Survival Rate of Teeth with a C-shaped Canal after Intentional Replantation: A Study of 41 Cases for up to 11 Years

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Abstract

Introduction: Teeth with a C-shaped canal have been regarded as a challenge for nonsurgical root canal treatment (RCT) and apical microsurgery because of their anatomic variations and low accessibility. For such teeth, intentional replantation might be a treatment option. The purpose of this study was to investigate the prognostic factors for the clinical outcome of intentionally replanted teeth with a C-shaped canal. **Methods:** We retrospectively investigated patients who had undergone intentional tooth replantation at the Department of Conservative Dentistry, Yonsei University Dental Hospital, Seoul, Korea, from June 2002 to November 2015. Consequently, 41 intentionally replanted teeth with C-shaped canals were identified. The cumulative survival rate and related prognostic factors were assessed based on clinical and radiographic examination using survival analysis. **Results:** The cumulative survival rate of intentionally replanted teeth with a C-shaped canal was 83.4% at 4 years and 73.0% at 11 years postoperatively. Based on Cox proportional hazard regression analysis, extraoral time (≤15 minutes vs >15 minutes) and retrofilling material (ProRoot MTA [Dentsply, Tulsa, OK] vs others) were significantly associated with tooth survival ($P < .05$). **Conclusions:** Extraoral time exceeding 15 minutes and the use of ProRoot MTA as a retrofilling material were significantly associated with a lower survival of intentionally replanted teeth with C-shaped canals. With improved clinical procedures based on an understanding of the prognostic factors, intentional replantation would be a favorable treatment option for treating teeth with a C-shaped canal. *(J Endod 2016;42:1320–1325)*

Key Words

Extraoral time, mineral trioxide aggregate, root canal anatomy, survival analysis, tooth replantation

Significance

In the intentional replantation of teeth with C-shaped canals, reduction in the extraoral time and the use of fast-setting retrofilling materials were associated with significantly higher survival of those teeth, which should be considered in future clinical procedures.

Intentional replantation is one of the treatment options for teeth treated unsuccessfully with nonsurgical root canal treatment (RCT) and apical microsurgery; the process involves intentional extraction, extraoral repair, and subsequent repositioning of the tooth (1, 2). With the recent advances in apical microsurgery, many of the limitations of nonsurgical RCT have been complemented. However, there are still some cases that cannot be treated appropriately by apical microsurgery because of the surrounding anatomic structures (ie, proximity to the mental nerve or maxillary sinus) and lack of accessibility (ie, repair of the radicular groove or extensive endodontic perforation and thick buccal bone) but can be resolved by intentional replantation with fewer complications.

However, currently, evidence for the clinical outcome of intentional replantation is lacking. According to a recent systematic review, there have been only 8 clinical trials on intentional replantation from 1966 to 2014, whereas 27 clinical trials of single-implant placement since the 2000s were identified (3). Moreover, it should be noted that previous studies have mainly focused on the success/survival rate of the treatment, and the related prognostic factors have not been reported (4) or were limited to a few factors, such as the patient's age, sex, and the tooth position (1, 5, 6). This is in contrast with the case of tooth replantation after avulsion (7), for which various prognostic factors have been reported in detail. Thus, the prognostic factors of intentional replantation still need to be addressed.

One of the main targets of intentional replantation is mandibular second molars, which reveal a higher prevalence of anatomic variations, such as C-shaped canals, than other types of tooth (8–11). Although the incidence of the C-shaped canal in mandibular second molars is relatively low in whites (4.6% in the Greek population), it has been reported as being 7.0%–19.2% in the Middle Eastern and 9.4%–44.6% in the East Asian population, which should be considered when planning endodontic interventions (12, 13). Nevertheless, few clinical studies have investigated the outcome of intentional replantation in teeth with C-shaped canals. Because of the severe anatomic complexity of the C-shaped canal, not only is the efficacy of nonsurgical RCT reduced (14), but also the outcome of surgical endodontic treatment and the effect of related prognostic factors are likely to be affected (15). In this regard, further investigations into the intentional replantation of such teeth are needed.

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0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2016.05.010

The purpose of this study was to investigate the prognostic factors related to the clinical outcome of intentionally replanted teeth with a C-shaped canal. We performed a retrospective study of patients with intentionally replanted teeth with C-shaped canals with a follow-up period for up to 11 years and analyzed the outcome and related prognostic factors.

Materials and Methods

We investigated patients who had received intentional replantation of a tooth by a single operator (E.K.) recorded in the clinical database of the Department of Conservative Dentistry, Yonsei University Dental Hospital, Seoul, Korea, from June 2002 to November 2015. We included 41 intentionally replanted teeth with a C-shaped canal, which included 35 mandibular second molars, 4 maxillary second molars, 1 maxillary lateral incisor, and 1 mandibular first premolar (12, 16, 17), from 41 patients and reviewed their surgical record sheets and electronic and manual charts.

Preoperative Preparation

On the first visit, all patients provided written informed consent. Each patient's medical and dental history was recorded, and clinical and radiographic examination was conducted, which included periodontal probing, mobility, percussion, bite tests, and acquisition of periapical radiograph and computed tomographic images (Highspeed Advantage and Denta Scan Program; GE Medical Systems, Milwaukee, WI) images. From those examinations, the endodontic status of the tooth (ie, root canal anatomy, separated instrument, and endodontic perforation) and its anatomic relationship with the mental nerve, inferior alveolar nerve, and maxillary sinus were evaluated.

Indications for intentional replantation were as follows:

1. Teeth treated with nonsurgical RCT but still showing signs and symptoms of nonhealing, such as persistent pain or sinus tract
2. Teeth that could not be properly treated with apical microsurgery because of anatomic limitations, such as proximity to the mental nerve, thick buccal bone, and low accessibility for repair of the radicular groove or endodontic perforation

Contraindications for intentional replantation were as follows:

1. Teeth in which nonsurgical RCT had failed but apical microsurgery was available
2. Teeth diagnosed as having a vertical root fracture before or during intentional replantation

Before intentional replantation, elastic O-rings were inserted on the proximal contacts between the target tooth and adjacent teeth and maintained for 3 to 4 days to loosen the attachment between the tooth and the alveolar socket. In most cases, slight tooth mobility (1–2 mm of horizontal movement) could be obtained on the day of surgery.

Surgical Procedure

Patients were prescribed antibiotics (oral amoxicillin, 500 mg) and an anti-inflammatory drug (ibuprofen, 400 mg) 1 hour preoperatively. After rinsing their mouths with 0.1% chlorhexidine gluconate solution (Hexamedin; Bukwang Pharmaceutical, Ansan, Korea), patients received local anesthetic injections. To luxate the tooth with minimal trauma, a #15 blade was inserted in parallel to the periodontal ligament (PDL) space and knocked with a mallet. Then, the forceps were introduced, and the tooth was luxated slowly but steadily in the buccolingual direction until vertical displacement of the tooth was reached. An elevator was not used during the extraction to avoid any unnecessary damage to the root surface and alveolar bone crest. Immediately after extraction, the tooth underwent a 2- to 3-mm resection of the apical root with a #170 tapered fissure bur. The resected root surface was stained with methylene blue and inspected under an operating microscope (OPMI PICO; Carl Zeiss, Göttingen, Germany) to search for anatomic details such as unfilled canals, isthmuses, and fins. Including all anatomic irregularities, retrocavity preparation (3 mm depth) was performed along the long axis of the root by using a #330 carbide bur driven by a high-speed handpiece, and then the cavity was air dried and retrofilled. In this study, one of the following materials was used: ProRoot MTA (Dentsply, Tulsa, OK), Endocem (Maruchi, Wonju, Korea), or Super EBA (Harry J. Bosworth, Skokie, IL). As an extraoral storage solution, either Hank's balanced salt solution (HBSS) or saline were used to keep the root surface moist and to supply essential ions to PDL cells. After the extraction, the whole surgical procedure was performed under an operating microscope, and care was taken not to damage the root surface (below the CEJ) either manually or by surgical instruments, such as a forceps beak. Then, the tooth was gently replanted into the socket using finger pressure, and the occlusal relationship was confirmed. In cases in which the initial stability of the tooth was insufficient, the tooth was stabilized with a resin wire splint for 2 weeks. Patients were instructed to bite onto wet gauze for 2 hours and to continue a soft diet and 0.1% chlorhexidine gluconate mouth rinse (Hexamedin) for 2 weeks. Antibiotics (oral amoxicillin, 250 mg) and an anti-inflammatory drug (ibuprofen, 400 mg) were prescribed for 3 days (3 times per day) postoperatively.

Outcome Assessment

Patients were followed up at approximately 1, 3, 6, and 12 months and then every year thereafter. At these examinations, subjective symptoms were checked, and clinical and radiographic investigations were performed. These included periodontal probing (not performed up to 1 month after surgery), mobility, percussion, bite tests, and periapical radiography. Radiographic evaluation was performed in a blinded fashion by 2 independent clinicians, and any disagreement between them was resolved by discussion. In this study, treatment outcome was classified as either "tooth survival" or "treatment failure" on the basis of the following criteria:

1. "Tooth survival" was diagnosed when the tooth maintained normal masticatory function without any subjective discomfort, with the periapical lesion size remaining the same or decreasing in size. Slight tooth mobility (horizontal displacement of <2 mm), restricted root resorption, and tooth ankylosis were not regarded as treatment failure.
2. "Treatment failure" was diagnosed when the radiographic findings showed an increase in the size of the periapical lesion or when there were any signs and/or symptoms hindering normal masticatory function, which included excessive tooth mobility (any vertical displacement or horizontal displacement of >2 mm) because of surrounding alveolar bone loss or inflammatory root resorption and persistent masticatory pain.

For survival analysis, *event* was defined as the diagnosis of treatment failure, and cases in which the tooth did not experience treatment failure during the whole follow-up period were considered as "censored." "Survival time" corresponded to the period from the date of surgery to the date of the last follow-up. The preoperative factors analyzed were sex, age, tooth position, tooth type, periodontal condition, presence of a sinus tract, quality of nonsurgical RCT, and post placement. Intraoperative factors analyzed were extraoral time, retrofilling material, and resin wire splint. The postoperative factors analyzed were inflammatory root resorption and ankylosis. In terms of periodontal condition, representative probing depth was determined by the maximum value of 6 measurements around the tooth. Regarding the quality of non-surgical RCT, when either of the following was

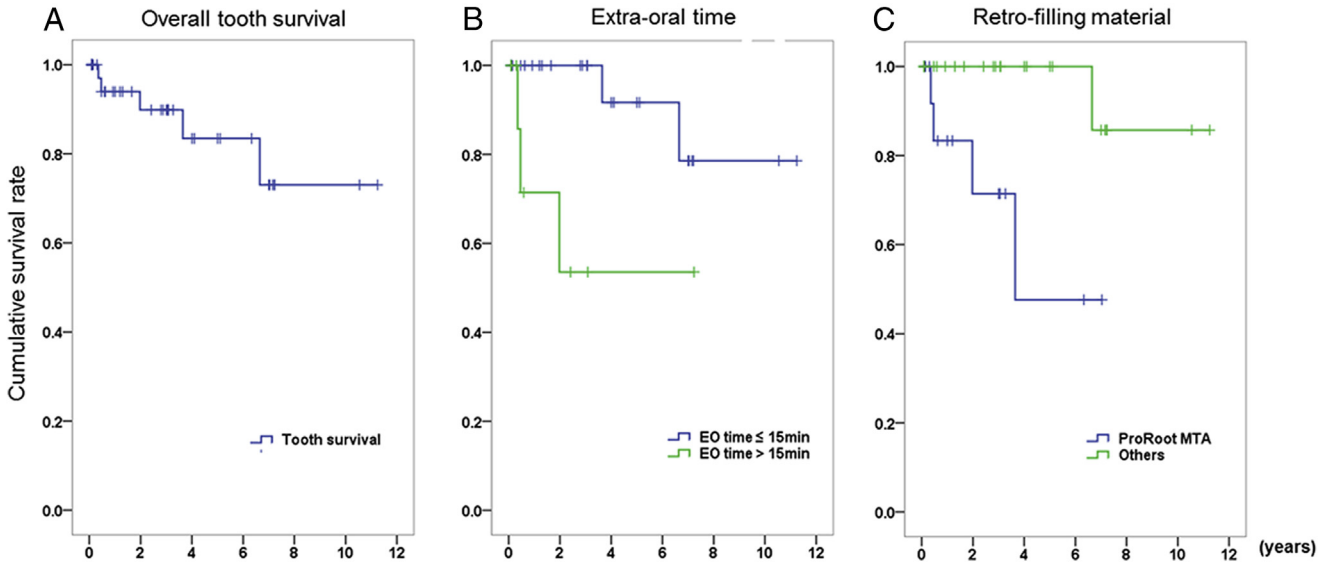

Figure 1. Kaplan-Meier survival plots of cumulative tooth survival arranged according to (*A*) overall outcome, (*B*) extraoral time, and (*C*) retrofilling material used.

detected on a periapical radiograph—any missing canal, over-filling, or under-filling exceeding 2 mm, and filling with voids—the case was classified as having poor quality, or alternatively as having good quality (18). Inflammatory root resorption was diagnosed when ongoing root resorption was observed with adjacent bone radiolucency on periapical radiographs (19). Ankylosis was diagnosed when disappearance of the PDL space and lamina dura were observed, without adjacent bone radiolucency on periapical radiographs and with metallic sounds on percussion tests (19).

Statistical Analyses

We used the Kaplan-Meier method to estimate the cumulative survival rate of intentionally replanted teeth and used the log-rank test to assess the effect of each clinical variable on the outcome. Then, we used multivariate Cox proportional hazard regression analysis to assess the variables revealed as significant in the log-rank test. Statistical analyses were performed in SPSS 20 (SPSS Inc, Chicago, IL), and a significance level of 0.05 was adopted.

Results

The cumulative survival rate of teeth with a C-shaped canal was 83.4% at 4 years and 73.0% at 11 years after intentional replantation (Fig. 1*A*). In univariate analysis, extraoral time and retrofilling material were found to be significant factors ($P < .05$) (Table 1; Fig. 1*B* and *C*; Supplemental Table S1). A multivariate Cox proportional hazard regression model was constructed using these 2 variables, and both extraoral time and retrofilling material remained significant ($P < .05$) (Table 2; Supplemental Table S2). More specifically, an extraoral time exceeding 15 minutes and the use of ProRoot MTA as a retrofilling material were significantly associated with a lower survival of intentionally replanted teeth with a C-shaped canal compared with the counterparts of these factors.

Discussion

This study aimed to investigate the prognostic factors for the long-term outcome of intentionally replanted teeth with a C-shaped canal. We included not only the basic demographic factors (ie, sex and age of the patient) but also the factors that had been reported as significant in the field of apical microsurgery and tooth replantation after avulsion (ie, periodontal condition, retrofilling material, and extraoral time) to provide more detailed information on predicting the outcome of intentional replantation.

TABLE 1. Univariate Analysis of Clinical Variables for Tooth Survival by Log-rank Test

	Censored (*n*)	Failed (*n*)	*P* value
Preoperative factors			
Sex			.433
Male	11/12	1/12	
Female	25/29	4/29	
Age			.294
≤36.2	20/21	1/21	
>36.2	16/20	4/20	
Periodontal condition			.373
Probing depth ≤6 mm	28/31	3/31	
Probing depth >6 mm	8/10	2/10	
Sinus tract			.414
Absent	22/24	2/24	
Present	14/17	3/17	
Nonsurgical RCT quality			.068
Good	17/17	0/17	
Poor	19/24	5/24	
Post			.653
Absent	25/29	4/29	
Present	11/12	1/12	
Intraoperative factors			
Extraoral time			.010*
≤15 min	24/26	2/26	
>15 min	8/11	3/11	
Retrofilling material			.006*
ProRoot MTA	12/16	4/16	
Others	24/25	1/25	
Resin wire splint			.183
Absent	33/36	3/36	
Present	3/5	2/5	
Postoperative factors			
IRR			.529
Absent	34/39	5/39	
Present	2/2	0/2	
Ankylosis			.567
Absent	35/40	5/40	
Present	1/1	0/1	

IRR, inflammatory root resorption; MTA, mineral trioxide aggregate; RCT, root canal treatment.
*Statistical significance was set at $\alpha = 0.05$.

TABLE 2. Multivariate Cox Proportional Hazard Regression Analysis of Selected Clinical Variables for Tooth Survival

	OR	95% CI	*P* value
Extraoral time			.038*
≤15 min	1	Reference	
>15 min	13.24	1.16–151.29	
Retrofilling material			.013*
ProRoot MTA	1	Reference	
Others	0.040	0.003–0.504	

CI, confidence interval; OR, odds ratio.

*Statistical significance was set at $\alpha = 0.05$.

Extraoral Time

An extraoral time >15 minutes was identified to exert a negative effect on tooth survival (Table 2), which is consistent with previous clinical (7) and *in vivo* studies of replantation (20–22). Andreasen et al (7) investigated 400 avulsed and replanted permanent teeth and suggested dry and wet extra-alveolar time as 2 of the significant factors related to PDL healing of replanted teeth. Hammarstrom et al (23) also reported that intentionally replanted teeth with 1 hour of extraoral time revealed extensive root resorption, whereas the other group with 15 minutes of extraoral time showed better periodontal healing accompanying re-establishment of the periodontal membrane. During the extraoral procedure, PDL cells inevitably experience interruption of the blood supply and dehydration, and in this respect, an extended extraoral time has been considered as a factor that reduces the PDL cell viability and compromises periodontal healing of replanted teeth. For this reason, a carbide bur driven by a high-speed handpiece, which shows higher cutting efficiency compared with an ultrasonic instrument (24), was used in this study to reduce time spent on retrocavity preparation. However, the results of this study show that there is still a need to minimize extraoral time as far as possible to improve the prognosis of intentional replantation. Preoperative use of cone-beam computed tomographic imaging would be a beneficial option when considering that it provides information regarding the root canal anatomy and exact location of endodontic complications before surgery (25). It should also be noted that PDL cell viability could be affected by the type of

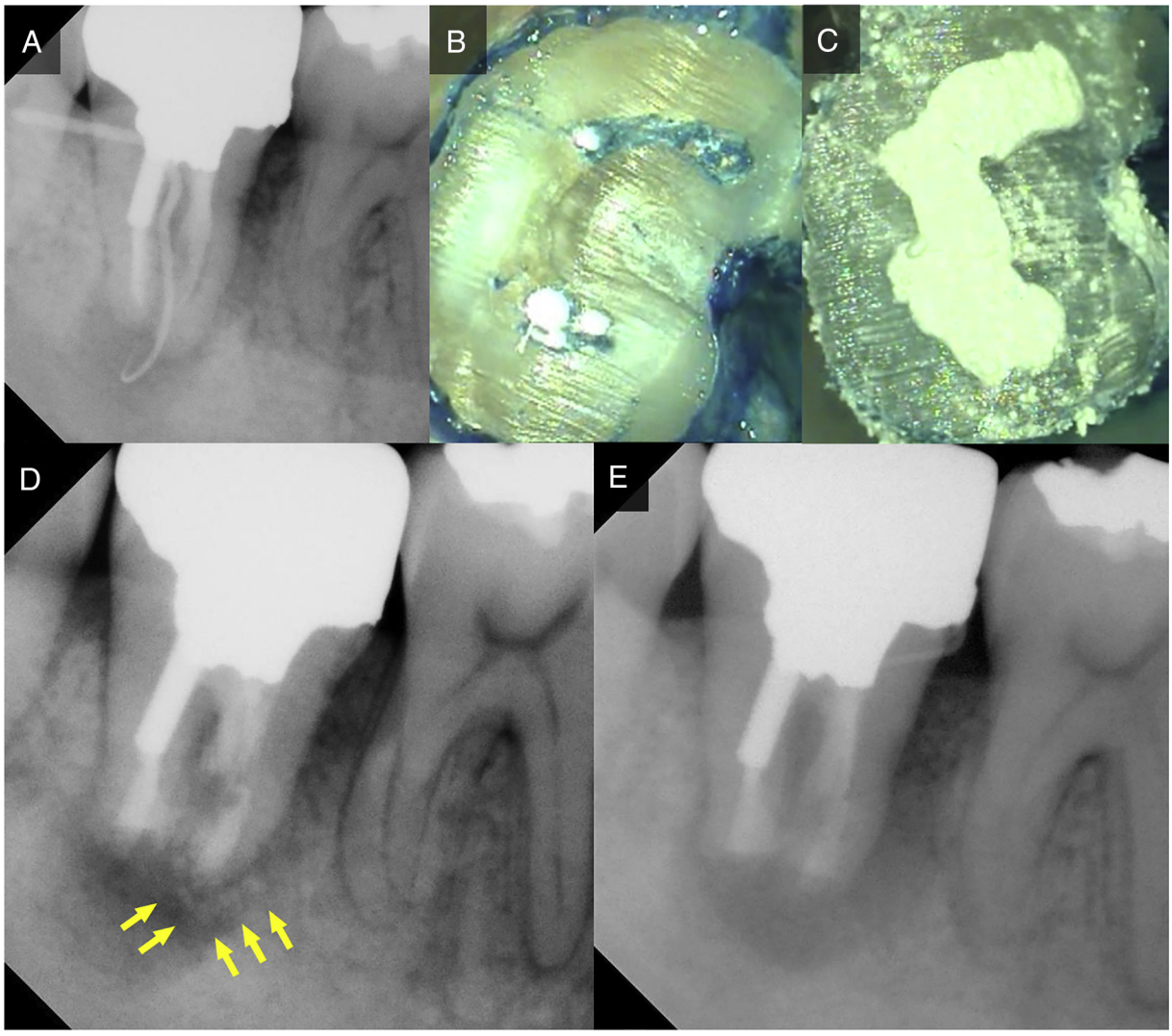

Figure 2. A case of treatment failure with MTA washout. The mandibular right second molar was scheduled for intentional replantation because of a persistent sinus tract. (*A*) Preoperative periapical radiograph. (*B*) The resected root surface stained with methylene blue. (*C*) Retrocavity filled with ProRoot MTA. (*D*) Postoperative periapical radiograph. Note the MTA partially washed out from the retrocavity (*arrows*). (*E*) Five months after intentional replantation. Treatment failure was diagnosed because of recurrence of the sinus tract and increased tooth mobility.

extraoral storage medium (26). In this regard, a "clinically acceptable" extraoral time might be able to further be increased with the routine use of HBSS as the extraoral storage medium, which has been reported to provide a favorable condition in the long-term storage of teeth (27).

Retrofilling Material

Mineral trioxide aggregate (MTA) has consistently shown outstanding performances in many areas of the endodontic field because of its superior sealing ability and biocompatibility compared with those of other materials. However, in this study, MTA was associated with a significantly lower survival of teeth with C-shaped canals than other materials (Table 2), which was not consistent with previous studies of apical microsurgery (28–31).

In apical microsurgery, sufficient hemostasis around the periapical cavity could be achieved before placement of the retrofilling material. However, in case of intentional replantation, it is difficult to achieve proper bleeding control of the surgical site because of the limited surgical intervention into the alveolar socket and the periapical cavity. Consequently, retrofilled materials inevitably face blood contamination immediately after intentional replantation. Furthermore, in teeth with C-shaped canals, retrocavities are often more extended to include all the isthmuses and fins between the canals, which might result in a significant increase in the contact area between tissue fluids and retrofilled material compared with that in normal canals.

In this regard, the long setting time of ProRoot MTA, which requires >4 hours to set completely, could be a factor that makes it more susceptible to early contamination and washout in intentional replantation compared with the other materials (ie, Super EBA and Endocem), which require <15 minutes of setting time (32–34). Actually, we have identified a case in which the retrofilling material (ProRoot MTA) had partially washed out from the retrocavity and failed by 5 months postoperatively (Fig. 2*A*–*E*). Previous literature has consistently reported that the material property of MTA could be deteriorated when it is contaminated before it completely sets. Recently, Song et al (35) have reported that persistent contact with human blood induces setting failures of ProRoot MTA around the exposure site. Other *in vitro* studies have also reported that blood contamination causes deterioration to the microstructure and mechanical properties of MTA and interferes with chemical bonding at the MTA-dentin interface (36, 37), which is associated with a reduction in the sealing ability and washout resistance of MTA (38, 39).

Therefore, clinicians should consider that in intentional replantation of teeth with a C-shaped canal, the use of retrofilling materials with long setting times could result in early contamination and subsequent deterioration of the material properties. In this respect, alternative treatment options could be considered, such as the use of an antiwashout gel in the mixing of MTA (40) or the use of other retrofilling materials that set more rapidly (32).

In terms of the extraoral storage media, 2 types of extraoral storage medium (saline or HBSS) were used in this study; however, these were not statistically compared. Because HBSS was only recently implemented in our institute, relatively fewer cases have been treated with HBSS than with saline, and, therefore, statistical power was not likely to be sufficient to allow a reliable comparison. This issue could be addressed in future studies.

Teeth with a C-shaped canal have been regarded as a treatment challenge in nonsurgical RCT because anatomic variations and narrow isthmuses create difficulties in orifice searching, canal instrumentation, irrigation, and filling (11, 41). Moreover, when considering that most C-shaped canals are distributed in the mandibular second molars, where the application of apical microsurgery is limited because of the presence of the thick buccal bone (42), intentional replantation could be a preferred treatment option for these cases. In this study, the survival rate of intentionally replanted teeth with a C-shaped canal was 83.4% at 4 years and 73.0% at 11 years postoperatively, which is less than that reported in a recent systematic review (overall survival rate of intentionally replanted teeth = 88%) (3). However, clinical procedures and related outcomes could be further improved by a firmer understanding of the prognostic factors. In this regard, the present study has shown that a reduction in the extraoral time and the use of fast-setting retrofilling materials can significantly increase the survival rate of intentionally replanted teeth with C-shaped canals. Further biological and clinical studies are needed to improve our understanding of the prognostic factors related to the clinical outcome of intentional replantation of teeth with C-shaped canals.

Acknowledgments

Supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (grant no. 2015R1D1A1A09057552).

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

Supplementary Material

Supplementary material associated with this article can be found in the online version at www.jendodon.com (http://dx.doi.org/10.1016/j.joen.2016.05.010).

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