

Problems with the Quality of Root Canal Treatment Performed by Undergraduate Students on Single-Rooted Teeth

Diş Hekimliği Öğrencilerinin Tek Köklü Dişlerde Uyguladıkları Kök Kanal Tedavileriyle İlgili Problemler

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ABSTRACT Objective: This study aims to analyze the radiographic quality of root canal fillings performed by fourth year dental undergraduate students in the Biruni University Faculty of Dentistry, İstanbul, Turkey. **Material and Methods:** Endodontic records from 505 completed endodontic therapies performed on 337 patients by dentistry students with the same pre-clinical education between 2017 and 2018 were examined. Four variables were analyzed: the length of the root canal filling, the density of the root canal filling, the amount of taper and the cutting level of excess gutta-percha. Iatrogenic errors, including ledges, perforations and fractured instruments were also documented. The samples were defined as “optimum” radiographically, if the obturation material ends 0-2 mm short of the radiological apex with adequate taper, no voids visible and the cutting level of excess gutta-percha is 1 mm below the cemento-enamel junction with no iatrogenic error. Radiographs were examined by two experienced endodontists. A chi-square test was used to determine statistical significance between different parameters. **Results:** There was no significant difference between all examined anterior (27%) and premolar (23%) teeth while there was a statistically significant difference between the “optimum” root canal fillings on maxilla (27.7%) and mandible (18.1%) ($p=0.018$). **Conclusion:** Upon consideration of many criteria, the “optimum” cases we defined were found to be low compared to other studies. Therefore, more studies are required, considering multiple criteria.

ÖZET Amaç: Bu çalışmanın amacı, Biruni Üniversitesi Diş Hekimliği Fakültesi, 4. sınıf öğrencileri tarafından uygulanmış kök kanal dolumlarının radyografik kalitesini değerlendirmektir. **Gereç ve Yöntemler:** Aynı endodonti prelinik eğitimini tamamlamış diş hekimliği öğrencilerinin, 2017-2018 yıllarında endodonti kliniğinde 337 hastada uyguladığı, 505 adet tamamlanmış endodontik tedavi kayıtları değerlendirilmiştir. Bu çalışmada, kök kanal dolumu uzunluğu ve homojenitesi, preparasyon açısı miktarı ve kural bölümdaki fazla gutta-perkanın kesim seviyesi olmak üzere dört farklı değişken incelenmiştir. Aynı zamanda, basamak, perforasyon ve alet kırığı gibi iyatrojenik hatalar da kayıt edilmiştir. Örneklerden, obtürasyon uzunluğu radyolojik apeksin 0-2 mm gerisinde olan, preparasyon açısı yeterli ve kanal dolumunda boşluk görülmeyen, koronal bölümdaki fazla gutta-perkanın kesim seviyesi uygun olan ve iyatrojenik hata içermeyenler radyografik olarak “ideal” kök kanal dolumu şeklinde nitelendirilmiştir. Radyografiler iki tecrübeli endodontist tarafından incelenmiştir. Farklı parametreler arasındaki istatistiksel anlamlılık Ki-kare testi ile analiz edilmiştir. **Bulgular:** “İdeal” olarak tanımlanan örnekler incelendiğinde, anterior (%27) ve premolar (%23) dişler arasında istatistiksel olarak anlamlı bir farklılık tespit edilememiştir. Buna karşın, üst çene (%27,7) ve alt çenedeki (%18,1) “ideal” olarak tanımlanan dişler arasında istatistiksel olarak anlamlı bir fark bulunmuştur ($p=0,018$). **Sonuç:** Tüm değerlendirmelerin doğrultusunda, “ideal” olarak tanımladığımız vakaların yapılmış benzer çalışmalara kıyasla daha az olduğu tespit edilmiştir. Bu sebeple, endodontik tedavinin kalitesini değerlendirmede daha fazla parametrenin göz önünde bulundurulduğu ileri çalışmalara ihtiyaç vardır.

Keywords: Dental students; education; radiography; root canal obturation

Anahtar Kelimeler: Diş hekimliği öğrencileri; eğitim; radyografi; kök kanalını tıkama

The technical quality of root canal therapy has a significant impact on the periradicular health of endodontically-treated teeth.¹⁻⁵ A graduating student must demonstrate capability to perform

acceptable nonsurgical endodontic treatment. This includes irrigation, mechanical preparation and obturation of the root canal system. In addition, the student must be aware of iatrogenic mistakes, such as frac-

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tured instruments, apical perforations and ledges, that can occur during nonsurgical endodontic therapy, and of how to prevent them.

Root canal treatment is regarded as one of the most substantial tasks that a dentist must undertake throughout her/his career. At present, the endodontic routine has moved forward significantly in all its forms. Even though dentists can usually perform root canal treatment well, there are various determinative factors in outcome evaluation, the possibility of which must be allowed for, with the technical quality of obturation being the most essential one. Periapical radiographs acquired before and after the application of root canal treatment are commonly used for evaluating the success of treatment.^{6,7} The technical quality of root canal obturation is a function of various factors, such as the length between the obturation material and the radiological apex, the density of obturation material and root canal taper.⁸ It has been noted by various pieces of research that the distance between the radiological apex and the obturation material must not be greater than 2 mm.⁹ Additionally, the extrusion of obturation materials from the apex may compromise the treatment's success. Moreover, a correct root canal obturation without any voids will decrease the risk of subsequent periradicular diseases. Correspondingly, it has been emphasized by many researchers that when an obturated root canal has voids in the apical third and middle third areas, tooth endurance can decline significantly.¹⁰

It has been shown by many studies that the amount of taper has an important impact on the elimination smear layer and debris from the root canal walls.^{11,12} Besides, an adequate taper, constituted during biomechanical preparation, is essential during root canal obturation in terms of apical and coronal sealing.¹³ It also effects the quality of root canal filling. The cutting level of excess gutta-percha is one of the other important factors in root canal treatment. Although it is a significant point, it has not generally been mentioned in previous studies. Excess gutta-percha remaining in the pulp chamber leads to coronal colorization and leakage.¹⁴ Differently from many other studies, we included the taper quality and cutting level of coronal gutta-percha as examination criterias.

Many earlier studies have tried to examine the technical quality of root canal treatment performed by endodontists, dental practitioners and undergraduates. Mainly, they noted that the technical quality of endodontic treatment performed by undergraduates is inadequate.¹⁵⁻¹⁷ Considering the significance of this subject in preparation for an improved education for dentistry students, the aim of this study was to assess the outcome of pre-clinical educational approaches in endodontics for dentistry students in the Dentistry Faculty of Biruni University. This was undertaken by analyzing the radiographic quality of root canal obturation and the occurrence of iatrogenic mistakes made by the 4th year dentistry students. In this way, we intend to improve education quality in the endodontics department by determining in which stages dentistry students have trouble, according to the results of this study.

MATERIAL AND METHODS

This study was approved by the Institutional Review Board of the Biruni University on 27.11.2018 with the number of 2018/23-03 and was followed the principles of Helsinki Declaration. All participants were asked to read and sign the informed consent form. Endodontic records from completed endodontic therapies performed on patients by dentistry students with the same pre-clinic education at the Biruni University Faculty of Dentistry between 2017-2018 were examined for analysis. The inclusion criteria for this selection were as follows:

1. Endodontic records from patients between 18 and 65 years of age were taken.
2. All endodontic treatments were performed by 4th year dentistry students on completely formed single-rooted and single-canal anterior and premolar permanent teeth.
3. Teeth treated using at least 4 parallel technique radiographs (preoperative, working-length, master gutta-percha and postoperative) of high quality that revealed the whole length of the root and the periradicular area. The radiographs were taken by a phosphor-plate radiography system (Dürr Dental, Bietigheim-Bissingen, Germany). Cases which were difficult to read were excluded resulting in examining 505 completed endodontic therapies performed on 337 patients.

Root canal treatments were performed by undergraduates in accordance with the following protocol: After analysis of the medical and dental history of every patient, local anesthesia was administered if necessary. Later, rubber-dam isolation, access cavity preparation and determination of the working length using K-files (Mani, Tochigi, Japan) with a periapical radiograph was completed. Every root canal was instrumented with a step-back technique, using stainless steel hand instruments (K-files of 0.02 taper). Master apical file was standardized as #40. In cases which are thought to be challenging to create an adequate taper and in order to facilitate straight line access, Gates-Glidden drills were used in the coronal section of the canals. Root canals were irrigated with 2.5% sodium hypochloride, while in cases of calcified and narrow canals EDTA Cream (Nexobio, Chungbuk, Seoul, South Korea) was also used.

All root canals were obturated with cement (AD-SEAL, Osong, Republic of Korea) and gutta-percha cones with a cold lateral condensation technique. All spreaders and gutta-percha cones were of 2% taper.

Assessment of the technical quality of root canal obturation was based on the immediate postoperative periapical radiograph before coronal restoration. Radiographs were analyzed in PACS (Picture Archiving and Communication Systems) Software version (1.1.1.6) for Windows 10 (Microsoft Corporation, Redmont, WA, USA). The method of assessing radiographs was a modified form of the previous study by Balto et al. which examined three variables: the length of the root canal filling, the density of the root canal filling and the amount of taper. Iatrogenic errors, including ledges, perforations and fractured instruments, were noted according to Barrieshi-Nusair et al. In addition in this study, the cutting level of excess gutta-percha, also documented due to the importance of this parameter on the treatment quality.^{8,18}

Evaluation of root canal obturation was performed by two separate examiners. Inter-observer consensus for all parameters was evaluated by calculating Cohen's Kappa scores. All Kappa scores were between 0.85 and 0.9, indicating a very high level of agreement. Intra-observer consensus with a 2-month interval was achieved.

The technical quality of the root canal obturation and the existence of iatrogenic errors found on perapi-

cal radiographs were assessed, categorized and documented; root canal was the unit of evaluation.

The criteria for radiographic categorization of the technical quality of root canal obturations were based on four variables; length, density, amount of taper and cutting level of excess gutta-percha. They were categorized as "optimum" and "not optimum" as follows:

A. Optimum: The obturation material ends 0-2 mm short of the radiological apex with adequate taper and no voids visible within the material or between the material and the root canal walls. The cutting level of excess gutta-percha is 1 mm below the cemento-enamel junction. There is no iatrogenic error.

B. Not optimum:

1. Under-filled: The obturation material ends more than 2 mm from the radiological apex.

2. Over-filled: The obturation material extruded beyond the radiological apex.

3. Density problem: Visible voids within or between the material and the root canal walls.

4. Taper problem: The amount of taper is not adequate.

5. Cutting level of excess gutta-percha problem: The coronal level of the obturation material is higher than 1mm below the cemento-enamel junction.

The criteria for radiographic categorization of the iatrogenic errors were based on the following:

Ledges were regarded as present if the apical extent of gutta-percha in the post-operative radiograph departed from the original curvature compared with the working-length radiograph. Perforation was diagnosed when extrusion of the obturation material was identified in any area of the root. Fractured instruments were detected through examination of the post-operative radiograph and in accordance with the radiopacity between the fractured instrument and obturation material.

Data were analyzed using the IBM SPSS Statistics 22 (IBM SPSS, Turkey) program. Chi-square, Fisher Freeman Halton Tests were used to test for the significance of associations where relevant, with the level of statistical significance set at $p < 0.05$.

RESULTS

The total number of collected cases that received endodontic treatment by the 4th year undergraduates was

522. From those, 17 (3.2%) were excluded because of radiographic artifacts. In all, 505 teeth were involved. According to location, 339 teeth were maxillary and 166 teeth were mandibular while according to tooth type 305 teeth were premolar and 200 teeth were anterior.

According to Table 1, there is a significant statistical difference between the acceptable root canal fillings on maxilla (27.7%) and mandible (18.1%) ($p=0.018$). There is no significant statistical difference according to tooth localization (maxillary and mandibular) and the length of obturation ($p=0.705$). Table 2 lays out a detailed report on the quality of the obturation length. The table shows that there wasn't a significant association between the tooth type and the length of obturation ($p=0.142$). Of all examined anterior teeth, 78.5% had a proper length, 11% had over-filling and 10.5% had under-filling, while 71.1% of all examined premolar teeth had a proper length, 12.8% had over-filling and 16.1% had under-filling.

Table 3 shows a detailed report on the density of fillings. According to this data, there is no significant interaction between the tooth type and the density of root canal fillings seen on periapical radiograph ($p=0.106$). Of all analysed anterior teeth, 75.5% showed no voids and 24.5% had voids, while 68.9% of all analysed premolar teeth had no voids and 31.1% had

voids. There is no significant statistical difference according to tooth localization (maxillary and mandibular) and density of root canal fillings ($p=0.108$) (Table 1).

Table 4 shows a detailed report on the taper quality of the root canal fillings. According to this data, 75% of all anterior teeth looked at had proper preparation tapers while 63.6% of all considered premolar teeth had improper preparation tapers, which constitutes statistical significance ($p=0.007$). There is no significant statistical difference according to tooth localization (maxillary and mandibular) and the taper quality of root canal fillings ($p=0.827$) (Table 1).

Table 5 shows the cutting level of excess gutta-percha, examined by periapical radiography. Accordingly, there was no significant correlation between tooth type and the coronal cutting level of excess gutta-percha ($p=0.440$). In 54% of all anteriors examined, the cutting level was determined to be appropriate, while in 50.5% of all premolars examined, the cutting level was inappropriate. There is no significant statistical difference according to tooth localization (maxillary and mandibular) and the cutting level of excess gutta-percha ($p=0.127$) (Table 1).

Moreover, the distribution of iatrogenic errors were examined. According to this, 3.5% of all ante-

TABLE 1: Distrubution of all criteria according to location.

		Maxillary (n=339)	Mandibular (n=166)	p
		n (%)	n (%)	
Obturation length	Proper	248 (73.2%)	126 (76%)	¹ 0.705
	Over-filled	41 (12.1%)	20 (12%)	
	Under-filled	50 (14.7%)	20 (12%)	
Density	Without voids	250 (73.7%)	111 (66.9%)	¹ 0.108
	Voids	89 (26.3%)	55 (33.1%)	
Taper quality	Adequate	232 (68.4%)	112 (67.5%)	¹ 0.827
	Inadequate	107 (31.6%)	54 (32.5%)	
Cutting level of	Appropriate	184 (54.3%)	78 (47%)	¹ 0.127
Excess gutta-percha	Inappropriate	155 (45.7%)	88 (53%)	
Iatrogenic errors	Ledge	14 (4.1%)	7 (4.2%)	² 0.455
	Perforation	3 (0.9%)	3 (1.8%)	
	Broken instrument	2 (0.6%)	3 (1.8%)	
	None	320 (94.4%)	153 (92.2%)	
Obturation quality	Acceptable	94 (27.7%)	30 (18.1%)	¹ 0.018*
	Unacceptable	245 (72.3%)	136 (81.9%)	
¹ Chi-square test		² Fisher Freeman Halton test		* $p<0.05$

TABLE 2: Distribution of obturation length according to tooth type.

	Tooth Type	Obturation length			p
		Proper n (%)	Over-filled n (%)	Under-filled n (%)	
Maxillary	Anterior (n=135)	104 (77%)	15 (11.1%)	16 (11.9%)	0.383
	Premolar (n=204)	144 (70.6%)	26 (12.7%)	34 (16.7%)	
Mandibular	Anterior (n=65)	53 (81.5%)	7 (10.8%)	5 (7.7%)	0.321
	Premolar (n=101)	73 (72.3%)	13 (12.9%)	15 (14.9%)	
Total	Anterior (n=200)	157 (78.5%)	22 (11%)	21 (10.5%)	0.142
	Premolar (n=305)	217 (71.1%)	39 (12.8%)	49 (16.1%)	

Chi-square test

TABLE 3: Distribution of all criteria according to location.

	Tooth Type	Density		p
		No voids n (%)	Voids n (%)	
Maxillary	Anterior (n=135)	102 (75.6%)	33 (24.4%)	0.538
	Premolar (n=204)	148 (72.5%)	56 (27.5%)	
Mandibular	Anterior (n=65)	49 (75.4%)	16 (24.6%)	0.089
	Premolar (n=101)	62 (61.4%)	39 (38.6%)	
Total	Anterior (n=200)	151 (75.5%)	49 (24.5%)	0.106
	Premolar (n=305)	210 (68.9%)	95 (31.1%)	

Chi-square test.

rior teeth examined had ledges, 0.5% had broken files and no perforations, while 4.6% of all premolar teeth examined had ledges, 2% had root/apical perforations and 1.3% had separated files. There is no significant statistical difference according to the teeth localization (maxillary and mandibular) and the iatrogenic errors ($p=0.455$) (Table 1).

DISCUSSION

Periapical radiograph is one of the essential and standard elements of root canal therapy which allows the performer to examine the treatment easily and quickly. In the present study, only periapical radiographs were utilized, and at least four radiographs-preoperative, working length identification, master cone adaptation and postoperative without coronal restoration-were performed in each case. Several studies have shown that the periapical health and the density of the obturation with the obturation length are directly connected.¹⁹⁻²¹ Many previous studies have also used these norms.²²⁻²⁵ These radiographic criteria have also been used in our study to determine the

quality of root canal fillings performed by dental students.

Our students have completed the pre-clinical course, which includes performing root canal therapy on both extracted human teeth and artificial blocks. Students had to perform root canal therapy on at least five of each tooth type and jaw during their clinical practice. Even though they perform on molars to complete their preclinical practice, there is no practice on molars in 7th and 8th semesters' curricula of Endodontics in our department. Thus, there are no molar teeth to be examined in this study.

According to our study, the obturation length is highly satisfactory above 70% in both maxillary and mandibular teeth, as well as both in anterior and premolar teeth. The obturation length has not been found to be significantly different among the tooth types and localization. Likewise, in the studies of Eskandarloo et al. and Alsulaimani et al., obturation lengths were also found to be highly satisfactory. In contrast, Khabbaz et al. found the length of root canal fillings performed by 4th grade students as 53.3% accept-

TABLE 4: Distribution of all criteria according to location.

	Tooth type	Taper quality		p
		Adequate n (%)	Inadequate n (%)	
Maxillary	Anterior (n=135)	100 (74.1%)	35 (25.9%)	0.069
	Premolar (n=204)	132 (64.7%)	72 (35.3%)	
Mandibular	Anterior (n=65)	50 (76.9%)	15 (23.1%)	0.055
	Premolar (n=101)	62 (61.4%)	39 (38.6%)	
Total	Anterior (n=200)	150 (75%)	50 (25%)	0.007*
	Premolar (n=305)	194 (63.6%)	111 (36.4%)	

Chi-square test.

TABLE 5: Distribution of cutting level of excess gutta-percha according to tooth type.

	Tooth type	Cutting level of excess gutta-percha		p
		Appropriate n (%)	Inappropriate n (%)	
Maxillary	Anterior (n=135)	73 (54.1%)	62 (45.9%)	0.951
	Premolar (n=204)	111 (54.4%)	93 (45.6%)	
Mandibular	Anterior (n=65)	35 (53.8%)	30 (46.2%)	0.156
	Premolar (n=101)	43 (42.6%)	58 (57.4%)	
Total	Anterior (n=200)	108 (54%)	92 (46%)	0.440
	Premolar (n=305)	154 (50.5%)	151 (49.5%)	

Chi-square test.

able.^{24,26,27} This might be due to the inclusion of molar teeth among the single rooted anterior and premolar teeth, whereas our study excluded molar teeth.

Adequate density of canal filling is a significant factor for the success of root canal therapy.^{28,29} In our study, more than 60% of root canals were of adequate density. This result is low compared to Vukadinov et al. which reported 92.6% of root canals with adequate density, but similar to the results of the other studies.^{8,10,30,31} No significant correlation was found between tooth type and density of root filling according to our study, whereas the study of Moussa-Badran et al. reported a significant correlation for this parameter.³¹ All teeth that were examined on the radiograph were obturated using gutta-percha and cement (AD-SEAL. Osong, Republic of Korea) with the cold lateral condensation technique. This technique is found to be reliable and successful for obturating root canals.³² Despite the fact that, in lectures, all recent obturation techniques are taught theoretically, cold lateral condensation is the only obturating technique

being used in the undergraduates' endodontics clinic. Moreover, cold lateral condensation is in use in variety of dental schools around the world.³³

Usually, the factors which were related to the obturation phase, such as length and density of root fillings, were commonly examined in other studies. However, in this study we analyzed the taper angle, which is not only related to the obturation stage but also to mechanical preparation. The present study reports that more than 2/3 of the preparation angles were adequate in all of the examined teeth. In addition, there is a statistically significant correlation of taper quality among the tooth types. Significantly better quality of preparation tapers was found in anterior teeth than in premolar teeth. Several studies also showed dental students around the world to be having trouble with the endodontic treatment of premolar and molar teeth rather than with anterior teeth.^{8,18,34} This situation may be related to the complexity of posterior teeth root canal anatomy and a more comfortable field of vision in the case of anterior teeth.

The cutting level of excess gutta-percha is a significant factor in the survival of root canal-treated teeth, because when the excess gutta-percha was not removed from the pulp chamber, there can be a coronal leakage due to failure to make the desired coronal restoration. Also, colorization can be another risk factor. We found no significant difference between the cutting levels of excess-gutta-percha in anterior and premolar teeth. Moreover, it was observed that the percentage of proper cutting levels (51.8%) was nearly equal to improper cutting levels (48.2%) in all of the examined teeth. While there were greater percentages at earlier stages, at this last stage of root canal treatment the percentage decreased. The type and quality of the cutting instruments directly effect this situation. For this reason, new-generation gutta-cutters or powerful torches could be used in undergraduates' endodontics clinics. In a comprehensive literature review, no study could be found which examined the cutting level of excess gutta-percha. Hence, this study could not be directly compared with any other study.

Iatrogenic errors were found to be relatively rare in our study of all the examined teeth (6.3%). Working on single-rooted teeth and mostly non-curved roots is one of the reasons for this. Moreover, a lot of preclinical practice was another factor. Lastly, due to the fact that the staff-student ratio for our endodontics clinics is 1:3, educators were able to pay close attention to students. This low rate of iatrogenic errors consisted of ledges, perforations and fractured instruments. The major cause of ledge formation was probably the stainless-steel K-files used in the endodontics clinic. Several reports support this opinion.³⁵⁻³⁸ Perforation is another procedural error which mostly occurred in curved root canals and during mechanical preparation due to the loss of working length. As to fractured instruments, using deformed files and files not being used properly in root canals might be the cause.

Proper length and density, adequate preparation of tapers and the desired cutting level of gutta-percha with no iatrogenic errors were categorised as "optimal" in the present study. "Optimal" cases were higher in maxilla than mandible while the level of both maxillar and mandibular optimal cases was found to be below 50%. The reason for this is that we

examined many criteria which had not been considered in most previous studies, especially taper quality and the cutting level of gutta-percha.

In order to develop the quality of endodontic treatments provided by undergraduates, it is suggested that the variety and number of cases be increased. In this manner, educator/student ratio may be increased in both preclinical and clinical courses. Furthermore, instruments and devices of high quality could be used in students' endodontics clinics. Further studies examining the taper quality and the cutting level of gutta-percha are needed in order to compare the results with the present study as well as to develop the quality of endodontics education.

CONCLUSION

In conclusion, by considering many criteria, the "optimal" cases we defined were found to be low compared to the other studies. On the other hand, the considered criteria were highly successful on their own. Given that root canal therapy is a highly complex and multi-staged procedure, the definition of "optimal" shouldn't be defined using only a few criteria. Consequently, further studies are required, taking into account multiple criteria.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: Sema Sönmez Kaplan, Tuna Kaplan; **Design:** Sema Sönmez Kaplan, Güzide P. Sezgin; **Control/Supervision:** Sema Sönmez Kaplan, Tuna Kaplan, Güzide P. Sezgin; **Data Collection and/or Processing:** Sema Sönmez Kaplan, Tuna Kaplan; **Analysis and/or Interpretation:** Sema Sönmez Kaplan, Tuna Kaplan, Güzide P. Sezgin; **Literature Review:** Sema Sönmez Kaplan,

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