Evaluation of Related Factors in the Failure of Endodontically Treated Teeth: A Cross-sectional Study

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Abstract

Introduction: The aim of this study was to review the factors related to the failure and extraction of unsuccessful endodontically treated teeth. **Methods:** A total of 1000 teeth treated with nonsurgical root canal therapy were analyzed, and the following information was recorded for each patient: reasons for failure and extraction, type of tooth, presence and type of coronal restoration, smoking status, age, gender, and level of education. One main reason was recorded for each failed tooth. The associations between reasons for failure, patient, and tooth were tested by using χ^2 analysis. **Results:** Of the 1000 endodontically failed teeth analyzed in this study, 28.1% ($n = 281$) were extracted, 66% ($n = 660$) were re-treated, and 5.9% ($n = 59$) were treated with apical surgery. Among the reasons for failure, restorative and endodontic reasons were seen most frequently (43.9%, $n = 439$), whereas orthodontic reasons were seldom seen (0.1%, $n = 1$). The most common reason for extraction was for prosthetic reasons (40.8%), and perforation/stripping was the least common (2.9%). The mandibular first molars were the most frequently extracted teeth (27.4%, $n = 77$). **Conclusions:** The most common reason for the extraction of endodontically treated teeth was for prosthetic reasons. Among the reasons for failure, restorative and endodontic reasons were the most frequently seen, and orthodontic reasons were the most seldom. The teeth that failed most frequently were mandibular first molars, and the teeth that failed least frequently were maxillary third molars. The most common reason for the extraction of failed endodontically treated teeth was for prosthetic reasons. *(J Endod 2018;44:38–45)*

Key Words

Endodontically treated teeth, extraction, failure, retreatment, root canal treatment

Significance

The results of this study show that those teeth without appropriate/sufficient coronal restoration after root canal treatment are more likely to fail in the future.

The main goal of nonsurgical root canal treatment is the healing of periapical tissues (1) by eliminating infected or necrotic remnants from the root canal system (2), while maintaining the function of the tooth in the oral environment (1, 3). Although previous studies have shown a nearly 90% success rate for endodontic treatment (4), nonsurgical root canal treatment often fails when adequate standards are not achieved (insufficient preparation and irrigation and short/long root canal filling length) (2). However, "well-treated" cases can also fail (5). Surgical and nonsurgical procedures are 2 of the major therapies applied after a failed nonsurgical root canal treatment (6). Other than these, clinicians may decide to extract endodontically treated teeth for various reasons.

Several studies in the literature have analyzed the reasons for the failure of extraction of endodontically treated teeth (7, 8). However, these studies only focused on the specific reasons for the extraction of endodontically treated teeth, with small sample size of patients. For example, Vire (7) listed the most common reasons for the extraction of endodontically treated teeth as prosthetic failure (59.4%), periodontal reasons (32%), and endodontic causes (8.6%). Fuss et al (9) reported that 43.5% of the extractions of endodontically treated teeth were due to restorative reasons. They also reported that the major extraction reasons were for endodontic treatment (21.1%) and vertical root fractures (10.9%). According to Chen et al (10) and Zadik et al (11), the most common reason for extraction was non-restorable caries (46.4%–61.4%). Toure et al (12) prepared a questionnaire to plan a prospective study to evaluate the reasons for extraction in endodontically treated teeth. They reported that the extraction reasons were periodontal disease (40.3%), endodontic failures (19.3%), vertical root fractures (13.4%), non-restorable cuspid and crown fractures (15.1%), non-restorable caries (5.2%), iatrogenic perforations and stripping (4.2%), and prosthetic reasons (0.8%). Tzimpoulas et al (8) found that the most prevalent reason for extraction was non-restorable caries (37.1%).

To our knowledge, the majority of these studies used retrospective processes, with a few exceptions (8, 12). Because this is an important topic requiring further evaluation, our research focused not only on extraction but also included most of the reasons for the failure of endodontically treated teeth within a larger sample size.

The aims of the present cross-sectional study were to investigate the reasons for the failure of endodontically treated teeth (ie, vertical root fractures, prosthetic reasons,

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periodontal reasons, endodontic failures, non-restorable caries, non-restorable cusp/tooth fractures, and perforations/stripping), and whether there were associations between these reasons and the personal characteristics of the patients (ie, age, gender, level of education, and smoking status), tooth locations, and post-type endodontic permanent coronal restorations.

Methods

This study was approved by the Ethics Committee of the Selcuk University Faculty of Dentistry (no: 2011/02-08). All of the patients included in this study presented to the Selcuk University, Faculty of Dentistry, Department of Oral Diagnosis and Radiology for various complaints or routine care during a 17-month period (January 2011–May 2012). After the clinical and radiographic examinations, all of the failed endodontically treated teeth were referred to the Department of Endodontics for consultation (ie, Should the tooth be treated or extracted?). Two endodontists (S.B., K.O.) evaluated all of the endodontically failed teeth. Endodontically treated tooth failure was defined on the basis of the following situations: clinical problems such as percussion, palpation, swelling, fistula, fracture, marginal leakage, and loss of coronal restoration and/or radiographic problems such as an unhealed periapical lesion (after 4 years), insufficient obturation, and perforation/stripping.

The study was explained to the patients whose teeth were to be retreated, and informed written consent was obtained from each patient. After the clinical and radiographic examinations of the tooth, the questionnaire was filled out by the same practitioner (K.O.) via dialogue with each patient. The questionnaire included the following information:

- Personal characteristics of the patient (age, gender, level of education)
- Smoking status (currently smoking, never smoked, quit at least 4 years ago)
- Examination of the failed tooth (status of coronal restoration, root canal filling)
- Reason for failure (vertical root fracture, prosthetic reasons, periodontal reasons, endodontic failure, non-restorable caries, non-restorable cusp/tooth fracture, perforation/stripping).

A total of 1000 endodontically failed teeth from 671 patients were evaluated in this cross-sectional study. Only one reason for failure was noted for each tooth. In those cases with no treatment possibilities (eg, vertical root fracture, non-restorable cusp/tooth fracture, non-restorable caries), the worst condition was selected as the main reason for failure versus the other treatable reasons (eg, restorative, endodontic, periodontal reasons). The quality of the root canal filling and coronal restoration was confirmed via radiographs. Those teeth extracted before finishing the initial endodontic treatment were not included in this study. When determining the main causes for the failure of the root canal treatment and extraction, the following criteria were used:

- Vertical root fracture: a severe crack in the tooth extending longitudinally down the long axis of the root. It often extends through the root to the periodontium.
- Prosthetic reasons: teeth with an insufficient crown-to-root ratio, teeth that are considered not able to bear a prosthetic load as an abutment tooth, teeth that are excluded from the prosthetic treatment plan after consultation with a prosthodontist from the Department of Prosthodontics because of poor prognosis.
- Periodontal reasons: teeth with excessive bone loss, mobility outside of acceptable limits, furcal problems, and/or teeth that have extraction indication according to a consultant from Department of Periodontology.
- Orthodontic reasons: teeth that were chosen for extraction in an orthodontic treatment plan.
- Endodontic failure: Although the root canal treatment was adequate and there were no caries, marginal staining, and/or leakage of the coronal restorations, the root canal treatments were considered clinically unsuccessful if the patient has complaints from related tooth. In some cases, the related teeth may exhibit persistent/unhealed periapical problem radiographically.
- Non-restorable caries or non-restorable cusp fractures: teeth with cavity borders below the gingival line and/or reaching the furcal area or fractures that cannot be restored successfully within the limitations of the current dental technology.
- Perforation/stripping: teeth that must be extracted because of the formation of untreatable perforations/stripping as detected by radiography.
- Restorative reasons: teeth that have caries, marginal staining, and/or leakage of the coronal restoration, although the root canal treatment was radiographically successful.
- Endodontic reasons: teeth that have short or overextended filling from the root canal apex and/or exhibited insufficient root canal filling radiographically. These teeth are considered failed, although there were no caries, marginal staining, and/or leakages in the coronal restoration.
- Restorative and endodontic reasons: teeth that failed for both endodontic and restorative reasons (as described above) at the same time.
- Patient request: The patient was insistent on having the tooth extracted, even after the treatment options and success rates were described. Generally, these patients experienced previous traumatic endodontic treatment. The failed teeth in this group could have been treated surgically or nonsurgically, but the patient certainly did not accept the treatment.

A 3-level classification was used for the patient's level of education:

- Basic education or less: up to 9 years of education. Those patients without educational degrees belonged to this class.
- Secondary education: approximately 10–12 years of education. This group included patients with vocational training as well as those with upper secondary school certificates but without further training.
- Higher education: an educational level of 13 years or more. This group included people with institute or university-level certificates or degrees.

The acquired data were statistically analyzed by using SPSS 17.0 (SPSS Inc, Chicago, IL). The associations between the patient's gender, level of education, and smoking status were examined by using a χ^2 test.

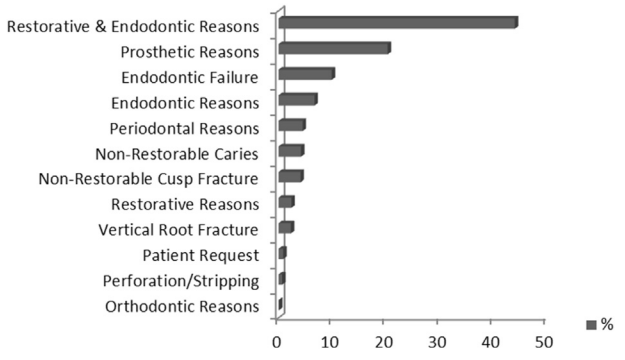

Figure 1. Distribution of reasons for failure of endodontically treated teeth.

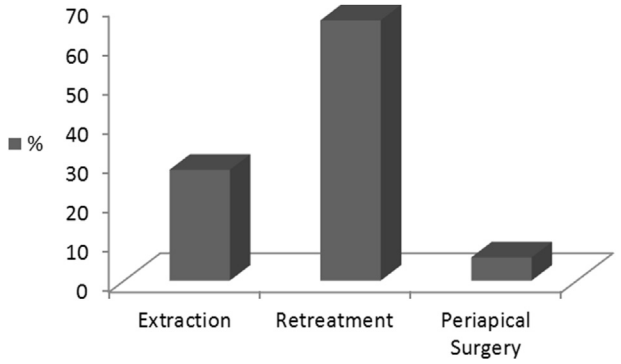

Figure 2. Distribution of final decisions for failed endodontically treated teeth.

The differences regarding the patients' ages were analyzed with the Mann-Whitney *U* test. The relationships between the reasons for failure and extraction and the tooth type, final indication, treatment completion time, periapical status, root canal filling length, coronal restoration, and periodontal status were evaluated by using a χ^2 test. A *P* value $\leq .05$ was accepted as the level of significance.

Results

Figure 1 shows the reasons for the failure of the endodontically treated teeth. There was a statistically significant difference between the reasons for failure ($P < .01$). Among these, restorative and endodontic reasons were seen most frequently (43.9%, $n = 439$), whereas orthodontic reasons were most seldom (0.1%, $n = 1$) ($P < .01$). Other significant reasons for failure were as follows: prosthetic reasons (20.3%, $n = 203$), endodontic failure (9.9%, $n = 99$), endodontic reasons (6.7%, $n = 67$), periodontal reasons (4.5%, $n = 45$), non-restorable caries (4.2%, $n = 42$), non-restorable cusp fractures (4.1%, $n = 41$), restorative reasons (2.4%, $n = 24$), vertical root fractures (2.3%, $n = 23$), as per patient request (0.9%, $n = 9$), and perforation/stripping (0.7%, $n = 7$) ($P < .01$). Of the 1000 endodontically failed teeth evaluated in this study, 28.1% ($n = 281$) were extracted, 66.0% ($n = 660$) were re-treated, and 5.9% ($n = 59$) were treated with apical surgery ($P < .01$) (Fig. 2).

The ages of the participants of this study were between 11 and 81 years. The distribution of the ages is shown in Table 1. The average age of the patients was 37.09 ± 13.6 years (60.0% female, $n = 403$ and 40.0% male, $n = 263$). There were significant differences with regard to the age and reason for failure ($P < .01$) and the gender and reason for failure ($P < .01$). The relationships between age, gender, and failure reason are shown in Tables 2 and 3, respectively. There was a significant difference with regard to the level of education and reason for

TABLE 1. Distribution of Patients' Age Ranges

Age (y)	Total, *n* (%)
11–20	82 (12.2%)
21–30	155 (23.0%)
31–40	158 (23.5%)
41–50	156 (23.3%)
51–60	85 (12.7%)
61–70	32 (4.8%)
71 and older	3 (0.4%)
Total	671 (100%)

TABLE 2. Relation between Age and Reasons for Failure

Reasons for failure	Age (y), *n* (%)							Total
	11–20	21–30	31–40	41–50	51–60	61–70	71 and older	
Vertical root fracture	1 (0.1%)	6 (0.6%)	6 (0.6%)	8 (0.8%)	0 (0.0%)	1 (0.1%)	1 (0.1%)	23 (2.3%)
Prosthetic reasons	3 (0.3%)	22 (2.2%)	28 (2.8%)	73 (7.3%)	47 (4.7%)	29 (2.9%)	1 (0.1%)	203 (20.3%)
Periodontal reasons	1 (0.1%)	3 (0.3%)	9 (0.9%)	7 (0.7%)	14 (1.4%)	11 (1.1%)	0 (0.0%)	45 (4.5%)
Orthodontic reasons	1 (0.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
Endodontic failure	17 (1.7%)	28 (2.8%)	17 (1.7%)	23 (2.3%)	8 (0.8%)	6 (0.6%)	0 (0.0%)	99 (9.9%)
Non-restorable caries	5 (0.5%)	11 (1.1%)	11 (1.1%)	8 (0.8%)	5 (0.5%)	2 (0.2%)	0 (0.0%)	42 (4.2%)
Non-restorable cusp fracture	4 (0.4%)	10 (1.0%)	13 (1.3%)	8 (0.8%)	4 (0.4%)	2 (0.2%)	0 (0.0%)	41 (4.1%)
Perforation/stripping	0 (0.0%)	2 (0.2%)	3 (0.3%)	0 (0.0%)	2 (0.2%)	0 (0.0%)	0 (0.0%)	7 (0.7%)
Restorative and endodontic reasons	65 (6.5%)	107 (10.7%)	117 (11.7%)	96 (9.6%)	47 (4.7%)	6 (0.6%)	1 (0.1%)	439 (43.9%)
Patient request	1 (0.1%)	5 (0.5%)	1 (0.1%)	1 (0.1%)	0 (0.0%)	1 (0.1%)	0 (0.0%)	9 (0.9%)
Restorative reasons	5 (0.5%)	7 (0.7%)	3 (0.3%)	3 (0.3%)	2 (0.2%)	4 (0.4%)	0 (0.0%)	24 (2.4%)
Endodontic reasons	10 (1.0%)	21 (2.1%)	21 (2.1%)	10 (1.0%)	1 (0.1%)	3 (0.3%)	1 (0.1%)	67 (6.7%)
Total	113 (11.3%)	222 (22.2%)	229 (22.9%)	237 (23.7%)	130 (13%)	65 (6.5%)	4 (0.4%)	1000 (100%)

TABLE 3. Relation between Gender and Reasons for Failure

Reasons for failure	Male, *n* (%)	Female, *n* (%)	Total, *n* (%)
Vertical root fracture	8 (0.8%)	15 (1.5%)	23 (2.3%)
Prosthetic reasons	70 (7.0%)	133 (13.3%)	203 (20.3%)
Periodontal reasons	30 (3.0%)	15 (1.5%)	45 (4.5%)
Orthodontic reasons	0 (0.0%)	1 (0.1%)	1 (0.1%)
Endodontic failure	36 (3.6%)	63 (6.3%)	99 (9.9%)
Non-restorable caries	21 (2.1%)	21 (2.1%)	42 (4.2%)
Non-restorable cusp fracture	21 (2.1%)	20 (2.0%)	41 (4.1%)
Perforation/stripping	4 (0.4%)	3 (0.3%)	7 (0.7%)
Restorative and endodontic reasons	173 (17.3%)	266 (26.6%)	439 (43.9%)
Patient request	4 (0.4%)	5 (0.5%)	9 (0.9%)
Restorative reasons	1 (0.1%)	23 (2.3%)	24 (2.4%)
Endodontic reasons	25 (2.5%)	42 (4.2%)	67 (6.7%)
Total	393 (39.3%)	607 (60.7%)	1000 (100%)

failure ($P < .01$). The distribution of the level of education was as follows: 21.1% had basic education or less ($n = 142$), 30.0% had secondary education ($n = 202$), and 48.6% had higher education or more ($n = 327$). There was also a significant difference with regard to the smoking status and failure of the endodontically treated teeth ($P < .01$). Of the treated patients, 23.1% ($n = 155$) were currently smoking, and 76.9% ($n = 516$) had never smoked or quit smoking more than 4 years ago ($P < .01$).

Of the 1000 failed endodontically treated teeth examined, 18.3% ($n = 183$) were maxillary anterior, 4.9% ($n = 49$) were mandibular anterior, 16.6% ($n = 166$) were maxillary premolar, 13.9% ($n = 139$) were mandibular premolar, 17.8% ($n = 178$) were maxillary molar, and 28.5% ($n = 285$) were mandibular molar teeth ($P < .01$). A total of 52.7% of the failed endodontic treatments ($n = 527$) were in maxilla, and 47.3% ($n = 473$) were in the mandible ($P > .05$). The teeth that failed most frequently were mandibular first molars (21.2%, $n = 212$), and the teeth that failed least frequently was a maxillary third molar (0.1%, $n = 1$) ($P < .01$). Root fillings of 351 teeth (35.1%) were 0–1 mm, 194 teeth (19.4%) were 1–2 mm, 403 teeth (40.3%) were more than 2 mm beyond the radiographic apex, and 5.2% ($n = 52$) of the teeth were overfilled ($P < .01$). For those teeth with several roots, the root that had the shortest root canal filling was always used for the evaluation.

With regard to the time that had passed since the initial treatment, 38.5% of the cases ($n = 385$) presented 0–2 years after the completion of root canal treatment, 23.8% ($n = 238$) presented 2–4 years after, 17.2% ($n = 172$) presented 4–6 years after, and 5.5% ($n = 55$) presented 8–10 years after. A total of 13.8% ($n = 138$) presented more than 10 years after the completion of root canal treatment ($P < .01$). In total, 28.9% of the examined teeth ($n = 289$) had periodontal problems, and 71.1% ($n = 711$) did not ($P < .01$). Moreover, 48.7% of the teeth ($n = 487$) had periapical lesions, and 51.3% ($n = 513$) had none ($P < .01$).

The comparisons between the coronal restorations and reasons for failure are shown in Table 4. A significant difference was found between the coronal restoration type and reason for failure ($P < .01$).

Extraction of Failed Endodontically Treated Teeth

Among the 200 patients who were between the ages of 14 and 68 years, 281 extracted teeth that failed endodontically were evaluated. The mean age of the patients who were referred to the Oral Surgery Department for extraction was 40.31 ± 13.1 years, including 53.0% female ($n = 106$) and 47.0% male patients ($n = 94$). The percentage of patients currently smoking was 28.5% ($n = 57$).

The comparison of the main reasons for extraction is shown in Figure 3. The results showed that the most common reasons for extraction were prosthetic (40.8%), periodontal (15.8%), non-restorable cusp/tooth fracture (15.4%), non-restorable caries (10.0%), vertical root fracture (6.4%), endodontic failure (5.4%), and perforation/stripping (2.9%). In addition, 3.3% of the extractions were due to the patients' insistence.

The distribution of the extracted teeth according to the tooth type was as follows: 10.4% ($n = 29$) were anterior teeth, 28.4% ($n = 80$) were premolars, and 61.2% ($n = 172$) were molars. The mandibular first molars were the most frequently extracted teeth (27.4%, $n = 77$). The distribution of the extracted endodontically treated teeth is shown in Figure 4. Overall, 53.7% of those extracted ($n = 151$) were mandibular teeth, and 46.2% ($n = 130$) were maxillary teeth.

The coronal restorations of the extracted teeth are shown in Figure 5. Of the extracted teeth, 6.0% ($n = 17$) were restored with a post and crown. Moreover, 22.7% ($n = 64$) did not have coronal restorations, 28.4% ($n = 80$) had composite restorations, 18.5% ($n = 52$) had crown restorations, 16.3% ($n = 46$) had amalgam restorations, 5.0% ($n = 14$) had temporary restorations (glass ionomer, zinc phosphate, zinc oxide–eugenol cement, Cavit, etc), and 2.8% ($n = 8$) had only post and composite restorations.

Discussion

In the present study, 2 specialists (S.B. and K.O.) evaluated 1000 failed endodontically treated teeth that were referred to the Selcuk University, Faculty of Dentistry, Department of Endodontics. Of these, 281 treated teeth (28.1%) were extracted, 660 teeth (66.0%) were retreated nonsurgically, and 59 of the evaluated teeth (5.9%) were referred for surgical treatment. Unlike the results of the current study, Tzimpoulas et al (8) found a 79% extraction rate ($n = 217$) and 21% retreatment rate ($n = 58$) in endodontically treated teeth. They explained that the key factor in the decision to extract or retain the teeth in their study was the pronounced loss of dental tissue. In our study, the most frequently seen reasons for failure were restorative and endodontic reasons, and most of the teeth were nonsurgically re-treated and scheduled for recall examinations. In a 2-year follow-up retrospective study, Lazarski et al (13) examined 44,613 teeth, and they reported the rates of extraction, retreatment, and periapical surgery as 5.56%, 2.47%, and 1.41%, respectively. In another 5-year follow-up study that examined 857 teeth, Chen et al (10) found a 9.7% failure rate. Among these failed teeth, they reported 71.1%, 24.1%, and 4.8% rates of extraction, retreatment, and periapical surgery, respectively. The

TABLE 4. Comparison of Coronal Restorations and Reasons for Failure

Reasons for failure	Coronal restoration type, *n* (%)							
	Post	Crown	Post and crown	Amalgam	Composite	Temporary restoration	No restoration	Total
Vertical root fracture	1 (0.1%)	1 (0.1%)	6 (0.6%)	4 (0.4%)	7 (0.7%)	2 (0.2%)	2 (0.2%)	23 (2.3%)
Prosthetic reasons	10 (1.0%)	79 (7.9%)	11 (1.1%)	19 (1.9%)	36 (3.6%)	12 (1.2%)	36 (3.6%)	203 (20.3%)
Periodontal reasons	0 (0.0%)	9 (0.9%)	3 (0.3%)	8 (0.8%)	23 (2.3%)	1 (0.1%)	1 (0.1%)	45 (4.5%)
Orthodontic reasons	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	0 (0.0%)	1 (0.1%)
Endodontic failure	0 (0.0%)	7 (0.7%)	0 (0.0%)	7 (0.7%)	80 (8.0%)	5 (0.5%)	0 (0.0%)	99 (9.9%)
Non-restorable caries	0 (0.0%)	5 (0.5%)	2 (0.2%)	7 (0.7%)	6 (0.6%)	1 (0.0%)	21 (2.1%)	42 (4.2%)
Non-restorable cusp fracture	0 (0.0%)	4 (0.4%)	0 (0.0%)	8 (0.8%)	7 (0.7%)	0 (0.0%)	22 (2.2%)	41 (4.1%)
Perforation/stripping	0 (0.0%)	3 (0.3%)	2 (0.2%)	0 (0.0%)	2 (0.2%)	0 (0.0%)	0 (0.0%)	7 (0.7%)
Restorative and endodontic reasons	0 (0.0%)	87 (8.7%)	8 (0.8%)	78 (7.8%)	195 (19.5%)	33 (3.3%)	38 (3.8%)	439 (43.9%)
Patient request	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	8 (0.8%)	0 (0.0%)	0 (0.0%)	9 (0.9%)
Restorative reasons	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.6%)	10 (1.0%)	8 (0.8%)	24 (2.4%)
Endodontic reasons	0 (0.0%)	15 (1.5%)	6 (0.6%)	16 (1.6%)	30 (3.0%)	0 (0.0%)	0 (0.0%)	67 (6.7%)
Total	11 (1.1%)	210 (21.0%)	38 (3.8%)	148 (14.8%)	400 (40.0%)	65 (6.5%)	128 (12.8%)	1000 (100%)

differences between the diagnoses may be related to the operators' knowledge, experience, and practice (14). In the study by Bader and Shugars (15), 1187 teeth were examined by different operators in 43 patients, but only 62% of the cases could be diagnosed as the same. One reason for the differences between the diagnoses could be related to the differences between the study designs.

In this study, the mean age of the patients was 37.09 ± 13.6 years. The lowest amount of failure was seen in those patients 71 years old and older (0.4%), and failure was seen most frequently in the 41- to 50-year-old age group (23.7%). Similarly, Ricucci et al (16) reported that the failure rate was 12.2% for those patients 50 years old or younger, whereas the failure rate was 5.4% for those patients older than 50 years. As stated in these studies, it seemed that the possibility of failure decreased with the increasing age of the patients. Unlike these findings, Swartz et al (17) and Dammaschke et al (18) reported that there was no age effect on the success rate of root canal treatment. Moreover, the meta-analysis by Kojima et al (19) also endorsed that outcome. Before extracting a general conclusion and evaluating the differences in the current study from the others, it should be noted that 0.4% of the patients in our clinics were 71 years old and older, the general age distribution was between 20 and 50 years old, and the evaluation was carried out by using a non-homogeneous distribution. The gender and level of education findings of the current investigation are in accordance with those of Zadik et al (11), who reported no significant influences of the patient gender or educational status on the reasons for extraction. In addition, Toure et al (12) reported that the gender, educational level, and smoking status did not show any differences when compared with the reasons for the extraction of endodontically treated teeth. At this point, we would like to state that although in other studies only extracted teeth were examined, our study included all failed teeth, not only the extracted ones.

As reported also by Toure et al (12), the main consultation motive of the patients in our study was pain. The percentage of patients with complaints of pain was 45.7%, followed by a high rate of 15.2% prosthetic necessity. Despite this, the questionable clinical status of the teeth was the main motive for endodontic referral in the study by Tzimpoulas et al (8). Furthermore, similar to a study by Zadik et al (11), we found that periodontitis was more common in the current smokers than among the non-smokers. Contradictory to our results, Toure et al reported that there was no significant difference between the smokers and non-smokers with regard to the reasons for the extraction of endodontically treated teeth.

In the study by Alley et al (20), which compared endodontic specialists and general dentists, the specialists showed higher root canal treatment success rates (98.1%). Unfortunately, we could not successfully obtain reliable data from the patients participating in our study about whether their root canal treatments had been performed by specialists. Because of this, it was assumed that all of the treatments were performed by non-specialists, which was one of the limitations of our study. It is likely that the little experience of the operators and/or operators' careless root canal therapy were responsible for the relatively high percentage of restorative and endodontic reasons (43.9%) for the failed endodontically treated teeth. There are also some limitations that could have led to failure of endodontically treated teeth such as time lapse between completion of root canal treatment and placement of permanent restoration (21), difference in microleakage between different temporary restorative materials and time lapse before permanent restoration placement (22), and the effect of occlusal trauma on the coronal seal and possible tooth fracture (23).

Despite its limitations, the results of this study indicated that the most common reason for the extraction of endodontically treated teeth

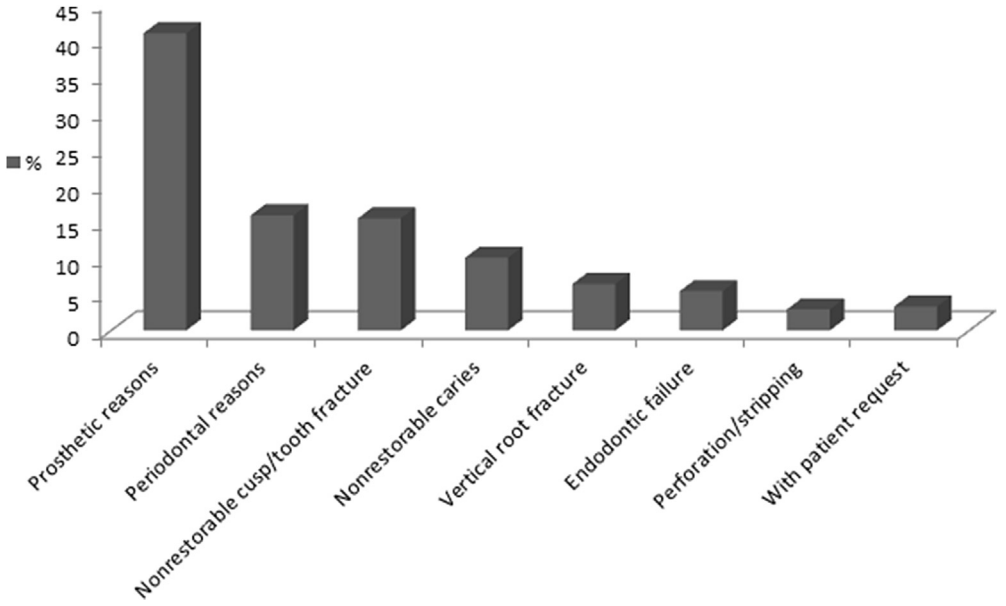

Figure 3. Comparisons of main reasons for extraction.

was for prosthetic reasons (40.8%). This confirms the results of the study by Vire (7), which noted that 59% of the extractions were for prosthetic reasons. The necessity for extraction in both the study by Vire and our study was related to planning further prosthetic restorations or the tooth's lack of ability to bear a prosthetic load. Patients generally wish for prosthetic restorations that they can use for a longer period of time, and they do not prefer a preparation in their sound teeth to support prosthesis. The clinicians and the patients also do not want to risk having a possible problematic tooth under the prosthesis because of economic and personal reasons.

The second most common reason for extraction in the present study was for periodontal reasons (15.8%), which was different from Chen et al (10), Vire (7), and Toure et al (12), who reported that the percentages for periodontal reasons were 26.8%, 32%, and 40.3%, respectively. In another study by Fuss et al (9), a lower frequency of periodontal reasons was reported (5.5%). The extraction criteria for the periodontal reasons included extensive bone loss, mobility, and/or symptoms (such as pain, sensitivity to percussion, abscess) that precluded further periodontal therapy after a process of decision-making by the periodontists in our study. No information was added regarding these criteria in the previous studies, with the exception of the study by Vire; therefore, the contradictory results cannot be explained by the criteria used. The low percentage of periodontal reasons in our study (4.5%) may be related to the young mean age of the study patients.

In the current study, the mandibular first molars were the most frequently extracted teeth (23.3%), and the maxillary first molars were the second (16.6%), which correlated with the study by Zadik et al (11) (44.6% and 20.5%, respectively) and the study by Toure et al (12) (51.3% and 16.6%, respectively). These findings may have been due to the localization of the tooth, making it prone to caries because the first molars are the first to erupt and thus are exposed to more challenges from acid, sugar, and caries than other molars that erupt at least 5–6 years later. After the mandibular and maxillary first molars, the maxillary second molars were the third most frequently extracted teeth, with a rate of 12.9%. This may be related to the susceptibility to caries because of the complicated positions of third molars. Contrary to our results, no mandibular incisors or canines were

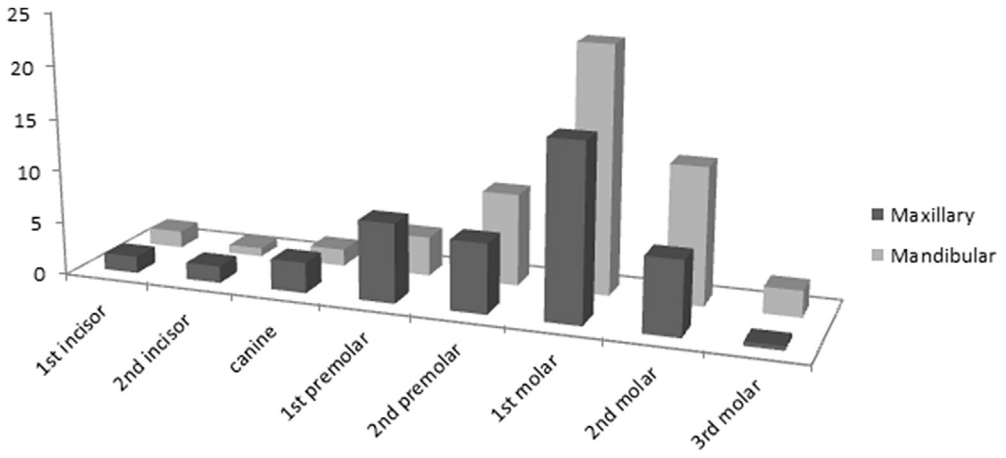

Figure 4. Distribution of extracted endodontically treated teeth.

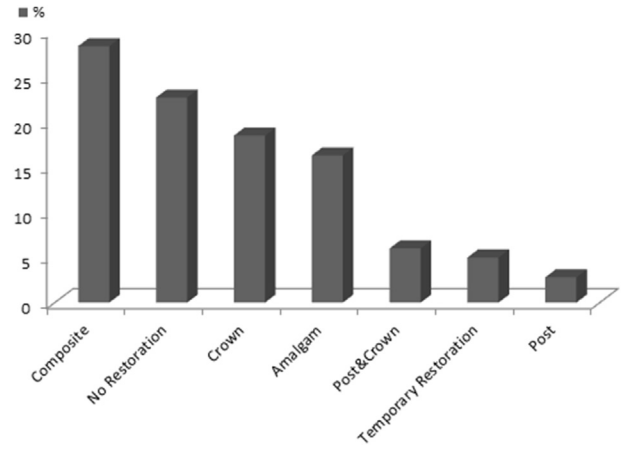

Figure 5. Distribution of coronal restorations of extracted teeth.

extracted in the study by Zadik et al, but we reported that 10.4% of the mandibular anterior teeth were also extracted.

In the present study, 7.1% of the extracted teeth were restored with a post and crown, and among these, only 4 teeth were extracted after a vertical root fracture. In agreement with Zadik et al (11), the presence of an intracanal post did not increase the prevalence of vertical root fractures, but the percentage of teeth extracted because of vertical root fractures was 6.2%. These findings are similar to those of Zadik et al, who reported an 8.8% prevalence of vertical root fractures among the extracted teeth in their study. Fuss et al (9), Vire (7), and Toure et al (12) reported the percentages of teeth extracted because of vertical root fracture as 11%, 13%, and 13.4%, respectively. Moreover, Sjögren et al (24) reported 31% prevalence of vertical root fractures. Contrary to the results of Zadik et al, vertical root fractures were found in similar frequencies in the mandibular and maxillary teeth in our study.

Previous studies have concluded that coronal restoration has an important function in the survival rate of endodontically treated teeth (9, 25). In these studies, the full coronal coverage of endodontically treated teeth was recommended. In our study, 73.7% of the extracted teeth were not crowned, which was similar to the results of the studies by Zadik et al (11), Toure et al (12), and Salehrabi and Rotstein (6) (85%, 94%, and 85%, respectively). Similar to the results of Toure et al, 72.5% of the teeth in our study had coronal restorations; 22.1% of the extracted teeth had composite restorations, 19.1% had crown restorations, 14.1% had amalgam restorations, and 7.1% had post and crown restorations. In addition, 6.6% had temporary restorations (glass ionomer, zinc phosphate, zinc oxide–eugenol cement, Cavit, etc), and 3.3% had post restorations without crowns.

In our study, the percentage of perforation/stripping rate was 0.7% for failed teeth and 2.9% for extracted teeth. This is lower than the data reported by Toure et al (12) (17.6%) and Zadik et al (11) (8.8%). Strindberg (26) reported that the highest endodontic therapy success rate was obtained when the length of the root canal filling was 1 mm shorter than the apex. In this study, the most common failure was seen in those teeth that were 2 mm shorter than the radiographic apex. This finding was in agreement with several previous studies (16, 18). The reason for the failure in the teeth with short root filling may have been the presence of microorganisms that were in the non-instrumented parts of the root canal (27, 28).

Conclusion

In summary, this cross-sectional study indicated that the most common reason for the extraction of endodontically treated teeth was for prosthetic reasons. Among the reasons for failure, restorative and endodontic reasons were seen most frequently, and orthodontic reasons were seen least frequently. The teeth that failed most frequently were mandibular first molars, and the teeth that failed least frequently were maxillary third molars.

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The authors deny any conflicts of interest related to this study.

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