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Post-treatment periapical status related to the quality of root canal fillings in adults living in Vojvodina

Povezanost periapikalnog statusa zuba nakon lečenja sa kvalitetom punjenja kanala korena zuba kod odraslih osoba na području Vojvodine

Bojana Ramić, Karolina Vukoje, Milica Cvjetićanin, Tanja Veljović, Jelena Mirnić, Aleksandra Maletin, Milan Drobac, Miloš Čanković, Ljubomir Petrović

University of Novi Sad, Faculty of Medicine, Department of Dental Medicine, Novi Sad, Serbia

Abstract

Background/Aim. Apical periodontitis (AP) is an acute or chronic inflammation of the periradicular tissue, usually caused by the presence of microbial irritants in the root canal system. The aim of the study was to radiographically assess the AP prevalence in root-filled teeth (RFT) in adults from an urban area of Vojvodina, Serbia. **Methods**. Randomly selected digital ortopantomographs of 616 subjects who visited the Clinic of Dentistry of Vojvodina, from January 2019 to December 2020 were examined. Periapical status, root canal filling (RCF) quality, type of coronal restorations, and their relationships were evaluated. The Chi-squared (χ^2) test was used for statistical analysis. **Results.** The total number of endodontically treated teeth was 965; 44.25% of them received an adequate RCF score, and 34.9% had AP, which was diagnosed in 57.4% of inadequately scored RFT. Posterior teeth had significantly worse RCF quality than anterior teeth ($p < 0.001$). The direct logistic regression results indicated that a technically well-performed RCF reduced the risk of AP almost 21-fold. The prevalence of AP in our cohort was not influenced by the type of restoration (direct or indirect), but statistically significantly, the highest prevalence of AP was found in RFT without any coronal restoration. **Conclusion.** The results of this study reaffirm that technically high-quality root canal treatment is crucial to ensure a more predictable root canal treatment outcome.

Key words:
dental restoration, permanent; periapical periodontitis; radiography; serbia.

Apstrakt

Uvod/Cilj. Apikalni periodontitis (AP) je akutna ili hronična inflamacija tkiva oko vrha korena zuba (KZ), koja se najčešće javlja kao posledica prisustva mikrobioloških iritanasa u kanalnom sistemu KZ. Cilj rada bio je da se radiografski proceni učestalost AP na zubima koji su lečeni punjenjem kanala KZ (PKKZ) kod odraslih osoba iz urbanih područja Vojvodine, Srbija. **Metode**. Analizirano je 616 nasumično odabranih digitalnih ortopantomografa osoba, koje su posetile Kliniku za stomatologiju Vojvodine u periodu od januara 2019. do decembra 2020. godine. Ocenjen je periapikalni status, kvalitet PKKZ, tip nadoknade krunice zuba, kao i njihovi međusobni odnosi. Za statističke analize primenjen je χ^2 test. **Rezultati.** Ukupan broj endodontski lečenih zuba iznosio je 965, od kojih je 44,25% ocenjeno da poseduje adekvatno PKKZ, a 34,9% je imalo znake AP, koji je dijagnostikovan kod 57,4% zuba sa neadekvatnim PKKZ. Posteriorni zubi imali su značajno lošiji kvalitet PKKZ u odnosu na frontalne zube ($p < 0,001$). Direktnom logističkom regresijom je pokazano da je tehnički dobro izvedeno PKKZ smanjilo rizik od pojave AP skoro 21 put. Na učestalost pojave AP u našoj studiji nije uticao tip nadoknade (konzervativna ili protetska), ali je kod zuba sa PKKZ kojima nije rađena nadoknada krunice nađena statistički značajno viša učestalost AP. **Zaključak.** Rezultati ove studije su potvrdili da je visok tehnički kvalitet lečenja kanala KZ od ključnog značaja za predvidljiviji ishod terapije.

Ključne reči:
zub, trajni ispuni; periodontitis, periapikalni; radiografija; srbija.

Correspondence to: Bojana Ramić, University of Novi Sad, Faculty of Medicine, Department of Dental Medicine, Hajduk Veljkova 3, 21 000 Novi Sad, Serbia. E-mail: bojana.ramic@mf.uns.ac.rs

Introduction

The success of root canal treatment (RCT) depends on the prevention or complete healing of the periradicular tissue, usually caused by the presence of bacteria in the root canal system (RCS). Based on their comprehensive epidemiological study, Sjögren et al. [1] found that the expected RCT success rate for previously vital cases was 96%, whereas 86% of patients with infected RCS and chronic apical periodontitis (AP) showed signs of periradicular healing. Insufficiently cleaned and inadequately sealed areas of RCS can represent a reservoir of residual bacteria, inducing a constant stimulus that does not allow the AP healing process to begin.

As the RCT outcome is influenced by both clinician- and patient-related factors, clinicians should ensure the high technical quality of the root canal filling (RCF) as well as a long-lasting bond between the tooth structure and restorative material. By fulfilling these prerequisites, the risk of apical and coronal microleakage will be minimized, making the RCT outcome more predictable. Undoubtedly, even if all clinician-related factors are completely fulfilled, impaired inflammatory response (such as that seen in diabetes mellitus [2, 3]) might have an unfavorable impact on the final RCT outcome and should always be taken into consideration as an important prognostic aspect [4, 5].

However, there is presently no consensus on the relative importance of RCF and coronal restoration quality for RCT success, as some authors ascribe greater value to the coronal restoration quality [6, 7], while others emphasize the importance of the quality of the RCF, citing apical leakage as the main reason for endodontic failure [8, 9]. Still, it is widely accepted that apical termination for enlarging, shaping, cleaning, disinfecting, and filling should be at or within 2 mm of the radiographic apex [10]. Available evidence further suggests that an inadequate RCS disinfection due to missed canals [11] or other procedural errors, along with the low coronal or apical seal, is positively correlated with the poorer prognosis of endodontically treated teeth [12].

Moreover, AP is more commonly associated with root-filled teeth (RFT) than those that have not been subjected to RCT, but its prevalence in extant studies was highly variable and ranged from 24.5% to 61%. Thus, cross-sectional epidemiological studies are necessary for reliably assessing the burden of this disease in the general population and ascertaining if the applied RCT was successful [13, 14]. The observation of the prevalence of AP and its predisposing factors is gaining more and more importance and publicity, especially after gaining some knowledge about a possible connection with general health disorders [15, 16].

Considering the amount of useful data yielded by cross-sectional studies, the aim of the present study was to assess radiographically the AP prevalence and factors contributing to its occurrence in endodontically treated teeth, including apical RCF extension and coronal restoration type. These parameters were observed in adults treated at an urban dentistry clinic in Vojvodina, Serbia.

Methods

This cross-sectional study included randomly chosen ortopantomographs (OPGs) of 616 subjects; out of them, 265 (43%) were male and 351 (57%) were female, requiring full-mouth periapical radiographic examination as a part of the diagnostic and planning procedures at the Clinic of Dentistry of Vojvodina, seen between January 2019 and December 2020. The Ethics Committee of the Clinic of Dentistry approved the study (No. 01-16/61-2017, from November 23, 2017), and patient anonymity and data confidentiality were strictly respected. Periapical status and RCF quality were assessed during the examination of digital OPGs. To be eligible for participation, patients had to be between 18 and 70 years old and have fully readable OPGs. On the other hand, those with poor radiograph quality, as well as patients with fewer than nine natural teeth and/or teeth with root resection, were excluded. All teeth (except third molars) with radiopaque material in the root canals were considered endodontically treated. In every OPG, the patient's age and gender were recorded, along with the number of remaining teeth, the number and location of endodontically treated teeth, the technical quality of the RCF (length of root filling from the radiographic apex and its density), the type of coronal restoration placed on these teeth, and the presence/absence of AP signs and symptoms.

Digital OPGs were obtained using a Heliodent Vario D3350 (Sirona Dental Systems GmbH, Bensheim, Germany) and were automatically saved into the patient's electronic records. They were analyzed using Kodak Dental Imaging Software version 6.12.10.0-B for Windows (Carestream-Health, Inc. 2009).

Two endodontics specialists independently analyzed and scored only readable, clear radiographs in the darkroom using an illuminated viewing box and loupe. Their calibration was performed by double scoring 15 OPGs not included in the main study [17]. Inter-examiner agreement concerning the technical quality of RCF and the existence of apical radiolucency was evaluated by calculating Cohen's Kappa scores ($k = 0.82$).

The RCF was considered adequate when its tip was situated within 2 mm from the radiographic apex and was homogeneous without visible voids, with uniform radio-opacity across the entire length of RCS. Applied scoring was based on the European Society of Endodontology guidelines [18]. Multirooted teeth were scored according to the technical quality of the worst RCF and the most severe periapical status. If the canal was underfilled, poorly condensed, overfilled, with a separated file or any of the present canals was missed, the RCF was scored as inadequate.

In order to obtain results comparable to those yielded by similar cross-sectional studies, periapical tissues were assessed using the PeriApical Index (PAI score) developed by Orstavik et al. [19] whereby PAI 1 signified normal apical structures, PAI 2 denoted minor changes in bone structure, PAI 3 indicated changes in the bone structure with little mineral loss, PAI 4 was associated with periodontitis with a ra-

diolucent, well-defined area, and PAI 5 was assigned for severe periodontitis with aggravating features.

All data were processed and analyzed using SPSS, version 23.0 (Statistical Presentation System Software; SPSS Inc., Chicago, IL, USA). Statistical significance was assessed by the Chi-squared (χ^2) test and direct logistic regression was performed to calculate odds ratios (ORs) with 95% confidence intervals (CIs), whereby $p < 0.01$ was considered statistically significant. Finally, direct logistic regression was performed to assess the effect of the possible predictors of AP in RFT.

Results

The 616 OPGs used in the analyses featured 15,448 teeth in total, examined along with the associated periradicular tissues. The mean number of remaining teeth per subject in the overall sample was 25.08, while the mean of 25.11 was noted in female patients and 25.04 in male patients, with no significant differences between these groups ($p > 0.05$). The average values of the remaining teeth followed a downward trend in relation to patient age (Table 1).

The analyzed sample contained 965 RFT, corresponding to 6.25% of the overall number of teeth. Out of the total number of RFT, 44.25% received an adequate RCF score. Maxillary teeth were more frequently endodontically treated (69.7%) than teeth in the mandible (30.3%), and this difference was statistically significant ($p < 0.001$). Moreover, a significantly higher percentage of posterior teeth (65.6%) than frontal teeth (34.4%) had been endodontically treated ($p < 0.001$). The RCT was most prevalent in maxillary premolars (24.4%), and the lowest percentage was noted in mandibular canines (0.96%). Finally, 62.4% of female patients had RFT compared to 56.2% of male patients.

In the entire sample, only 427 (44.25%) teeth received an adequate RCF score. Moreover, 63.7% of posterior teeth had inadequately filled root canals, while in 40.7%, the technical quality of RCF in frontal teeth was statistically significantly superior ($p < 0.001$). The majority of RFT (420/538 or 78.1%) were assessed as inadequate due to short and inhomogeneous RCF in at least one of the root canals, and this issue was particularly prevalent in posterior teeth ($p < 0.001$). On the other hand, overfilling was detected in only 1.06% of RFT, and missed canals were noted in 10.4% of the examined cases. Canals were statistically significantly more likely to be missed in maxillary molars (63%) compared to lower molars (24%) ($p < 0.001$). File separation was noted only in posterior teeth, with an overall prevalence of 1.28% (Table 2).

AP (PAI ≥ 3) was noted in 507 (3.5%) of the examined teeth. While only 1.2% of non-RFT exhibited signs of AP, this percentage increased to 34.9% in RFT. In particular, 75.9% of posterior RFT were affected by AP compared to only 24.1% of frontal teeth, and this difference was statistically significant ($p < 0.001$). On the other hand, the prevalence of AP in RFT in the maxilla was comparable to that in the mandible (37.7% vs. 33.6%).

Periradicular pathosis was diagnosed in 309 (57.4%) of the 539 inadequate RFT while affecting only 8% of teeth in which RCF was assessed to be technically adequate. Moreover, 67.3% of short and/or homogenous RCFs were accompanied by radiographically visible resorptive changes in the periradicular area. Additionally, AP was observed in 78% of all RFT in which at least one canal was missed during treatment.

Indirect coronal restoration was performed on 313 (32.4%) RFT, and in 219 (70.2%) of those cases, periapical status was healthy. On the other hand, 581 (60.2%) teeth were directly restored coronally, and AP was evident in 33% of these cases. There were no statistically significant differences between the periapical status of teeth that had been indirectly coronally restored and those that had been directly restored ($p > 0.05$). Only 71 (7.4%) of RFT were not subjected to any restoration and exhibited statistically significantly the highest prevalence of AP (71.8%, $p < 0.001$), as shown in Table 3.

Table 1

Distribution of the number of remaining teeth according to patient's age and gender

Age group (years)	Patients (n)	Female/Male	Mean n of teeth (F/M)
18–29	184	112 (18.2)/72 (11.7)	29.5 (29.3/29.8)
30–39	184	102 (16.6)/82 (13.3)	26.04 (25.8/26.3)
40–49	135	75 (12.2)/60 (9.7)	22.5 (22.4/22.7)
50–59	70	39 (6.3)/31 (5.03)	20.5 (20.97/19.8)
≥ 60	43	23 (3.7)/20 (3.2)	17.5 (17.3/17.8)
Total	616	351 (57)/265 (43)	25.08 (25.1/25.04)

All values are expressed as numbers (percentages).
n – number; F – female; M – male.

Table 2

Distribution of technical quality of root canal filling according to the group of teeth

[1]Score	Group of teeth		*p*	Jaw		*p*
	frontal	posterior		mandibula	maxilla	
Adequate	197 (46.1)	230 (53.9)		121 (28.3)	306 (71.7)	< 0.001
Short/inhomogeneous	129 (30.7)	291 (69.3)	< 0.001	146 (34.8)	274 (65.2)	< 0.001
Missed canal	0 (0.0)	100 (100.0)	< 0.001	24 (24.0)	76 (76.0)	< 0.001
File separation/overfilled	6 (33.3)	12 (66.7)	< 0.001	1 (0.3)	17 (94.4)	< 0.001

All values are expressed as numbers (percentages).
[1] Score reflects the technical quality of root canal filling.

Table 3

Periapical status of root-filled teeth as a function of coronal restoration

Restoration type	Root-filled teeth	Root-filled teeth with AP	Root-filled teeth without AP
Direct	581 (60.2)	192 (33)	389 (67)
Indirect	313 (32.4)	94 (29.8)	219 (70.2)
Unrestored	71 (7.4)	51 (71.8*)	20 (28.2)
Total	965 (100)	337 (34.9)	628 (65.1)

AP – apical periodontitis. All values are expressed as numbers (percentages).
***Statistically significant $p < 0.001$.**

Table 4

Possible predictors of apical periodontitis in root-filled teeth

Parameter	B	SE	Wald	df	*p*	OR (95% CI)
Inadequately root-filled teeth	-3.034	0.230	174.448	1	< 0.001	20.8 (13.3–32.2)
Presence of any coronal restoration	-1.987	0.352	31.886	1	< 0.001	7.3 (3.66–14.49)
Constant	1.997	0.420	22.643	1	< 0.001	7.368

OR – odds ratio; CI – confidence interval; SE – standard error.

Based on the aforementioned findings, a model of RFT was developed based on the data from 965 examined cases. Even though the full model with tooth group, jaw, RCF score, and presence of coronal restoration included as four independent variables was statistically significant ($\chi^2 = 352.6$; $p < 0.001$), as shown in Table 4, only two predictors made a unique statistically significant contribution to its output. Based on the findings yielded by this more parsimonious model that excluded the tooth group and jaw, inadequate RCF increases the probability of AP in the root by 20.8-fold ($p < 0.001$; OR = 20.8; CI = 13.3−32.2). Additionally, the absence of coronal restoration increases the chance of AP by 7.3-fold ($p < 0.001$; OR = 7.3; CI = 3.66−14.49).

The *post-hoc* power analyses were conducted using G*Power 3.1.7.9. to estimate the achieved power of logistic regression analysis for two predictors with OR1 = 20.8 and OR2 = 7.3 on a sample of n = 965 and an alpha of 0.01. Results showed that the achieved power in both cases had a value of 1.

Discussion

Since one of the main goals of this study was to assess the AP prevalence, it was inevitably affected by the limitations commonly associated with all cross-sectional radiographic studies. In particular, as the time that elapsed between RCT, permanent restoration placement, and panoramic radiograph capture cannot be established, AP prevalence can be both under- and overestimated, as OPGs only provide a snapshot of patients' radiographic status. Although AP recorded on an OPG can be in a developing or healing phase, Petersson et al. [20] found that the number of healed and newly developed periapical lesions across a particular period was comparable. These findings prompted numerous cross-sectional studies based on radiograph analysis as a means of assessing AP prevalence within a particular population [21].

Additionally, the occurrence of clinical symptoms like pain, swelling, or sinus tract is a direct clinical indicator of RCT failure, which can be suspected when periapical lesion development or persistence in RFT is evident on the radiograph. According to Estrela et al. [22], a bone mineral loss of approximately 30–50% is required for lesions to be detected on conventional radiographs, which may lead to considerable AP underestimates when this approach is adopted. Similarly, although cone-beam computed tomography (CBCT) is more sensitive when adopted as an AP prevalence diagnostic tool, it leads to overestimates compared to histopathological analysis [23]. Furthermore, according to the most important recent recommendations, to limit radiation exposure, CBCT should be reserved for specific clinical cases rather than used for evaluation studies [24].

This study analyzed panoramic radiographs, which are not only more readily available and affordable but also expose patients to a lower radiation dose and allow all teeth to be displayed on a single radiograph [25]. Additionally, digital OPGs enable magnification of different areas in the panoramic radiograph as well as image enhancement to achieve better visualization of the region of RCS and periradicular tissue that is of particular interest. Still, despite the disadvantages related to the undesirable superimposition of anatomical structures, panoramic radiographs are useful for assessing the patient's overall dental health and detecting periapical lesions [26]. These observations are confirmed by the findings of a recent systematic literature review indicating that the majority of studies in this domain were based on panoramic radiographs, allowing their results to be compared and contrasted, which increases their external validity [27].

Given that the number of general dental practitioners in Serbia is significantly higher than the number of specialists, the majority of endodontic treatments examined in this study were likely performed by general practitioners. Consequently, RCT outcome is less likely to be successful, as rubber dam is rarely used in general dental practice, and there are also shortcomings in the cleaning process and shaping of RCS, as well as evidence of noncompliance with the irrigation protocol. Moreover, as this study was con-

ducted in only one state-funded clinical center, its findings cannot account for likely variations in the RCT outcome depending on the region of the country and the patent's income level. For instance, patients from rural areas tend to have fewer remaining natural teeth, and the RCF quality is typically lower than in urban settings. Therefore, the results reported here cannot be generalized to the entire adult population living in Vojvodina or the types of dental practice in which RCF is performed. Nevertheless, one of the main strengths of this study that can be highlighted, thanks to the size of the population sample, is that it provides a valuable overview of the general dental health of the observed population in a given period and shows that the prevalence of AP is one of the most important indicators of the outcome of RCT. Regarding this, obtained data may serve as important tools for further improvements in prevention and treatment plans for AP.

In the present study, the average number of remaining teeth per subject was 25.08, with a mean of 25.11 noted in females and 25.04 in males. These results are in line with the findings obtained in previous epidemiological studies conducted in Finland [28] and Greece [29] and are attributed to a relatively young patient age. Namely, more than half of our sample was aged below 40 and patients with fewer than nine remaining teeth (who probably lost most of their teeth owing to the periodontal disease) were excluded.

The prevalence of RFT (6.25%) in our sample was also comparable to that noted in studies carried out in Finland [28] and Spain [30]. Taking into account that the first mandibular molar is the first permanent tooth to erupt, it is not surprising that RCT is most frequently detected in mandibular molars [31]. In our study, 69.7% of all RFT were located in the maxilla, and posterior teeth were more likely to be endodontically treated compared to frontal teeth, concurring with previously reported results [29]. Furthermore, RCT was most likely to be performed in maxillary premolars, which coincides with the findings reported for the Austrian subpopulation [32].

Given that AP is a dynamic process, it is likely to be affected by RCT quality. Indeed, in our study, AP was detected more frequently in RFT (34.9%) than in non-RFT, and the same findings were reported by other authors [8], whereby 35% was reported for Thailand [33], 34.1% for Germany [34], and 31.5% for France [35]. Nonetheless, in previous studies, the prevalence of AP associated with RFT ranged from 24.5% to 61% [36], and this significant discrepancy likely arises due to differences in sample characteristics, OPG quality, and criteria applied for diagnosing AP.

The current study revealed that 55.8% of all RFT were inadequately obturated, concurring with 52.6% reported by Loftus et al. [17]. One of the main aims of this study was to establish the link between the low technical quality of RCT and periapical pathology, given that insufficient elimination of bacteria from RCS contributes to the AP development or persistence. In line with earlier findings, in our cohort, AP prevalence in posterior RFT was significantly higher compared to frontal RFT, likely due to the poorer technical quality of RCF in those groups of teeth owing to their more complex anatomy [25]. Therefore, it was not surprising that only 8% of technically adequate RFT were affected by AP, concurring with 7.3% reported for the Turkish population [36]. On the other hand, in the only previously published study involving the Serbian population, 25.9% of adequately scored RFT showed evidence of AP [37].

According to our model, the presence of AP was correlated significantly with inadequate RCF ($p < 0.01$). Indeed, 57.4% of the technically inadequate RFT (which comprised 55.7% of the sample) showed signs of AP, slightly exceeding 50.3% reported by Kielbassa et al. [32]. Inadequate root-filling length indicates insufficient canal disinfection and consequently increases the likelihood that AP will persist or develop. In this study, 67.3% of teeth with short and/or inhomogeneous RCF showed evidence of AP, in line with the previously published results [12, 38].

Missed canals during RCT in multirooted teeth usually indicate inadequate practitioner knowledge of tooth anatomy or complex canal configuration, which is conducive to bacterial proliferation, causing the development or maintenance of existing periapical lesions as a sign of treatment failure. In this study, 10.4% of all RFT had at least one missed canal, which is in line with the 12% reported by Baruwa et al. [39]. These authors also noted that canals were most likely to be missed in maxillary molars (59.5%), which supports our findings (63%). Similarly, both mesiobuccal root canals of maxillary molars were frequently missed during RCT, likely due to frequent deposition of tertiary dentin over their orifices, as a consequence of persistent untreated caries or the presence of deeper restorations, which significantly complicates the RCT procedure.

Unless there is a radiographically visible defect in the proximal surfaces, the quality of restoration, whether direct or indirect, can only be assessed when radiographs are interpreted alongside clinical findings. Thus, in this study, RFT were evaluated only if they were coronally restored, and the type of restoration was taken into consideration. According to Torabinejad et al. [40], bacterial colonization of root-filled canals without coronal restoration can be detected within three weeks. Our results also highlight the importance of coronal restoration as radiographic signs of AP were noted in 71.8% of teeth that had not been coronally restored. Moreover, in 23.5% of cases, AP was visible even though the technical quality of the RCF was adequate. Indirect restorations usually require the placement of temporary restoration material prior to its cementation in the next visit, which increases the possibility of coronal microleakage in the interim period. The major concern related to *post*-placement stems from the risk of perforation as well as poor cementation, which can also lead to microleakage [41]. On the other hand, placement of direct restorations, especially composites, carries the risk of gap formation on the gingival margins, which might provide an ideal path through which bacteria can access the root-filled canal, compromising the endodontic treatment success [42]. Still, it is worth noting that AP prevalence in our cohort was not affected by the restoration type (direct or indirect).

It should be emphasized that the strength of these cross-sectional studies is that they provide the information needed for the continuous improvement of dental education and subsequent dental practice. In this context, the present study can also be seen as a call for enhancing general dentists' knowledge and clinical skills, but also points to the need for referring patients to endodontics specialists when RCT needs to be performed on posterior teeth, especially molars. Finally, researchers must follow certain clearly defined guidelines for conducting cross-sectional studies so that results are more comparable. Recently, it was recommended that these guidelines be aligned with the developed checklist of Preferred Reporting points for Observational studies in Endodontics (PROBE 2023) [43] to improve the quality of these types of studies.

Conclusion

Despite the limitations of this study related to the possible underestimation of the real clinical situations, the yielded results indicate that well-performed RCF reduced the risk of AP by almost 21-fold, confirming its exceptional importance for RCT success.

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