Original Article

Long-Term Survival of Different Deep Dentin Caries Treatments: A 5-Year Clinical Study

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ABSTRACT

Objective: The aim of this *in-vivo* study was to evaluate the long-term clinical survival of different deep dentin caries treatment options. **Materials and Methods:** In total, 391 patients with at least one permanent tooth with clinically diagnosed deep dentin caries were inspected. Two hundred and fourteen patients were examined at recall visits. Inclusion criteria were teeth with deep caries lesions with pulp vitality but absence of spontaneous pain and periapical alterations. The subjects received either stepwise removal (SWR), complete caries removal (CCR), or direct pulp capping (DPC). The radiological and clinical exams were performed after a mean observation time of 62 months. Success was defined as pulp sensitivity to vitality test and absence of periapical lesions as well as a clinical symptom. Data were statistically analyzed using Kaplan–Meier and log-rank (Mantel–Cox) tests (α = 0.05). **Results:** Of the total 214 patients evaluated, 126 received SWR, 88 received CCR, and 67 received DPC treatment. One hundred and twenty-seven restorations were amalgam and 141 were composite. The mean observation period was 62 months. Survival rates were 85.7%, 90.9%, and 59.7% for SWR, CCR, and DPC, respectively (P = 0.001). Success rates of amalgam restorations (86.6%) were similar to composite restorations (83%), and both were found to be successful (P = 0.401). **Conclusion:** SWR treatment should be considered to preserve pulp vitality of deep dentin lesions instead of CCR or DPC. **Clinical Relevance:** SWR method for deep dentin caries management had acceptable results over 5 years.

KEYWORDS: *Complete caries removal, deep dentin caries, stepwise excavation*

INTRODUCTION

Inflammation of the pulp caused by a deep caries infection can be clinically managed either by preserving the partial pulp tissue or removing it and root-filling the tooth.[1,2] If no inflammation of the pulp or symptoms are present, the complete caries removal (CCR) method is preferred as a traditional technique that involves excavating the soft, demineralized dentin. It is common to have the pulp exposed during the operative procedure in these cases. The incidence of pulp exposure is much higher and lesion treatments result in a poor prognosis.[3-5]

CCR is a common treatment method that often leads to different treatments that compromise the vitality of the tooth.[6] Therefore, other alternatives to treat deep dentin caries lesions have been developed, including two-step caries removal, which is a stepwise removal (SWR) procedure that intends to preserve pulp vitality.[7,8] Dental clinicians often encounter extremely deep dentin caries, which results in pulp exposure if the caries is completely removed.[9] However, whether it is necessary to remove all carious tissue when there is a possibility of pulp exposure remains controversial.[10] Most clinicians continue to follow the basic principle that it is necessary to remove all affected tissue. Although

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endodontic therapy is a conventional approach with a high rate of clinical success, viable bacteria and necrotic host tissue can remain in the root canal system after instrumentation and obturation.[11] A survey conducted among dental clinicians to understand their choice of treatment for deep carious lesions found that about 62% of dentists preferred removing all caries even in cases of pulp exposure.[12] Approximately 20% of network dentists preferred a partial caries removal technique and indicated that deep dentin caries treatment outcome studies are warranted, given the various treatments employed. According to these findings, SWR is still not popular among dental practitioners. These choices might be attributable to the lack of knowledge about SWR treatment. Incomplete caries removal approach is performed in two steps at two visits over 6-12 months. The first visit involves selective removal of the soft dentin, and the carious dentin (still soft) is left in proximity to the pulp under a temporary restoration. The second visit after 6-12 months involves reopening the cavity to selectively remove the firm dentin and install a permanent restoration.[6] This two-step procedure aims to arrest progression of the carious lesion. A complete seal of the remaining caries lesion enhances the defense mechanisms of the pulp-dentinal complex allowing formation of tertiary dentin prior to the final visit for a permanent restoration.[13] If the pulp becomes exposed, direct pulp capping (DPC) can be applied as a conservative solution rather than a root-canal treatment. DPC has good outcomes,[14] whereas SWR treatment has some advantages over CCR and DPC.[15]

There is high regeneration ability, which can reverse pulp inflammation in a tooth with deep dentin lesions.[16,17] Recent studies have highlighted the importance of preserving pulp health to stimulate the pulp–dentin complex.[3,18] The healthy vital status of a tooth leads to the deposition of apatite crystals within the dentinal tubules, and dentine tubule sclerosis protects pulp vitality.[19] Vitality of the pulp is critical, because complications, such as a tooth fracture, often occur in pulpless teeth.[20] Clinicians should strive to preserve the pulp for a better prognosis if exposure occurs.[3,16,18] Although DPC is typically applied to exposed pulp during the caries removal procedure, the outcomes have not been promising in some clinical studies.[3,16,17] The consensus on tissue removal is to completely excavate the peripheral caries dentin and remove as much of the caries adjacent to the pulp as possible, avoiding pulp exposure. Because the prognosis of DPC is reportedly unpredictable,[3,16-18] protecting pulp vitality without exposing the pulp is crucial for long-term survival of the tooth.

In this clinical study, we compared the survival rates of SWR, CCR, and DPC treatments for deep dentin caries lesions associated with different factors, such as sex, tooth, treatment type, restoration material, cavity surfaces, and region of the treated tooth.

MATERIALS AND METHODS

Patient selection

Participants were selected from among patients who applied for treatment of deep dentin caries and received the SWR, CCR, or DPC treatments at our clinic between 2008 and 2012. The follow-ups of the patients were conducted and finished between October 2014 and March 2015. The study was approved by the Institutional Ethics Committee (Ethics No: GO 14/211-18) of Hacettepe University, Ankara, Turkey. In total, 391 patients (age 18-60 years) received SWR, CCR, or DPC during these years.

Clinical procedures

Patients were informed and willing to return for follow-up. All teeth had asymptomatic deep dentin caries lesions and there was neither clinical nor radiographic evidence of the lesions having reached the pulp of the tooth before receiving treatment. Only vital teeth with primary deep dentin caries were included after a clinical examination. Lesions with caries (as determined via radiology) involving more than or equal to three-fourths of the dentin (reached the pulp quarter) were considered deep dentin caries. The decision to employ SWR or nonselective caries removal (SWR or CCR) was made based on cavity depth as assessed by a research assistant using radiological analyses. In the SWR treatment group, the caries was slightly deeper than the nonselective caries removal group and there was no clearly identifiable radiodense area between the carious lesion and the pulp. All patients were treated by fifth-year students under the observation of research assistants at the Department of Restorative Dentistry. All research assistants were supervised by an instructor.

Stepwise removal

All peripheral caries were removed using a sharp excavator and/or slowly rotating sterile round bur, so that the decayed tissue was completely cleaned from the external cavity walls. After removing the soft necrotic caries tissue, a skin-like scaly caries,[21] which could be removed with an excavator, was left on the pulpal wall to prevent pulp exposure. The pulp wall was protected with calcium hydroxide. The cavity was sealed temporarily using a restorative glass-ionomer cement. Patients who received SWR were followed up by a clinician to restore the tooth permanently after 6 months. Patients who received SWR were examined according to the clinical

symptoms, and pulp sensitivity was assessed by means of a cold test after taking a periapical radiograph. The cavity was re-opened and the remaining caries was removed using either a sharp excavator or a rotating sterile round bur. The permanent fillings were placed by two experienced clinicians. The teeth were restored with a composite resin or amalgam after applying calcium hydroxide paste and glass-ionomer cement as base materials. Further periapical radiographs were taken for the new restoration.

Complete caries removal

The decision to completely remove caries was made when the clinician predicted that there would be no pulp exposed when there was a well-defined radiodense zone on the pulp chamber under the carious lesion. The pulp wall was protected with calcium hydroxide and glass-ionomer cement before placing the amalgam or composite resin restorations.

Direct pulp capping

All peripheral caries was removed using a sharp excavator and/or slowly rotating sterile round bur. If pulp was exposed during caries removal from the pulp wall, the DPC treatment was applied. Calcium hydroxide was placed on the exposure, and glass-ionomer cement was added before placing the amalgam or composite resin.

Recall visits

The patient's files included details of all of the treatments that the patient received. These information forms were archived in our department. Tooth information obtained from the patient record included treated tooth number, number of surfaces, whether the patient received SWR, CCR, or DPC, and restorative material used in the treated tooth. In addition, the type of final restoration placed at the re-entry appointment was recorded.

The patients were recalled and evaluated by two calibrated examiners. Of the 391 patients, 281 patients visited our department for a follow-up examination. Fifty-nine of the remaining patients could not be contacted because of wrong or changed phone numbers. Fifty-one patients refused to come for an examination for different reasons.

All patients received a clinical examination, and a periapical radiograph was taken to determine if the treated tooth had any periapical lesions or secondary caries. Vitality testing was performed using the cold test. Asymptomatic and vital teeth without clinical and radiographic evidence of periapical changes were considered successfully treated. Teeth that received root canal treatment or were extracted without our knowledge (reason claimed from the patients' statements), and the presence of symptoms, spontaneous pain, and/or periapical lesions were listed as failed treatment.

Statistical analyses

Descriptive statistics were used to summarize the overall re-evaluation status by subgroup defined by categorical factors of interest, and the relationships between the outcome of treatment (re-evaluation status) and the clinical characteristics. The relationship between the restoration type and re-evaluation status for each treatment subgroup was evaluated using Pearson's Chi-square test. Survival analyses, including survival comparisons based on categorical covariates, were performed with the Kaplan-Meier method and log-rank test. A P value < 0.05 was considered significant.

RESULTS

We evaluated 281 patients (171 females and 110 males) who received SWR, CCR, or DPC treatment between 2008 and 2012. The mean observation time calculated via Kaplan-Meier analyses was 62 months.

The descriptive data of the study parameters are presented in Table 1. In total, 151 teeth were on the maxillary arch and 130 were on the mandibular arch. Among the 281 patients, 126 received SWR, 88 received CCR, and 67 received DPC. In total, 127 amalgam and 141 composite restorations were placed [Figure 1]. Results of survival probabilities and the log-rank test results to assess the equality of the survival time distributions for the different levels of categorical factors are summarized in Table 1. There were no significant differences in survival time between the levels of all categorical variables ($P > 0.05$) except for treatment factor ($P = 0.001$) [Figure 2]. A comparison of survival rates among the SWR (110), CCR (80), and DPC (40) treatment methods indicated success rates of 85.7%, 90.9%, and 59.7%, respectively. Mean survival time and survival percentage were significantly lower in patients treated with DPC than in the two other treatment types ($P < 0.01$).

The causes of failure in the SWR group were pulpitis in 10 patients, who received temporary glass ionomer restorations at the first control visit, pulp necrosis in 3 (two composite restorations and one amalgam), and pulpitis in 2 teeth after the second appointment. Two failed teeth in this group (SWR) were extracted for unknown reasons but one other was extracted because of a severe fracture. Seven failures were recorded in the CCR group because of pulpitis, and one, which received an amalgam restoration, failed because of pulp necrosis.

The number of restored teeth surfaces (one, two, and three) was not different [Figure 3]. Most of

Table 1: Survival distributions and test results according to some categorical clinical factors

Variable	Category	Reevaluated	Mean time (months)	Survival/percentage (%)	P
Sex	Female	171	62.99	140 (81.9)	0.999
	Male	110	62.36	90 (81.8)	
Tooth arch	Maxillar	151	61.42	119 (78.8)	0.193
	Mandibular	130	64.26	111 (85.4)	
Treatment	SWR	126	66.65	110 (85.7)	0.001
	CRR	88	68.76	80 (90.9)	
	DPC	67	47.15	40 (59.7)	
Restorativematerial	Amalgam	127	65.43	110 (86.6)	0.401
	Composite	141	63.68	117 (83.0)	
Surfaces treated	One surface	8	43.37	5 (62.5)	0.092
	Two surface	248	63.76	208 (83.9)	
	Three surface	25	55.96	17 (68.0)	
Region of teeth treated	Anterior	25	59.48	19 (76.0)	0.171
	Premolar	62	66.98	56 (90.3)	
	Molar	194	61.85	155 (81.9)	

*Tooth with glass ionomer restoraitons are not mentioned in the table
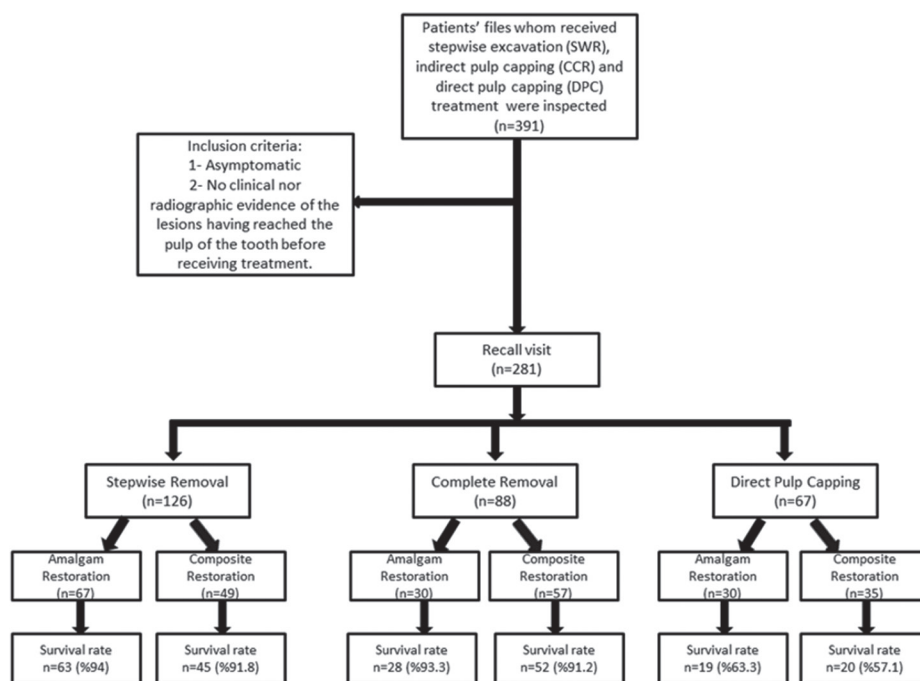
Glass ionomer restorations are not mentioned in the diagram

Figure 1: Study diagram

the teeth evaluated at the follow-up examination had restorations on two surfaces [Table 1]. The distributions of survival probabilities versus time by restorative material type are shown in Figure 4. Survival of teeth according to the restorative material for patients who received stepwise treatment is separately presented in Figure 5. We detected significant difference in terms of a treatment effect in bivariate statistical analyses ($P = 0.001$). The Kaplan-Meier curves also confirmed the similarities between the groups.

The frequencies and treatment results of patients who received SWR, CCR, or DPC treatments were evaluated according to the type of restorative material. The results of Fisher's exact Chi-square test are given in Table 2. There were no significant differences between restorative material type and clinical survival for all three treatment methods ($P > 0.05$).

From the total number of 116 patients who received stepwise treatment, 67 were treated with amalgam and 49 were treated with composite restorations. Overall, 94%

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Table 2: Comparison of different treatment types associated with restorative materials used

Treatment	Restoration type	Total *n*	No. of events (%)	No. of censored (%)	*P*
Stepwise removal	Amalgam	67	4 (5.97)	63 (94.0)	0.458
	Composite	49	4 (8.16)	45 (91.8)	
	Overall	116	8 (6.9)	108 (93.1)	
Complete removal	Amalgam	30	2 (6.66)	28 (93.3)	0.543
	Composite	57	5 (8.77)	52 (91.2)	
	Overall	87	7 (8.0)	80 (92)	
Direct Pulp capping	Amalgam	30	11 (36.7)	19 (63.3)	0.612
	Composite	35	15 (42.9)	20 (57.1)	
	Overall	65	26 (40)	39 (60)	

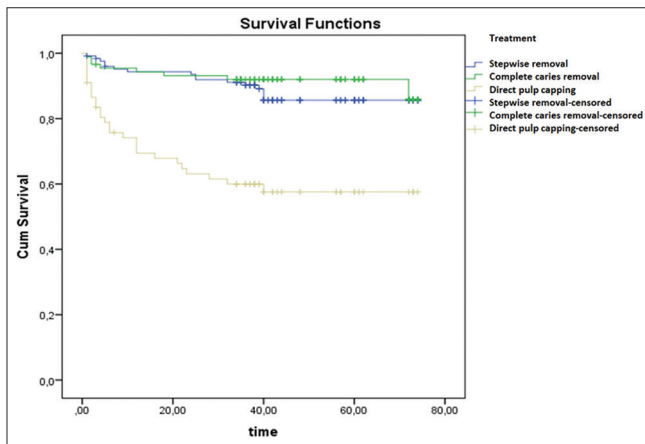Glass ionomer restorations are not shown in the table

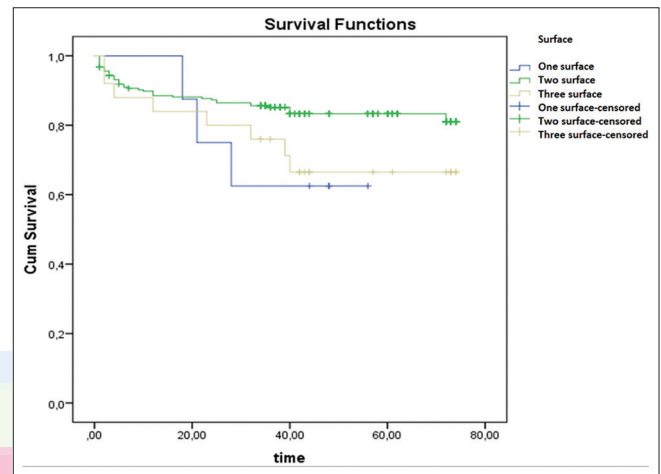**Figure 2:** Survival of teeth according to treatment methods

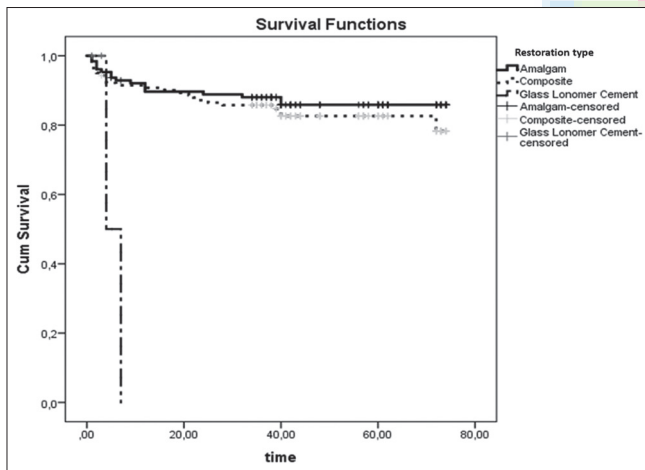**Figure 3:** Survival of teeth according to surfaces treated

Figure 4: Survival of teeth according to restorative materials used
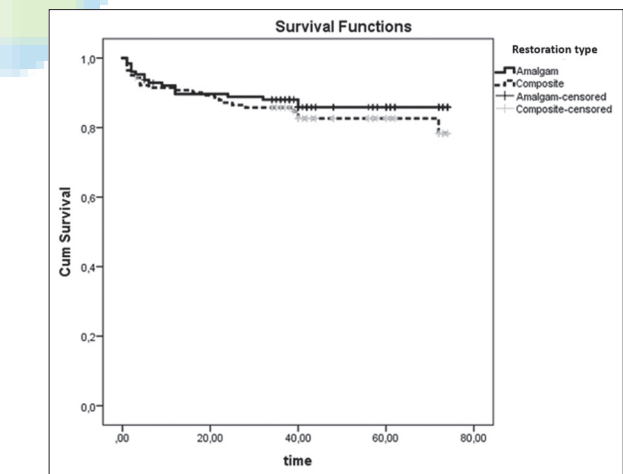

Figure 5: Survival of teeth according to restoration type for patients received stepwise treatment

of patients with amalgam restorations had successful outcomes, and 91.8% of patients who had composite restorations had successful outcomes. Similarly, of the 88 patients who received complete removal treatment, 30 were treated with amalgam (93.3% successful) and 57 were treated with composite restorations (91.2% successful) (*P* = 0.401).

The results of survival analyses based on the different treatment options and restorative materials are given

in Table 3. The estimated mean time to failure of SWR was 70.85 months for patients who received amalgam restorations and 70.02 months for patients who received composite restorations. Survival times did not significantly differ between the different levels of restorative material, although the patients were classified according to the type of treatment (*P* > 0.05).

Table 3: Survival comparison results for the different levels of treatment and restorative materials

Treatment	Restorative types	Mean±SD	95% confidence interval	P
Stepwise removal	Amalgam	70.85±1.55	67.81-73.89	0.666
	Composite	70.02±1.88	66.32-73.72	
	Overall	70.50±1.20	68.14-72.85	
Complete removal	Amalgam	69.20±3.27	62.77-75.62	0.654
	Composite	69.15±2.22	64.79-73.51	
	Overall	69.19±1.85	65.56-72.82	
Direct pulp capping	Amalgam	49.46±5.91	37.87-61.05	0.562
	Composite	45.08±5.51	34.27-55.89	
	Overall	47.33±4.07	39.34-55.33	

P-value was obtained from log-rank test

The estimated mean time to failure for the complete removal treatment was 69.20 months for patients who received amalgam restorations and 69.15 months for patients who received composite restorations. No significant differences in survival times were observed between the levels of restorative material for a complete treatment ($P > 0.05$). Similarly, no significant differences were observed between the mean survival times according to the restorative material in the DPC treatment ($P > 0.05$). However, the mean survival time was lower for DPC (47 months) than the other two treatments.

DISCUSSION

A comparison between SWR, CCR, and DPC was demonstrated in association with the restoration type placed with a mean survival time. SWR (85.7%) is a more conservative technique and showed a significantly higher survival rate compared with DPC (59.7%) for deep caries. A recent study evaluated 8 years of follow-up of SWR treatments for deep carious lesions and reported that the decision to treat with SWP should be based not only on clinical signs and symptoms but also on certain patient-centered factors because of the high risk for loss to follow-up.[22] Bjorndal *et al*. reported that the SWR causes less pulp exposure leading to a better prognosis for deep dentin caries lesions.[4] A clinical study in which the treatments were carried out by fourth- and fifth-year undergraduate dental students at conservative dentistry clinics reported that mechanical exposure (with a sterile excavator or round bur) had a 92.2% success rate.[18] The same study also showed that if exposure occurred by a caries, the success rate declined to 33.3%. Another study in which pulp capping was performed by students at different time intervals reported 44.5% failures after 5 years and 79.7% failing cases after 10 years. The authors reported that placement of a permanent restoration 2 days after pulp exposure significantly contributed to the survival rate of these

teeth.[3] In this study, calcium hydroxite paste was used on the pulp walls, as in many studies.[23-27] These studies placed calcium hydroxite paste deep in the cavity after removing the caries, resulting in positive outcomes. A randomized clinical trial[27] showed that partial dentin removal (CCR was conducted at the second visit as in our SWR group) resulted in a significant improvement (success rate: 91%) with regard to the maintenance of pulp vitality compared to indirect pulp capping (success rate: 69%) after a 3-year follow-up. In this study, the SWR (85.7%) and CCR (90.9%) groups had similar survival rates. This difference with the previous study may be related to the different methodologies used in the two studies.

Partial removal studies all carry a risk that patients may not return after 6-12 months for their second appointment, which could cause a low survival rate, as emphasized in Maltz *et al*.[27] Jordan and Suzuki[26] reported that teeth receiving SWR and reopened after 3 months demonstrated a clinical success rate of 98%. In this study, only 7 of 243 teeth needed endodontic treatment.

Glass ionomer cement was preferred for temporary restorations in this present study, as reported previously.[7,22] However, different materials can be selected for temporary restorations. Other studies in which deep caries lesions were treated used zinc oxide-eugenol,[28,29] IRM[27,30,31] (reinforced zinc oxide-eugenol), or amalgam[7,26] for temporary restorations before the second reopening visit.

According to the Kaplan-Meier analyses conducted in our study, all glass ionomer restorations failed after a mean survival interval of 47 months. These were mostly temporarily placed restorations and were detected in patients whom did not attend the second appointment for a permanent restoration.

A previous study that evaluated partial and complete removal using radiographic and scanning electron microscopic analyses found no significant differences between these treatment methods.[32] Similarly, Mertz-Fairhurst *et al*.[33] used a randomized clinical design to compare composite restorations treated using the partial caries removal technique, with both sealed and unsealed amalgam restorations from which all carious tissue had been removed. Evaluations after 6 months, 1 year, and 2 years revealed no significant differences among the three treatments. The researchers followed up these patients for 10 years and reported that even after a decade, the group who received the partial caries removal procedure still had no differences from the other groups that received complete removal.

This study found no significant differences between permanent restorative choices. The SWR and CCR treatments with final amalgam restorations had similar and high survival rates, such as 85.7% and 90.9%, respectively. Moreover, cases that received composite restorations also showed high survival percentages as well (91.8% for the SWR and 91.2% for the CCR group). Amalgam restorations have the ability to self-seal over time and the ability to minimize microleakages of any kind, which prevents bacterial invasion.[34,35] It is important to gain a firm marginal adhesion at the peripheral regions to protect the pulp from bacteria when composite restorations are installed. Infected dentin or infected caries lesions negatively affect the adhesion of bonding agents compared with sound dentin,[36,37] which emphasizes the importance of caries-free dentin and enamel at the margins of cavity preparations.

Radiographic findings show remineralization of the dentin structure during deep dentin carious treatment. Some studies[26,27] have reported radiographic evidence of remineralization after the SWR and complete removal treatments; however, it is difficult to determine changes in radiopacity in a standard radiograph. Furthermore, radiographic findings would show clinicians if reopening of the cavity is necessary. The condition of the dentin upon reopening has been reported in some studies; the remaining softened dentin in the cavities becomes darker, harder, and drier after 6-12 months following SWR.[23-25,27] We also detected darker and harder cavities at recall sessions.

The probability of pulp exposure during the second session should not be overlooked. In this study, no exposure occurred after the second procedure; however, two teeth that received SWR suffered pulpitis after reopening for caries removal and placement of a permanent filling.

In addition, teeth with clinical evidence of vital pulp (cold test), uncompromised restorations, and radiographic evidence of no lesion were considered survived cases. Survival rates were compared with sex, tooth arch, tooth type (anterior, premolar, molar), treatment type, and number of treated surfaces. The need for two appointments for the stepwise technique might be discomforting to patients, because the treatment is prolonged over 6-12 months. Examiners could not reach many of the patients for recall visits and control appointments. In total, 391 patients received either the SWR (*n* = 208) or CCR (*n* = 183) treatments. Nevertheless, 214 patients were ultimately examined. Another limitation of this study was that most of the treated teeth had two surfaces; therefore, the relationship between the number of surfaces and survival rate

could not be clearly defined. The SWR, CCR, and DPC treatments practiced in the clinic were examined and evaluated retrospectively. The parameters were not uniformly distributed. Further prospective clinical studies should be conducted because of these limitations of this study.

CONCLUSION

SWR showed comparable results as CCR; therefore, partial caries removal should be considered for treating deep dentin caries lesions to preserve pulp vitality. In contrast, DPC did not show desirable results for treatment of deep dentin caries at the long-term follow-up.

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Conflicts of interest

There are no conflicts of interest.

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