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Original Article

Time assessment for final restoration of endodontically treated teeth in a university clinic setting: An observational study

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ABSTRACT

Background: The aim was to quantify the time elapsed between tooth reconstruction and the end of endodontic treatment, and to assess differences according to sex, age, and tooth group.
Material and Methods: A retrospective study was conducted with patient clinical records. Data relating to patient characteristics, treated teeth, endodontic treatment, and subsequent restorative treatment were recorded.
Results: For this study, 355 endodontically treated teeth by undergraduate students during 2019 were included. 24 teeth (6.76 %) were not restored, more direct (86.4 %) than indirect (13.6 %) restorations were performed, and the most frequent type of restoration was complex filling. The mean elapsed time from endodontic completion to direct restoration was 7 days, with a minimum of 0 and a maximum of 90 days. For indirect restorations the mean elapsed time was 21 days.
Conclusions: The median elapsed time for endodontic tooth reconstruction was 7 days (IQR = 7), however, treatment should not be considered completed until the tooth has been properly restored. In cases where an indirect restoration was also necessary, the median elapsed time was higher (21 days; IQR = 31.5).

1. Introduction

The main objective of endodontic treatment is elimination of bacteria from inside the root canal system and sealing of the root canal to block bacterial penetration as well as to prevent and/or cure apical periodontitis (Schilder, 1974). Several clinical studies (Aquilino and Caplan, 2002) (Frisk et al., 2015), (Ng et al., 2011) (Olcay et al., 2018), (Ray and Trope, 1995), (Salehrabi and Rotstein, 2004), (Stenhagen et al., 2020), (Tavares et al., 2009) have highlighted the importance of restorative treatment in the prognosis of endodontic treatment, emphasizing that coronal restoration is one of the most influential factors in the survival of endodontically treated teeth, even more than the quality of the treatment itself. For successful treatment, it is important to consider the length of time from completion of endodontic treatment to the final restoration, as the likelihood of bacterial leakage and fracture of the remaining tooth structure increases significantly with longer intervening periods (Heling et al., 2002). In addition, the absence of definitive restoration significantly increases the likelihood of failure of the endodontically restored tooth (Fransson et al., 2021), (Pratt et al., 2016), (Salehrabi and Rotstein, 2004). When planning restorative treatment of the endodontically treated tooth, arch location, occlusion, and periodontal status should be carefully considered (Bhuva et al., 2021).

The aim of this study was to quantify the time elapsed between the endodontic and restorative treatment phases in patients treated by undergraduate students, and to establish whether there were significant differences related to patient characteristics.

2. Materials and methods

2.1. Ethics committee approval and sample selection

A retrospective study was conducted where clinical records were analyzed. The study was approved by the Research Ethics Committee of European University of Madrid in October 2020 (CIPI/213006.40) which allowed access to the university clinic database. Compliance with the Data Protection and Researcher Confidentiality Act was ensured. All patients attending the university clinic provide consent stating that their

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data may be used for research purposes.

The sample size was calculated using G*Power software (ver. 3.1; Heinrich Heine Universität, Düsseldorf, Germany). Based on an effect size of 0.3, with alpha-type error set to 0.05 and power of 95 %. 220 teeth were required to properly power this study.

Inclusion criteria were patients who underwent endodontic treatment at the university clinic from January to December 2019. Exclusion criteria were: 1) patients under 18 years of age, 2) endodontic treatments was not completed, 3) tooth was extracted before endodontic treatment completion, and 4) endodontic treatments were started by undergraduate students but completed by others (postgraduates or professionals).

2.2. Recording of case study data

Each endodontic treatment was recorded on a spreadsheet with a number. This record sheet was kept by the principal investigator throughout the research process. Sociodemographic variables were recorded for each patient (age, sex, and birthplace), as well as data related to teeth treated (tooth number according to International Tooth Numbering System (FDI) nomenclature, dental group, and arch), endodontic treatment (pulp condition, cause, time elapsed from diagnosis to endodontic treatment, and number of sessions required to complete the treatment), and restorative treatment (reason and degree of tooth destruction, time elapsed from completion of endodontic treatment until the definitive restoration was started, type of restoration, and material of choice). For indirect restorations (crowns, inlay/overlay restorations), the time elapsed between the direct restoration (composite with/without post) and the cementation of the indirect restoration was included.

2.3. Statistical analysis

First, a descriptive analysis of all variables was performed, including the analysis of the assumption of normality of distributions for quantitative variables. Since none of the quantitative variables studied presented a normal distribution, non-parametric tests were performed: Kruskal-Wallis test for the comparison of three or more groups (e.g., dental groups) and Mann-Whitney *U* test for the comparison of the results of two groups (e.g., pulpitis vs. necrosis). Pearson's chi-square test was used to analyze the relationship between two nominal variables.

2.4. Information bias

Data quality assurance at the time of each treatment could be a source of bias in this study. Information was collected in 2020 and even though the treatments were supervised by a professor specialized in endodontics, the information collected by the student can sometimes be limited. The data collected followed the inclusion and exclusion criteria and was performed by a calibrated investigator.

3. Results

In 2019, 380 endodontic treatments were started at the clinic. Exclusions included 11 patients under 18 years of age, 5 endodontic treatments that were not completed, one tooth extraction, and 8 that were completed by postgraduate students or other professionals. In total, 355 eligible cases were included in this study (Fig. 1). Descriptive data of the samples, the teeth treated, and the restorations performed are shown in Table 1.

The most frequently treated tooth was 2.5 (8.73 %), followed by 1.5 (8.45 %), 1.4 (8.17 %), 4.5 (7.32 %), 2.4 (6.20 %), and 3.5 (5.63 %). Of the 355 endodontic treatments performed, 24 (6.76 %) were not

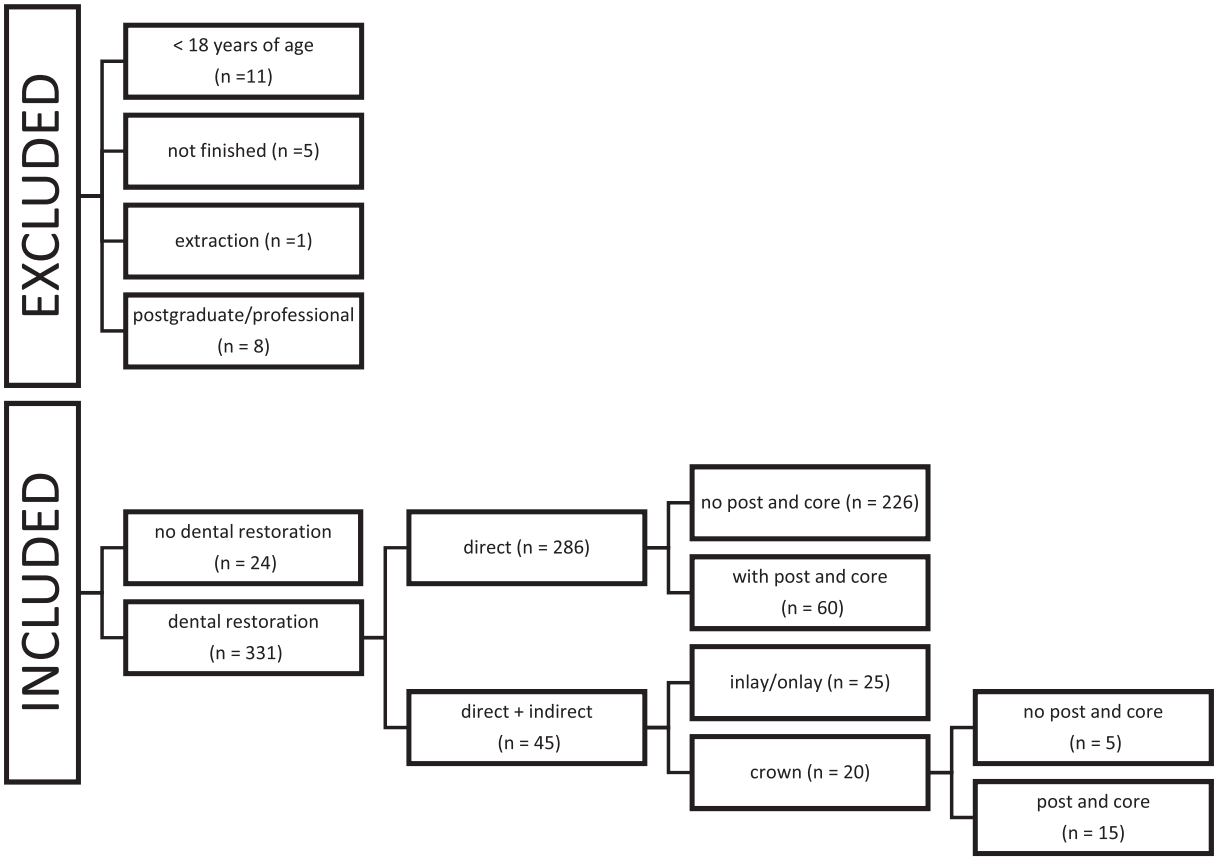

Fig. 1. Flow chart of selection of the sample after applying the inclusion and exclusion criteria.

Table 1
Descriptive statistics of the sample and endodontically treated teeth, on tooth destruction and post-endodontic restoration.

Variable	n	Percentage (%)
Sex		
Female	212	59.72
Male	143	40.28
Age group (years)		
18–40	130	36.62
41–60	154	43.38
61–80	55	15.49
> 80	16	4.51
Origin		
Private practice	332	93.52
Social services	23	6.48
Dental group		
Incisors	97	27.32
Canines	46	12.96
Premolars	178	50.14
Molars	34	9.58
Dental arch		
Maxilla	236	66.48
Mandible	119	33.52
Pulpal diagnosis		
Pulpitis	213	60
Necrosis	142	40
Cause of endodontic treatment		
Caries	283	79.72
Filling	47	13.24
Trauma	20	5.63
Prosthesis	5	1.41
Cause of destruction		
Caries	190	53.52
Filling and caries	92	25.92
Filling	48	13.52
Attrition	17	4.79
Tooth grinding	5	1.40
Fracture	3	0.85
Degree of dental destruction		
One wall	16	4.51
Two walls	171	48.17
Three walls	118	33.24
Four walls	24	6.76
Complete destruction	26	7.32
Complete restoration		
Yes	331	93.24
No	24	6.76
Type of restoration		
Direct restoration	286	86.4
Direct/indirect dental restoration	45	13.6
Types of direct dental restoration		
Complex filling	149	45.02
Large restoration	81	24.47
Fiber post and resin core	75	22.66
Simple filling	26	7.85
Types of indirect dental restoration		
Resin inlay/overlay	25	55.56
Metal-porcelain crown	20	44.44

[1]For cause of destruction and degree of tooth destruction, n = 355. For complete restoration, type of restoration, types of direct restoration, n = 331. For indirect restoration types, n = 45.

restored and 331 (93.24 %) were restored. Selection of teeth after the inclusion and exclusion criteria, as well as the distribution of the type and material of choice of final restoration and of the endodontically treated teeth are shown in Fig. 1.

The study analyzed the time elapsed from diagnosis to endodontic treatment, from endodontic completion to direct restoration, and the time spent during indirect final restorations (Table 2). Table 3 shows the time elapsed between the distinct phases of endodontic and restorative treatment in each dental group. For premolars, more days passed from completion of endodontic treatment to direct restoration compared to the other groups (Table 3).

In addition, for molars and premolars there was a greater proportion

Table 2
Endodontic and restorative treatment times.

Elapsed time (days)	n	Median	IQR	Minimum	Maximum
Diagnosis - Completing the endodontic treatment	355	14	28	0	1440
Completing endodontic treatment - Direct restoration	331	7	7	0	90
Direct restoration – Luting of indirect restoration	45	21	31.5	6	270

Table 3
Comparison of number of sessions and treatment times according to dental groups.

	Incisors Median (IQR)	Canines Median (IQR)	Premolars Median (IQR)	Molars Median (IQR)	*p Value*
Number of sessions	1 (1)	1 (1)	2 (1)	2 (1)	**< 0.001**
Diagnostic time – Endodontic treatment	20 (36)	19 (27.3)	14 (33)	7 (26)	0.072
Time of endodontic treatment – Direct restoration (n = 331)	7 (6.3)	7 (7)	11 (8)	7 (7)	**0.025**
Direct/ indirect restoration time (n = 45)	171	32	21(29)	17 (29)	0.169

* Time expressed in days.
Statistically significant results ($p < 0.05$) are shown in **bold** font.

of teeth restored directly and indirectly than for incisors and canines, where this option was a minority. The differences were statistically significant and were also significant in relation to the type of direct restoration chosen in each group (Table 4).

4. Discussion

Although some studies (Ricucci and Bergenholtz, 2003), (Siqueira et al., 2005) suggest that the type of restoration, whether temporary or definitive, does not have a significant influence on the success of root canal treatment, it is still advisable to perform a proper seal directly on the canal filling material to prevent bacterial leakage in cases of loss of the temporary restoration (Safavi et al., 1987). The restoration should ensure that the endodontically treated tooth is restored to function and aesthetics, as well as provide a proper coronal seal and protect the cusps, since endodontically treated teeth are at greater risk of fracture than teeth with preserved pulp tissue (Siqueira et al., 2005). Ideally, direct restorations should be performed immediately after completion of endodontic treatment, since the tooth has been thoroughly disinfected and is completely isolated with a rubber dam (Patel and Barnes, 2011).

For optimal aseptic conditions, it is essential to use a rubber dam throughout the entire procedure and remove carious tissue, previous fillings, and fissures that may facilitate bacterial penetration into the canals during *endo*-restorative treatment. This coronal preparation allows for a correct evaluation of the degree of tooth destruction and aids in planning for restorative treatment. If the crown destruction is extensive, it may be necessary to restore the contour of the tooth beforehand, either temporarily or permanently. This pre-endodontic restoration should maintain the aesthetics and function of the tooth, be biocompatible, stable over time, and facilitate a definitive restoration after endodontic treatment. It serves as a containment for irrigants

Table 4
Comparison of endodontic and restorative treatment data according to tooth groups.

	Incisors Frequency (%)	Canines Frequency (%)	Premolars Frequency (%)	Molars Frequency (%)	*p Value*
Restoration					
No	2 (2.1)	1 (2.2)	18 (10.1)	3 (8.8)	**0.040**
Yes	95 (97.9)	45 (97.8)	160 (89.9)	31 (91.2)	
Type of complete restoration					
Direct	93 (97.9)	43 (95.6)	127 (79.4)	23 (74.2)	**< 0.001**
Direct and indirect	2 (2.1)	2 (4.4)	33 (20.6)	8 (25.8)	
Type of direct restoration					
Simple filling	12 (12.6)	3 (6.7)	7 (4.4)	4 (12.9)	**< 0.001**
Complex filling	25 (26.3)	17 (37.8)	83 (51.9)	24 (77.4)	
Post and core	24 (25.3)	11 (24.4)	39 (24.4)	1 (3.2)	
Large restoration	34 (35.8)	14 (31.1)	31 (19.4)	2 (6.5)	
Pulpal diagnosis					
Pulpitis	45 (46.4)	29 (63)	115 (64.6)	24 (70.6)	**0.013**
Necrosis	52 (53.6)	17 (37)	63 (35.4)	10 (29.4)	
Cause of endodontic treatment					
Caries	67 (69.1)	39 (84.8)	150 (84.3)	27 (79.4)	**< 0.001**
Filling	15 (15.5)	3 (6.5)	22 (12.4)	7 (20.06)	
Prosthesis	0 (0)	1 (2.2)	4 (2.2)	0 (0)	
Trauma	15 (15.5)	3 (6.5)	2 (1.1)	0 (0)	
Cause of dental destruction					
Caries	45 (46.4)	30 (65.2)	99 (55.6)	16 (47.1)	**0.001**
Filling	15 (15.5)	3 (6.5)	25 (14)	5 (14.7)	
Filling and caries	22 (22.7)	9 (19.6)	48 (27)	13 (38.2)	
Attrition	12 (12.4)	3 (6.5)	2 (1.1)	0 (0)	
Fracture	3 (3.1)	0 (0)	0 (0)	0 (0)	
Tooth grinding	0 (0)	1 (2.2)	4 (2.2)	0 (0)	
Degree of tooth destruction					
Degree I	7 (7.2)	2 (4.3)	3 (1.7)	4 (11.8)	**< 0.001**
Degree II	27 (27.8)	18 (39.1)	102 (57.3)	24 (70.6)	
Degree III	41 (42.3)	20 (43.5)	54 (30.3)	3 (8.8)	
Degree IV	6 (6.2)	3 (6.5)	12 (6.7)	3 (8.8)	
Complete	16 (16.5)	3 (6.5)	7 (3.9)	0 (0)	

during endodontic treatment and helps to maintain the temporary filling (Gavriil et al., 2021). This filling occupies the access cavity to the canal system and must provide a good coronal seal to prevent leaks between appointments (Sivakumar et al., 2013).

Even when the obturation of the root canal is correct, gutta-percha does not serve as a barrier against the entry of fluids and microorganisms into the interior, where it can reach the apical region and provoke an inflammatory response in the apex (Ray and Trope, 1995). Several studies (Križnar et al., 2016), (Srivastava et al., 2017) on the filtration of different temporary filling materials have concluded that there is no temporary material on the market today that completely prevents the passage of fluids from the oral cavity to the inside of the tooth after one week. To prevent saliva penetration and microorganisms into the root canal, it would be advisable to remove 3–4 mm of the coronal gutta-percha and place a barrier material at the entrance of the canal or at the base of the pulp chamber (Özyurek et al., 2018). This material is recommended as additional protection in conjunction with the provisional coronal filling and serves to decrease bacterial leakage in the event that the provisional restoration is lost prior to completion of the definitive reconstruction (Jenkins et al., 2006). Ideally, the material should be easy to place, adhere to the tooth structure, seal against microleakage, be distinguishable from the natural tooth, and not interfere with the final restoration (Wolcott et al., 1999). However, completion of restoration should not be delayed to help ensure success of the root canal treatment (Ray and Trope, 1995).

Both direct and indirect restorations are indicated for restoration of endodontically treated teeth. However, indirect restorations require multiple appointments to complete the treatment (Bhuva et al., 2021), (Patel and Barnes, 2011). At the university clinic, the type of restoration for the endodontically treated tooth is determined by a professor specialized in prosthodontics, and undergraduate students perform direct composite restorations, with or without a fiberglass post, and indirect inlay/overlay composite restorations or metal-porcelain crowns. For the latter, more appointments are necessary than for composite inlays, as they require a metal try-in and a bisque try-in prior to final cementation of the restoration. In addition, the dental impressions are performed with silicone since an intraoral scanner is not available.

In our study, 331 endodontically treated teeth were definitively restored, of which 286 (73.90 %) were restored directly and 45 (19.34 %) indirectly, by inlay/overlay or metal-porcelain crown. Composite restoration of the cavity floor and walls was performed prior to tooth preparation in all teeth restored with inlays/overlays. Of the teeth restored with metal-porcelain crowns, 75 % were previously restored with a fiberglass post and core build-up with composite (Fig. 1). These data resemble those in the study by Pratt et al. (Pratt et al., 2016) but are different from the study by Sadaf (Sadaf, 2020). Compared with other studies (Pratt et al., 2016), (Sadaf, 2020), (Yee et al., 2018), a lower percentage of indirect restorations is reported here. However, in the present study the type of restoration was not related to other factors related to the treated teeth, such as previous pulp and/or periapical status, the existence of contact points with adjacent teeth, and occlusion with antagonist teeth among others, as well as patient-related factors such as general health status or socioeconomic level. These factors could influence the selection of restorative treatment of the endodontically treated tooth (Frisk et al., 2015), (Pratt et al., 2016), (Sadaf, 2020), (Stenhagen et al., 2020).

A maximum period of 90 days was observed between direct restoration and completion of endodontic treatment, but the median time elapsed was 7 days, a result similar to other studies (Pratt et al., 2016), (Sadaf, 2020), (Yee et al., 2018). To reduce this time, it would be better to perform a direct restoration immediately after endodontic treatment, when the tooth is asymptomatic, and especially when endodontic treatment has been performed in more than one session.

In Sadaf's study (Sadaf, 2020), direct restorations were performed 14 days after completion of endodontic treatment, and in none of these cases were intraradicular posts placed. However, composite core build-ups for crowns were performed immediately after canal obturation. At

the university clinic, direct restoration and/or pre-crown preparation for indirect restoration is usually completed one week after finishing endodontic treatment. Post space preparation is preferably completed at another appointment. Performing both procedures in the same session could increase postoperative pain due to the vibration transmitted by the rotary instruments to the periodontium during the preparation of the intra-canal space (Eyuboglu and Kim, 2020). However, it is recommended to perform the post prior, and 8 days after, the root canal treatment. (Aquilino and Caplan, 2002).

For indirect restorations, the median time to final cementation was observed to be 21 days. For crowns, it is common to make one appointment for metal try-in and a second one for bisque try-in before ordering the finished work. For these tests, a period of 7 days is required to allow time for the laboratory to complete their work, so it is usual for it to take up to 4 weeks from endodontic treatment completion to final placement, in agreement with the results of the study by Sadaf (Sadaf, 2020) that reported a mean time of 1.82 months for definitive crown placement. In the study by Yee et al. (Yee et al., 2018), 33.6 % of the endodontic treatments performed were restored with some type of indirect restoration and a mean time of 160.5 days was required to complete the restorative treatment.

According to the study by Pratt et al. (Pratt et al., 2016), endodontically treated teeth that were indirectly restored with a crown more than 4 months after completion of root canal treatment were extracted three times more than those that were restored during the 4 months after endodontic treatment. However, our study did not consider holiday periods in which the clinic is closed, so it can be assumed that endodontic treatments completed just before these periods took longer than expected to complete the restorative treatment. Therefore, since the treatment should not be considered completed until the endodontically treated tooth has been restored, proper planning of the endodontic treatment and its subsequent restoration is essential to foresee the working times necessary to complete the treatment, with consideration of the number of appointments and the waiting time between sessions.

To avoid leakage of the provisional material and/or fracture of the remaining structure, we have included in the clinical protocols the pre-endodontic reconstruction in large coronal destructions and the sealing of the coronal gutta-percha with flowable composite at the end of the root canal treatment. In addition, it is important to explain to the patient, orally and in writing, the importance of restoring the endodontically treated tooth as soon as possible.

5. Conclusions

In summary, the median elapsed time for direct restorations in the university clinic after endodontic treatment was 7 days. In cases in which an indirect restoration was also necessary, the elapsed time was greater, with a median of 21 days (IQR = 31.5). The most frequently treated tooth group was the premolars, and more days elapsed from the completion of endodontic treatment to direct restoration in the premolars. Incisors and canines were mostly restored directly, and premolars and molars were mostly restored indirectly. A median of 3 weeks was required from the direct restoration to the final cementation of the indirect restoration.

6. Ethics

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Research Ethics Committee at European University of Madrid (UEM) in October 2020 (CIPI/213006.40).

CRediT authorship contribution statement

Carolina Viola: Data curation, Writing – original draft, Writing – review & editing. **Marta Muñoz-Corcuera:** Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Ana Antoranz-Pereda:** Investigation, Methodology, Writing – review & editing. **Elisabeth Casañas:** Supervision, Writing – original draft, Writing – review & editing. **Natalia Navarrete:** Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2023.12.013.

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