

Evaluation of technical quality and periapical health of root-filled teeth by using cone-beam CT

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ABSTRACT

Objective: This study aimed to assess the quality of root fillings, coronal restorations, complications of all root-filled teeth and their association with apical periodontitis (AP) detected by cone-beam computed tomography (CBCT) images from an adult Turkish subpopulation. Material and Methods: The sample for this study consisted of 242 patients (aging from 15 to 72 years) with 522 endodontically treated teeth that were assessed for technical quality of the root canal filling and periapical status of the teeth. Additionally, the apical status of each root-filled tooth was assessed according to the gender, dental arch, tooth type and age classification, undetected canals, instrument fracture, root fracture, apical resorption, apical lesion, furcation lesion and type and quality of the coronal structure. Statistical analysis was performed using percentages and chi-square test. Results: The success rate of the root canal treatment was of 54.4%. The success rates of adequate and inadequate root canal treatment were not significantly different ($p>0.05$). Apical periodontitis was found in 228 (45.6%) teeth treated for root canals. Higher prevalence of AP was found in patients aging from 20 to 29 years [64 (27%) teeth] and in anterior (canines and incisors) teeth [97 (41%) teeth]. Conclusions: The technical quality of root canal filling performed by dental practitioners in a Turkish subpopulation was consistent with a high prevalence of AP. The probable reasons for this failure are multifactorial, and there may be a need for improved undergraduate education and postgraduate courses to improve the clinical skills of dental practitioners in endodontics.

Keywords: Cone-beam computed tomography. Root canal. Apical periodontitis.

INTRODUCTION

The quality of root canal fillings is associated with the adequate treatment of roots, which depends on their length in relation to the apex, homogeneity and quality and type of coronal restorations^{23,29}. The successful interpretation of endodontic problems was associated with diagnostic imaging techniques that provide information about the teeth and their surrounding anatomy.

Numerous studies have used periapical radiographs to assess the anatomic structure of teeth and to analyze the number and location of root canals^{23,29}. However, periapical radiographs provide two-dimensional images, therefore, they

cannot provide adequate information about the root canal configuration. Recently, cone-beam computed tomography (CBCT) is being widely used in dental practice and research. CBCT have been used to provide greater details about the root canal anatomy and their surrounding structures compared to radiographic images¹⁹.

Follow-up studies on root canal treatment in educational hospitals, which have showed that the reality for the overall population might be somewhat different, present success rates between 35%-96%^{14,20,21}. A root canal treatment applied with the highest standards of care can heal the periapical lesion¹². However, regardless of the population group and geographic location, studies confirm that outcomes of root canal treatments performed

by general dental practitioners show much lower success rates^{4,23,27,30}. One of the most important reasons for such poor quality treatment is an increase in the prevalence of apical periodontitis (AP).

The chronic inflammation of the periapical structure usually develops itself without the patient experiencing symptoms, thus, radiological examination is still fundamental for its detection. AP is generally underestimated and sometimes not detectable in panoramic and periapical radiographic images, because of the superposition of anatomical landmarks⁶. The main advantage of a 3D view of maxillofacial structures is that they have no superimpositions with anatomical landmarks¹⁵.

Previous studies assessed the quality of root canal fillings by radiography^{23,29}. However, no studies have yet assessed the quality of root canal fillings using CBCT in a Turkish subpopulation. This study was aimed to assess the quality and periapical status of root canal fillings by CBCT in a Turkish subpopulation.

MATERIAL AND METHODS

CBCT images of root canal fillings were obtained from patients who first visited the Faculty of Dentistry of Dicle University, Diyarbakir, Turkey, between 2009 and 2011. We assessed a database of 522 CBCT scans of endodontically treated teeth obtained from 276 patients according to sex and age (15-72 years), and records of third molars were excluded. This study was based on a retrospective assessment of CBCT images and approved by the Medical Ethics Committee of Şifa University (Protocol #33-2013).

The selection criteria included the following:

1. Patients over 14 years old;
2. Patients visiting the clinic for the first time;
3. CBCT images of good quality;
4. Previous root canal treatment performed by general practitioners.

Exclusion criteria included the following:

1. CBCT images presenting deformations;
2. Unsatisfactory coronal restoration;
3. Recently traumatized and treated teeth;
4. Orthodontic patients.

The CBCT images were obtained using a CBCT scanner (I-CAT Vision TM Imaging Science International, Hatfield, USA, 2008) at 120 kVp, 18.54 mA, with an exposure time of 8-9 s. The voxel size of the images was 0.3 mm. The acquisition process was performed by an experienced radiologist according to the recommendations of the manufacturer, with the minimum exposure necessary for adequate image quality. Intraexaminer calibration of the CBCT images was first performed to evaluate the reliability of the assessment. All images were assessed separately two times by two examiners (an endodontist and a maxillofacial radiologist) with a 2-week interval between the assessments. In the case of disagreements between the pair, these were discussed with another radiologist until a consensus was reached. The following factors were assessed in all images: sex, dental arch, tooth type and age classification, undetected canals, instrument fracture, root fracture, apical resorption, apical lesion, furcation lesion, type and quality of the coronal structure and sufficient (overfilled) and insufficient (underfilled) root canal filling (RF) (Figure 1). The criteria used for the examination were slightly modified from those described by De Moor, et al.⁴ (2000): sufficient RF was defined as a root canal space that was

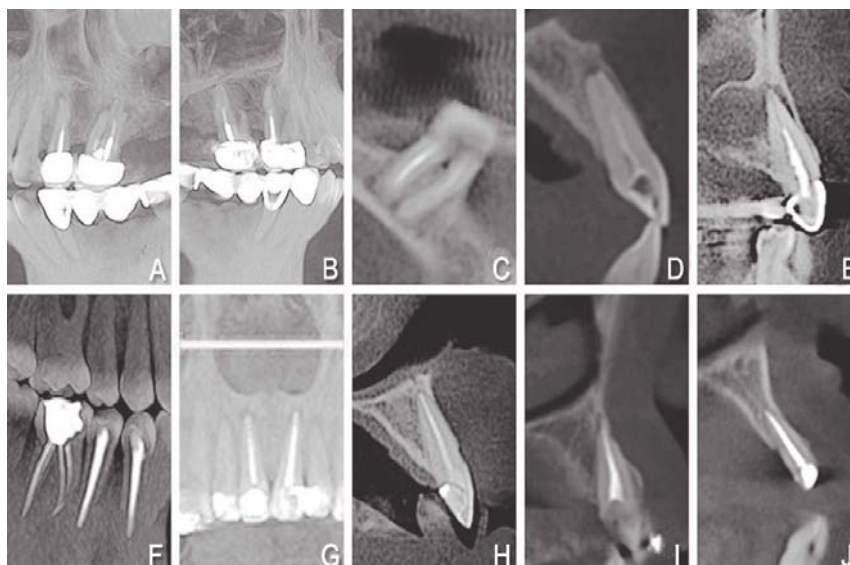


Figure 1- A-E) Insufficient (underfilled) root canal filling; B) undetected canals; C,G) Apical lesion; F) Overfilled root filling and instrument fracture I); Apical resorption H,J); Sufficient root filling

completely filled, ending 1–2 mm from the apex, and with no voids; insufficient RF was defined as a root canal space that was poorly condensed, ending more than 2 mm from the apex, and with voids. Additionally, the quality of coronal restoration was assessed according to any permanent restoration, radiographic signs of recurrent caries, open margins or presence of temporary coronal restorations or no restoration (Figure 2).

Statistical analysis

The CBCT images used to assess the technical quality of root canal fillings were analyzed using the chi-square test ($p < 0.05$).

RESULTS

In this study, a total of 522 teeth obtained from 276 patients (134 females and 142 males), aging from 15 to 72 years, were assessed. Of these teeth, 265 (50.8%) were from females, and 257 (49.2%) were from males; the difference between genders was statistically significant ($p < 0.05$). With regard to age, patients under 20 and over 60 years presented lower prevalence of endodontic treatment (Table 2).

Table 1 lists the types and prevalence of root-filled teeth. There were 370 (70.9%) maxillary

teeth and 152 (29.1%) mandibular teeth. Incisors and canines ($n=232$) were treated most frequently, followed by premolars ($n=166$) and molars ($n=124$). The periapical status of all root-treated teeth is presented in Table 1. Of all the endodontically treated teeth, 54.3% showed a healthy periapical structure, whereas 45.7% showed the presence of AP lesions in dental arches, and the difference was not statistically significant ($p > 0.05$). The distribution frequency of the AP affected the maxillae [168 teeth (45.4%)] and mandible [70 teeth (46%)] in the dental arch was similar. There were found 238 (45%) AP lesions. The AP lesions were located most frequently in maxillary incisors and canines [80 (15.3%) teeth], followed by maxillary premolars [50 (9.6%) teeth] and maxillary molars [38 (7.3%) teeth]. The AP lesions were located less frequently in mandibular incisors and canines [17 (3.3%) teeth]. In addition, without considering the technical quality of root canal treatments, the prevalence of apical health and coronal structure of the teeth showed no statistically significant difference ($p > 0.05$). An assessment of the coronal structure of the teeth with root canal fillings revealed that 61.9% had coronal restorations, whereas 38.1% had been crowned. The relationship between the periapical status

Parameters	Criteria	Characterization
Quality of root canal treatments		
Density of root canal filling	Adequate	No gaps present in the root filling or between root filling and root canal walls.
	Poor	Gaps present in the root filling or between root filling and root canal walls.
Length of root canal filling	Adequate	Root filling ending ≤ 2 mm from the radiographic apex.
	Poor	Root filling over the radiographic apex or root filling > 2 mm from the radiographic apex.
Quality of coronal restoration	Adequate	Any permanent restoration that appeared intact radiographically.
	Poor	Any permanent restoration with detectable radiographic signs of recurrent caries or open margins or presence of temporary coronal restorations.
	Missing	No permanent or temporary coronal restoration.
Periapical status	Healthy periodontal ligament	The periodontal ligament was intact with no signs of periapical pathosis.
	Apical periodontitis	The periapical radiolucency in connection with the apical part of the tooth exceeding at least two times the width of the lateral part of the periodontal ligament.

Figure 2- Parameters recorded on endodontically treated teeth with cone-beam computed tomography (CBCT)

Table 1- The outcome of 522 endodontically treated teeth as determined cone-beam computed tomography (CBCT)

	Total		Apical periodontitis		Periapical status Healthy		Chi-square P values
	n	%	n	%	n	%	
Sex							
Female (n:134)	265	50.8%	103	38.9%	162	61.1%	0.01
Male (n:142)	257	49.2%	135	52.5%	122	47.5%	
Dental arch							
Maxilla	370	70.9%	168	45.4%	202	54.6%	0.484
Mandible	152	29.1%	70	46%	82	54%	
Tooth type							
Incisors+Canines	232	44.5%	97	40.5%	135	47.5%	Maxilla:0.04
Premolars	166	32%	71	30%	95	33.5%	Mandible:0.29
Molars	124	23.5%	70	29.5%	54	19%	
Age classification							
14-20	44	8.4%	12	27.3%	32	72.7%	0.016
20-30	119	22.8%	64	53.8%	55	46.2%	
30-40	107	20.5%	52	48.6%	55	51.4%	
40-50	117	22.4%	47	40.2%	70	59.8%	
50-60	109	20.9%	47	43.1%	62	56.9%	
60 and ↑	26	5%	16	61.5%	10	38.5%	
Undetected canals	44	8.4%	30	68.2%	14	31.8%	0.002
Filling length							
Underfilled	152	29.1%	113	74.3%	39	25.7%	0.000
Adequate	323	61.9%	80	24.8%	243	75.2%	
Overfilled	47	9%	45	95.7%	2	4.3%	
Instrument fracture	1	0.2%	1	100%	-		0.456
Root fracture	2	0.4%	1	50%	1	50%	0.704
Apical resorption	77	14.8%	69	89.6%	8	10.4%	0.000
Apical lesion	76	14.6%	74	97.4%	2	2.6%	0.000
Furcation lesion	1	0.2%	1	100%	-		0.456
Type and quality of coronal structure							
Restoration	323	61.9%	156	65.5%	167	58.8%	0.06
Crowned	199	38.1%	82	34.5%	117	41.2%	

and type and quality of coronal structure was not statistically significant ($p > 0.05$); the distribution is presented in Table 1.

Of 522 teeth, 199 (38.1%) had inadequate length of filling, being short of the radiographic apex or overfilled, whereas only 323 (61.9%) had ideal filling length. The prevalence of AP was 113 (74.3%) in underfilled teeth, and 45 teeth (95.7%) had been overfilled with gutta-percha or sealer material. Overall, a root canal filling was considered as an adequate filling length with periapical healing in only 243 (75.2%) of all ideal filling length, whereas AP was recorded in 80 teeth (24.8%). In the present

study, the complications of all root-filled teeth were assessed. One (0.02%) had broken instruments inside the canals, 44 (8.4%) had undetected root canals, 2 (0.4%) had root fractures, 77 (14.8%) showed apical resorption, 76 (14.6%) had apical lesions, and 1 (0.2%) had furcation lesions.

DISCUSSION

This study is the first to assess the periapical status of root-filled teeth using CBCT images of a Turkish subpopulation. The negative factor of this study is that the data analyzed are restricted to

available information and thus may suffer from preconception²⁴. However, the most important advantage of this method is the comprehensive sample size⁸. Previous studies typically used conventional panoramic¹⁷ or full-mouth periapical radiographs^{8,23,29}. The main disadvantage of conventional radiographs is that they only provide static information about a dynamic process and it is impossible to estimate whether a periapical lesion is increasing or decreasing in size²³. Recently, CBCT has been widely used in endodontic therapy⁵. The most important advantage of CBCT in endodontics is that it allows a better visualization of the details of the root canal anatomy than radiographic images and provides a 3D view for diagnosing and managing endodontic complications^{5,19}, therefore, we used CBCT images in this study. In our study, endodontic treatment was more prevalent in patients aging between 20 and 30 (22.8%) and between 40 and 50 (22.4%) years, and these results lead to tooth loss with advancing age. Furthermore, patients aging over 60 years presented lower prevalence of endodontic treatment than those under 60 years in this study, because this population probably have extracted teeth - especially molar teeth.

In previous studies of root-filled teeth in a Turkish subpopulation, 40.5-74% of root fillings were reported to be inadequate; many of these were undertaken in general practice or hospital settings^{7,8,10,22,23}. Kayahan, et al.¹⁰ (2008) assessed 1268 teeth from 280 panoramic radiographs and found apical lesions in 40.5% (514) of the teeth. Sunay, et al.²² (2007) assessed panoramic radiographs of 375 patients and found pathological findings in 53.5% of the teeth. In this study, 238 (45.6%) teeth showed periapical lesions, and the other 284 (54.4%) showed a healthy periapical structure.

The present study targets a population from a rural area and parallel results regarding the prevalence of periapical lesions presented in other studies of a Turkish subpopulation^{7,10,22,29}. The relation between this study and these results lies in the fact that the income and treatment opportunities for patients, particularly those living in the rural areas of Turkey, are limited. Finally, the extraction of teeth due to low socioeconomic status leads to a limited epidemiological increase in the number of root-filled teeth.

However, Fernandes, et al.¹⁵ (2013) evaluated a total of 5585 teeth of 300 Brazilian patients assessed by CBCT images and found periapical lesions in only 192 teeth (3.4%). Peak, et al.¹⁶ (2001) evaluated the treatment outcome of a total of 406 teeth with root canal fillings done by military general dentists in the Royal British Army and found periapical lesions in 62 (15%) teeth. On the other hand, in a Taiwanese population, Chueh,

et al.² (2003) assessed a total of 1085 teeth and found that the rate of root canals with adequate fillings were 61.7%. While unacceptable fillings due to inadequate root fillings were of 25.0% and overfilling were of 12.6%, 0.6% had no fillings in their root canals. Similarly, in a Senegalese subpopulation, only 17.7% of the root fillings were technically acceptable²⁷. In the Kosovan population, Kamberi, et al.⁹ (2011) found that, following endodontic procedures by general dentists, 30.5% of the root filled teeth were technically acceptable.

Unlike the results of the studies mentioned above, Tarim, et al.²³ (2013) assessed 1448 roots of 831 teeth obtained from 484 patients. They found that 73.4% of these showed periapical lesions and the other 26.6% showed a healthy periapical structure. In another study⁷, the panoramic and periapical radiographs of 400 patients were investigated and the root canal treatment was applied to 890 teeth, and the presence of periapical lesions could be found in 658 (73.9%) teeth.

In our study, we found that 45.5% (238) of the teeth showed periapical lesions. This can be explained by the fact that the survey population did not represent the entire country; there were differences in healthcare services and socioeconomic factors; and the age of the assessed patients, sample of patients, and assessment methods differed from each other.

In addition, a common problem in endodontics is the limitation of conventional radiographic images, where the anatomical structures may be confused with periapical pathosis, and the number of canals in root canal treatment might often be unclear¹⁹. Furthermore, internal, external, buccal or lingual lesions could not be identified by conventional radiography when compared with CBCT¹³.

The correct diagnosis of complications such as perforations, resorptions, undetected canals and root fracture can be challenging and may result in an unsuitable treatment^{7,19}. Therefore, the assessment of such complications is particularly important in endodontics. These problems may be overcome using the CBCT technique that provides a 3D view for diagnosing and managing endodontic complications³.

The results of this study agree with those of other studies that found the quality of root canal treatment to be an important factor for prognosis of the coronal restorations. Different studies have disputed the effects of coronal restorations and quality of root canal treatment on periradicular tissues^{8,11,18,28}. Most studies recognized that a relationship exists between the type of restoration and the periradicular health. They concluded that the quality of the root canal filling was much more important than the type of restoration^{8,23}. Kayahan, et al.¹⁰ (2008) reported that healthy periradicular

tissues were significantly higher in teeth with optimal root canal fillings in any type of restoration. Furthermore, Tronstad, et al.²⁸ (2000) demonstrated that the quality of a well-sealed coronal restoration influenced the outcome significantly positively when combined with optimal root canal treatment. In the present study, root filled teeth restored with or without crowns showed no statistically significant differences in the occurrence of periapical pathology ($p>0.05$), but teeth without crowns showed more AP than crowned teeth.

In the literature, many epidemiological studies have shown that there is a high prevalence of periapical disease in the root filled teeth with poor technical quality^{1,22,23}. It is because bacteria can remain within the root canal system in filled teeth, and their products may cause reinfection of the root canal system in a relatively short time^{25,26}. The results from the present study confirm the findings of other studies that affirmed that inadequate root filling teeth present higher AP prevalence (74.3% underfilled and 95.7% overfilled, $p=0.00$). Adequate root canal fillings were found in 323 (61.9%) of all examined samples, 24.8% of these teeth were recorded with presence of AP.

Finally, it is clear that the quality of the root canal fillings is associated with higher professional standards and a better technique, undergraduate and postgraduate training and better equipment. Furthermore, we believe that an adequate coronal restoration and root canal treatment were important to the overall success of the root canal treatment.

CONCLUSION

The technical quality of root canal filling performed by dental practitioners in a Turkish subpopulation was consistent with a high prevalence of AP. The present study, despite its limitations, confirmed the findings of other studies. The probable reasons for treatment failure are multifactorial and may indicate the need for improved undergraduate education and postgraduate courses to improve the clinical skills of dental practitioners in endodontics. There is a need to standardize the assessment of the quality of root canal fillings, therefore, this study provides useful information about general dental conditions in a Turkish subpopulation, which can help in describing new strategies for the treatment and protection of periradicular tissues. Additionally, this study contributes toward future applications of CBCT images in cross-sectional studies.

REFERENCES

- 1- Bierenkrant DE, Parashos P, Messer HH. The technical quality of nonsurgical root canal treatment performed by a selected cohort of Australian endodontists. *Int Endod J.* 2008;41(7):561-70.
- 2- Chueh LH, Chen SC, Lee CM, Hsu YY, Pai SF, Kuo ML, et al. Technical quality of root canal treatment in Taiwan. *Int Endod J.* 2003;36(6):416-22.
- 3- D'Addazio PS, Campos CN, Özcan M, Teixeira HG, Passoni RM, Carvalho AC. A comparative study between cone-beam computed tomography and periapical radiographs in the diagnosis of simulated endodontic complications. *Int Endod J.* 2011;44(3):218-24.
- 4- De Moor RJ, Hommez GM, De Boever JG, Delmé KI, Martens GE. Periapical health related to the quality of root canal treatment in a Belgian population. *Int Endod J.* 2000;33(2):113-20.
- 5- Durack C, Patel S. Cone beam computed tomography in endodontics. *Braz Dent J.* 2012;23(3):179-91.
- 6- Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. *J Endod.* 2008;34(3):273-9.
- 7- Gencoglu N, Pekiner FN, Gumru B, Helvacioğlu D. Periapical status and quality of root fillings and coronal restorations in an adult Turkish subpopulation. *Eur J Dent.* 2010;4(1):17-22.
- 8- Gündüz K, Avsever H, Orhan K, Demirkaya K. Cross-sectional evaluation of the periapical status as related to quality of root canal fillings and coronal restorations in a rural adult male population of Turkey. *BMC Oral Health.* 2011;11:20.
- 9- Kamberi B, Hoxha V, Stavileci M, Dragusha E, Kuçi A, Kqiku L. Prevalence of apical periodontitis and endodontic treatment in a Kosovar adult population. *BMC Oral Health.* 2011;11:32.
- 10- Kayahan MB, Malkondu O, Canpolat C, Kaptan F, Bayirli G, Kazazoglu E. Periapical health related to the type of coronal restorations and quality of root canal fillings in a Turkish subpopulation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2008;105(1):58-62.
- 11- Kirkevang LL, Ørstavik D, Hörsted-Bindslev P, Wenzel A. Periapical status and quality of root fillings and coronal restorations in a Danish population. *Int Endod J.* 2000;33(6):509-15.
- 12- Liang YH, Li G, Shemesh H, Wesselink PR, Wu MK. The association between complete absence of post-treatment periapical lesion and quality of root canal filling. *Clin Oral Investig.* 2012;16(6):1619-26.
- 13- Liang YH, Yuan M, Li G, Shemesh H, Wesselink PR, Wu MK. The ability of cone-beam computed tomography to detect simulated buccal and lingual recesses in root canals. *Int Endod J.* 2012;45(8):724-9.
- 14- Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature - part 1. Effects of study characteristics on probability of success. *Int Endod J.* 2007;40(12):921-39.
- 15- Fernandes LMPSR, Ordinola-Zapata R, Duarte MAH, Capelozza ALA. Prevalence of apical periodontitis detected in cone beam CT images of a Brazilian subpopulation. *Dentomaxillofac Radiol.* 2013;42(1):80179163.
- 16- Peak JD, Hayes SJ, Bryant ST, Dummer PM. The outcome of root canal treatment. A retrospective study within the armed forces (Royal Air Force). *Br Dent J.* 2001;190(3):140-4.
- 17- Peters LB, Lindeboom JA, Elst ME, Wesselink PR. Prevalence of apical periodontitis relative to endodontic treatment in an adult Dutch population: a repeated cross-sectional study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2011;111(4):523-8.
- 18- Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. *Int Endod J.* 1995;28(1):12-8.
- 19- Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. *Int J Dent.* 2009;2009:634567.

- 20- Sjögren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. *Int Endod J*. 1997;30(5):297-306.
- 21- Sjögren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. *J Endod*. 1990;16(10):498-504.
- 22- Sunay H, Tanalp J, Dikbas I, Bayirli G. Cross-sectional evaluation of the periapical status and quality of root canal treatment in a selected population of urban Turkish adults. *Int Endod J*. 2007;40(2):139-45.
- 23- Tarim Ertas E, Ertas H, Sisman Y, Sagsen B, Er O. Radiographic assessment of the technical quality and periapical health of root-filled teeth performed by general practitioners in a Turkish subpopulation. *ScientificWorldJournal*. 2013;2013:514841.
- 24- Tavares PB, Bonte E, Boukpepsi T, Siqueira JF Jr, Lasfargues JJ. Prevalence of apical periodontitis in root canal-treated teeth from an urban French population: influence of the quality of root canal fillings and coronal restorations. *J Endod*. 2009;35(6):810-3.
- 25- Torabinejad M, Kettering JD, McGraw JC, Cummings RR, Dwyer TG, Tobias TS. Factors associated with endodontic interappointment emergencies of teeth with necrotic pulps. *J Endod*. 1988;14(5):261-6.
- 26- Torabinejad M, Ung B, Kettering JD. *In vitro* bacterial penetration of coronally unsealed endodontically treated teeth. *J Endod*. 1990;16(12):566-9.
- 27- Touré B, Kane AW, Sarr M, Ngom CT, Boucher Y. Prevalence and technical quality of root fillings in Dakar, Senegal. *Int Endod J*. 2008;41(1):41-9.
- 28- Tronstad L, Asbjørnsen K, Døving L, Pedersen I, Eriksen HM. Influence of coronal restorations on the periapical health of endodontically treated teeth. *Endod Dent Traumatol*. 2000;16(5):218-21.
- 29- Unal GC, Kececi AD, Kaya BU, Tac AG. Quality of root canal fillings performed by undergraduate dental students. *Eur J Dent*. 2011;5(3):324-30.
- 30- Weiger R, Hitzler S, Hermle G, Löst C. Periapical status, quality of root canal fillings and estimated endodontic treatment needs in an urban German population. *Endod Dent Traumatol*. 1997;13(2):69-74.