCF, 35.7% with nonhomogeneous RCF, and 15.5% in teeth with untreated root canals. The rate of RCF teeth with procedural errors associated with PTED was 76.2%. There was no significant difference between sexes in apical periodontitis (P>0.05), which developed more frequently in teeth with procedural errors.

Conclusions: The overall prevalence of poor fillings (having at least 1 procedural error) among RCF teeth was high (54.1%) in this subpopulation. There is a substantial need to improve the technical quality of endodontic treatment.

Keywords: Cone-Beam Computed Tomography • Epidemiology • Periapical Periodontitis • Tooth, Nonvital

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Background

Epidemiologic studies bring useful knowledge about trends in the incidence and prevalence of diseases and their risk factors. These data are valuable for planning health care strategies to prevent or decrease the occurrence of considered disorders [1]. The presence of apical periodontitis (AP) is evaluated by clinical symptoms and periapical radiographs. The radiological assessment is important for diagnosis, especially for different atypical odonalgia [2]. Conventional radiographs, as 2-dimensional (2D) images, show low sensitivity for detecting apical radiolucency [3]. AP is an inflammatory oral disease that can be detected when the destruction of cortical bone is present. Therefore, AP might not be detected in regions with a thick cortical plate [3]. The term “posttreatment endodontic disease” (PTED) has been suggested by Friedman and is defined as the disease associated with the radiolucency of endodontically treated teeth. PTED includes all persistent, recurrent, and emerged AP associated with endodontically treated teeth and differentiates these conditions from AP that is associated with untreated teeth [4].

Cone beam computed tomography (CBCT) is a relatively new imaging technique that shows 3D images of structures. CBCT scanning can be useful in endodontics for detecting AP, assessing root canal morphology, detecting procedural errors, and evaluating postoperative healing outcomes [5,6]. Estrela et al [7] evaluated a new periapical index (PAI) based on CBCT for the identification of AP.

Procedural improvements and advances in technology have changed endodontic therapy. However, this has not changed the outcome of endodontic treatment throughout the years [8]. Many observational studies identified the rate of inadequately obturated root canals in relation to periapical health, with results showing various treatment outcomes among different countries. The prevalence of inadequate filling was up to 72.4%, of which 87.0% showed periapical periodontitis [9]. Undoubtedly, endodontic treatment quality is not the only parameter associated with untreated teeth [4].

Material and Methods

This study was approved by the Non-Invasive Clinical Research Ethical Committee of Kocaeli University (KU GOKAEK2020/355).

The CBCT images (Planmeca Promax 3D Max Helsinki, Finland, 96 kVp and 10 mA) of 1069 patients (male, 50.9%; female, 49.1%; mean age, 45.3±13.50 years) who applied to Kocaeli University Faculty of Dentistry between 2015 and 2020 for general reasons, such as diagnosis and treatment planning, were retrospectively analyzed. The inclusion criteria required that only full-arch scans with voxel size of ≤200 µm would be eligible for the study. Patients under 18 years, third molar teeth, deciduous teeth, unrestorable root fragments, and completely edentulous patients were excluded. Teeth that could not be assessed owing to image artefacts were also excluded.

Teeth and their periapical regions were evaluated with the multiplanar reconstruction view of the software Planmeca Romexis viewer.

Apical radiolucency in CBCT images were determined by using a modified CBCT PAI, as developed by Estrela et al [7], except categories E (cortical expansion) and D (bone destruction), which were determined by 2 independent observers. Both examiners reached consensus on each image examination. The measurements for CBCT PAI were done in millimeters. For CBCT images, the selected teeth were analyzed in all planes, and the largest diameter of the apical radiolucency was used as the reference value for the CBCT PAI.

Based on the CBCT PAI, the periapical lesion diameters were classified as follows: 0, intact periapical bone structures; 1, >0.5-1 mm; 2, >1-2 mm; 3, >2-4 mm; 4, >4-8 mm; and 5, >8 mm. Absence of the periapical lesion was defined according to score 0 (intact periapical bone structures) and presence was defined according to scores 1 to 5 (diameter of periapical radiolucency above 0.5 mm).

A total of 20,646 teeth were examined; 1604 of these that had undergone root canal treatment and met the criteria were included in the study. Each tooth was classified according to the right and left maxilla and mandible and also with sex, age, and systemic status were examined.

Statistical Analysis

The statistical analyses were performed using MedCalc Statistical Software version 12.7.7 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2013). Means and standard deviations were calculated for normally distributed continuous variables; median and range were calculated for...
non-normally distributed continuous variables. Proportions were calculated for categorical variables. For the significant differences between groups, the chi-square test was used, with the significance level set at $P < 0.05$. Multivariate logistic regression was performed to evaluate the effect of individual parameters by adjusting them for other variables.

### Results

A total of 20,646 teeth from 525 women and 544 men with a mean age of 45.28 years were screened (Table 2). A total of 1604 endodontically treated teeth (7.8%) were identified. Among the endodontically treated teeth, the prevalence of PTED was 56.8% (911 teeth). The distribution of endodontically

| Table 1. Parameters for classification. |
|-----------------------------------------|
| ➢ Tooth number                          |
| ➢ Presence/absence of previous RCF      |
| ➢ Presence/absence of broken instruments|
| ➢ Extension of RCF (classified as: “short” when more than 2 mm short of the radiographic apex; “flush” when filled within 0-2 mm of the radiographic apex; and “long” when extended beyond the radiographic apex) |
| ➢ Homogeneity of RCF (classified as: “homogeneous” when RCF presented no voids; ‘nonhomogeneous’ when RCF presented voids, poor density) |
| ➢ Presence/absence of ledge formation   |
| ➢ Presence/absence of perforation       |
| ➢ Presence/absence of missed canals     |

RCF – root canal filling; AP – apical periodontitis; CBCT PAI – cone beam computed tomography periapical index.
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treated teeth according to sex and age is shown in Table 2: women had more endodontically treated teeth than men.

The apical status of teeth with root canal treatment was evaluated by CBCT PAI, and the score 0 was determined as “no apical lesion” and score 1 to 5 as “with apical lesion”. A significant difference was found between the average age of patients with periapical lesions and the average age of patients without lesions (P<0.05). The age group of 25 to 50 years, which was the age range with the highest prevalence of root canal treatment, was the group in which periapical lesions were most common. However, no statistically significant difference was found between age groups (P>0.05; Table 3).

Of the 911 teeth that had undergone root canal treatment and were associated with periapical lesions, 59.6% were in the maxilla and 40.4% were in the mandible. Of the 543 endodontically treated teeth, 57.4% were in women, while 42.6% were in men. However, no statistically significant difference was found between sexes in terms of periapical pathology (P>0.05). The age group of 25 to 50 years, which was the age range with the highest prevalence of root canal treatment, was the group in which periapical lesions were most common. However, no statistically significant difference was found between age groups (P>0.05; Table 3).

Table 2. Distribution of demographic variables.

|                          | n   | Mean±SD | Median (Min-Max) |
|--------------------------|-----|---------|------------------|
| Age                      | 1069| 45.28±13.5 | 46 (18-78)       |
| Number of teeth per patient | 20646 | 19.31±6.7   | 20 (1-28)        |
| Number of endodontically treated teeth per patient | 1604 | 1.52±2.1    | 1 (0-21)         |

|                          | n   | %       |
|--------------------------|-----|---------|
| Sex                      |     |         |
| Female                   | 525 | 49.1    |
| Male                     | 544 | 50.9    |

n – number; SD – standard deviation.
treated teeth in the maxilla and associated with apical lesions, 45.1% were anterior teeth and 54.9% were posterior teeth. According to multivariate logistic regression analysis, the incidence of apical lesions in maxillary posterior teeth was found to be 1.62 times lower than in maxillary anterior teeth (95% CI, odds ratio [OR]=0.617), and this difference was statistically significant (P<0.05). Of the 368 endodontically treated teeth in the mandible and associated with apical lesions, 26.4% were anterior teeth and 73.6% were posterior teeth. The incidence of PTED in mandibular posterior teeth was found to be 1.45 times lower than that in maxillary anterior teeth (95% CI, OR=0.891) and this difference was statistically significant (P<0.05). In the graphic in Figure 2, the prevalence of root canal treatment in each tooth in the mouth and the ratio of those associated with PTED are shown.

No procedural errors were detected in 45.9% of the endodontically treated teeth. The prevalence of PTED was 34% in teeth without procedural errors. At least 1 procedural error was detected in 54.1% of the evaluated endodontically treated teeth. The prevalence of PTED was 76.2% in teeth with procedural errors.

Apical lesions were detected in 30 (76.9%) of 39 teeth with a broken instrument, 141 (87%) of 162 teeth with missed canals, 30 (73.2%) of 41 teeth with ledge formation, and 6 (66.7%) of 9 teeth with perforation. When homogeneity and apical extent of root canal treatments were evaluated, 38.1% of 810 (50.5%) teeth with flush and homogenous canal fillings were found to be associated with apical lesions; 98 (78.4%) of 125 teeth with overfillings were associated with apical lesions; and 404 (75.1%) of 538 teeth with short canal filling were associated with apical lesions. In multi-rooted teeth, the shortest or the most extended root filling was used for the evaluation. Apical lesions were detected in 325 (80.2%) of 405 teeth with nonhomogeneous RCF (presenting voids and poor density) (OR=2.748). While the presence of broken instruments (OR=2.746), missed canals (OR=5.809), short canal filling (OR=3.142), and inhomogeneity of canal filling (OR=2.748) in endodontically treated teeth had statistically significant differences (P<0.05) in terms of the distribution of PTED; the presence of perforation and ledge formation did not show a statistically significant difference (P>0.05; Table 4).

### Discussion

Epidemiological studies provide important information about the prevalence and frequency of AP and endodontically treated teeth. It also provides data on the outcomes of endodontic treatments in the population [1]. There are very few studies that were conducted in large subpopulations and that revealed more generalized and accurate results than the present study. This study was an epidemiological study aimed at evaluating the quality of endodontic treatments in a large subpopulation of the Turkish population.

For a long time, conventional imaging techniques (digital panoramic and periapical radiographs) have been used to diagnose periapical radiolucencies and differentiate them from a healthy periapex. Conventional imaging techniques show some limitations, including 3D compression of the anatomies of structures, geometric alternation, and superposition of anatomical structures [11]. As a new clinical tool, CBCT provides 3D imaging of the pathology under investigation and has a higher sensitivity than conventional radiography, without superposition of adjacent structures [12]. Estrela et al [3] analyzed 1425 root-treated teeth in different imaging modalities and found the periapical lesion percentages were 63.3% for CBCT,

| Table 3. Distribution of the presence of posttreatment endodontic disease according to age and sex. |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| CBCT PAI | No lesion | With lesion | P |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| n | Mean±SD | Mean±SD | Odds ratio (95% CI) |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Age | 47.4±13.1 | 46.1±12.9 | 0.049 |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Sex | Male | 262 | 388 | 0.296 |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Female | 431 | 523 | 1.127 (0.901-1.41) |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Age | ≤25 | 30 | 59 | 0.113 |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| ≥50 | 305 | 382 | 0.601 (0.357-1.009) |

P values <0.05 are considered statistically significant. CBCT PAI – cone beam computed tomography periapical index; SD – standard deviation; n – number of samples.
35.3% for periapical radiographs, and 17.6% for panoramic radiographs. The researchers stated that CBCT has a higher sensitivity for identifying periapical lesions than do conventional modalities. Additionally, the 3D evaluation enables a more reliable assessment of other parameters, including extent of RCF, compared with 2D analysis.

The periapical index (PAI) has been used in numerous studies and has been accepted as the criterion standard for diagnosing periapical lesions. Ørstavik et al [13] used 2D radiographic images in the PAI scoring they developed, while Estrela et al [7] created CBCT PAI scoring based on the interpretation of 3D CBCT scans. These 2 periapical indices, therefore, have...
different scoring systems as a result of the characteristics of both imaging methods. The CBCT PAI scoring developed by Estrela et al [7] has some advantages for clinical applications. CBCT PAI scores are calculated by 3D analysis of the lesion, and tomography sections are obtained in the mesiodistal, buccopalatinal, and diagonal directions. Measuring the depth of the lesion contributes to the diagnosis and thus to improving patient prognosis. The purpose of using CBCT PAI scoring in this study was to present a method based on the interpretation of high resolution images that can provide a more accurate measurement of the lesion width, minimize the observer factor, and increase the reliability of the research results.

Regarding age, the ages of the patients included in studies were collected in very different subgroups. In some studies, no significant difference was found in the prevalence of AP and endodontic treatment between different age groups [14,15]. Studies with significant differences in age-related prevalence have reported that patients over 50 years of age are the most affected group [16,17]. In the present study, the age group with the highest PTED rate of 51.6% was in the age group of 25 to 50 years, and it was followed by the group above the age of 50 years, with a rate of 41.9%.

Studies have not found a relationship between patient sex and periapical health [18,19]. Similarly, in the present study, the rate of PTED incidence in women was 54.8%, while the rate was 59.6% in men, and this difference was not significant (p>0.05). However, there are studies in the literature in which the rate of AP in endodontically treated teeth was observed more frequently in men than in women [20,21]. These differences in endodontic treatment prevalence and AP prevalence can be attributed to more than 1 biopsychosocial mechanism [22].

The present study showed that 7.8% of all evaluated teeth had undergone endodontic treatment. These data appear to be lower than the results of other studies, which range from 8.8% to 13.4% [14,23]. This is probably because populations in which other studies were conducted had more dental awareness than the population we included in this study. In total, 56.8% of endodontically treated teeth in the present study were associated with AP, which is in accordance with the results of several different studies [17,24]. It can be speculated that root canal treatment is insufficient in controlling disease [25].

Of the 1604 teeth we evaluated, 45.8% of adequate (no procedural error) endodontic treatment was observed, and 34% of these were associated with PTED. These data revealed that the quality of endodontic treatments was below standard; however, our results were clearly above the results of previous studies (9.9-41.9%) that examined the prevalence of adequate root canal therapy [17,26].

Our results revealed a high prevalence of periapical lesions in teeth with short RCFs (more than 2 mm from the radiographic apex). Periapical lesions were observed in 75% of 538 teeth with short RCFs (OR=3.142). These results agree with those of several previous studies [14,23,27]. The flush root filling length (within 0 to 2 mm of the radiographic apex) was associated with a lower prevalence (43%).
Meirinhos et al [14] did not record any difference in terms of AP between canal systems with flush RCFs and long RCFs. Possible reasons for the differences between the results of the studies are differences in clinical protocols, differences between 3D and 2D imaging, and limitations of overextent root filling material in radiographic imaging.

During the endodontic treatment procedure, every loss of canal working length increases the chance of failure. Chugal et al [28] emphasized that shortening of the working length, including ledge formation and canal obstructions, decreases the chance of success, especially in teeth with periapical disease. It has been argued that this is due to the inaccessible microbial infection in the canal section not being controlled and the region not being able to be disinfected. In the present study, it was observed that 73.2% of the teeth in which ledge formation was observed had PTED. The relationship between ledge formation and PTED was not found to be significant (P>0.05).

In the present study, the prevalence of PTED was 80.2% (OR=2.748) in teeth with nonhomogeneous RCF (presenting voids and poor density). Gencoglu et al [23] found the prevalence of AP in teeth with voids in the adaptation of canal filling with canal walls to be 74.7% in their study. Segura-Egea et al [29] reported in their study that 49% of endodontically treated teeth did not have enough adaptation of the canal filling to the canal walls, and that AP was observed in 73.9% of these teeth. However, when comparing the results of the studies, it should be kept in mind that the quality of root canal debridement cannot be evaluated with radiological examinations.

Missed canals can accommodate microorganisms and their by-products. Therefore, untreated root canals are still one of the main causes of persistent apical lesions of endodontic origin.

Comparing mandibular anterior teeth and maxillary anterior teeth in the present study, similar results with previous studies were obtained: teeth in the mandibular anterior region were more likely to have missed canals than are teeth in the maxillary anterior region. This is because mandibular anterior teeth have more complex anatomy than maxillary anterior teeth [30]. Variations in anatomy should always be considered because having limited knowledge of tooth morphology can increase the likelihood of canals being missed during treatment, which can lead to treatment failure.

Karabucak et al [5] and Costa et al [31] reported that the highest rate of missed canals can be found in the maxillary first molars (44.2% and 59%, respectively). Although these results are similar to our results, in that the maxillary first molars have the highest missed canal prevalence, the values giving the ratio of missed canal (44.2-59%) are higher than the value in the present study (38%). Thus, endodontically treated teeth with missed canals were 5.809 times more likely to be associated with periapical lesions than were endodontically treated teeth without missed canals. The odds ratios noted in the present study are in between those of the studies by Karabucak et al and Metin girmek için buraya tıklayın veya dokunun.[5,31] (odds ratios of 4.4 and 6.25, respectively).

In the present study, the prevalence of periapical lesions was found to be 87% in endodontically treated teeth with missed canals. The rate stated in our study was compared with that of Karabucak et al [5] (82.8%) and Costa et al [31] (97.5%). The tight relationship between periapical lesions and missed canals can be explained as a result of the proliferation of bacteria in untreated canals and overriding the body’s immune response in apical tissues [32].

Ng et al [19] found in their prospective study that the presence of a broken instrument has a significant effect on the outcome of root canal treatment. Clinically, the type of the broken instrument, the location of the instrument, and maintaining apical patency correlate significantly with each other. “Maintaining apical patency” has been further analyzed as its direct effect on treatment outcome is more pronounced clinically. In present study, 76.9% of endodontically treated teeth with broken instruments were associated with PTED (95% CI, OR=2.746).

It has been found that the presence of perforation in the mid-third or coronal of the root significantly reduces the probability of success. This condition is likely due to bacterial contamination during or after treatment. In our present study, 66.6% of teeth with root perforation were found to be associated with PTED. These data are similar to those of previous studies [19,33].

Considering the long-term success of root canal therapy, coronal leakage can play an important role, perhaps as much as any other step of root canal treatment [34]. However, it should be kept in mind that the time elapsed between the completion of root canal treatment and the placement of the coronal restoration and the conditions in this process are unknown. Gillen et al [35] showed in a meta-analysis study that coronal leakage may not be of clinical significance, as shown in in vitro studies.

Unfortunately, the quality of coronal restorations is difficult to assess due to various image artefacts in CBCT imaging. Clinical examination and intraoral radiographs are considered more reliable methods of evaluating the quality of coronal restorations than is CBCT imaging [36]. In our preliminary study, it was not possible to examine coronal restorations on CBCT images due to artefacts. For these reasons, “compatibility of coronal restorations” was not among the parameters we investigated.
There was limited clinical data regarding some of the root filled teeth assessed in the present study. Additionally, the previous practitioners who treated the patients were not mentioned in all of the records. Therefore, there was no sufficient data to determine and assess this aspect properly in the present retrospective study.

A limitation of cross-sectional studies is the inability to determine whether a peripical lesion is healing or progressing [31]. However, it should be noted that the number of cases of healed periapical periodontitis is approximately equal to the number of newly developed lesions. This confirms that large numbers of CBCT evaluations show a realistic scenario in a given population [25].

Endodontic failure includes all teeth that have undergone root canal treatment and are clinically symptomatic and/or have periapical lesions radiographically. However, while terms such as “success” and “failure” refer only to treatment and its various methods, “healed”, “healing”, and “non-healed” lesions accept patient-centered factors, and this is considered an appropriate approach to individualized medicine [37].

Although the superiority of CBCTs over conventional techniques in detecting periapical radiolucencies has been proven in many studies, it should be emphasized that scanning artefacts such as beam hardening (caused by high density materials such as metal posts, metal restorations, and root filling materials) may reduce imaging quality and cause a limitation during CBCT assessment [3,12]. Moreover, recent recommendations are that CBCT should be used strictly for specific indications, not for routine diagnostic imaging in order to avoid exposing patients to an unnecessary radiation dose [38].

Conclusions

The quality of root canal treatment was poor in this subpopulation. More than half of root canal-treated teeth were demonstrated to have procedural errors. Procedural errors (the presence of a broken instrument, short canal filling length, inhomogeneity of canal filling) seems to result in a higher rate of PTED.

The lowest rate of PTED was observed in teeth with homogeneous and flush RCFs. Taken together, these findings suggest that there is a substantial need to improve the technical quality of endodontic treatment.

This study highlights that the AP rate of endodontically treated teeth was highly associated with procedural errors, whereas the lowest rate of AP was observed in teeth with homogeneous and flush RCFs. Our study underlines the substantial need to improve the technical quality of endodontic treatment.

Declaration of Figures’ Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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