



The clinical success of repaired posterior composite restorations with and without silane application

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Received: 15 December 2021 / Accepted: 3 May 2022 / Published online: 9 May 2022
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Abstract

Objective To evaluate the clinical success of posterior composite restorations repaired with and without silane application for up to 2 years.

Materials and method In this retrospective study, patient record files acquired from the 40 patients who were treated due to needing repair for two class II defective composite restorations and visited the clinical practice for regular check-up visits were used. In the experimental group, the defective restorations were repaired using a silane coupling agent (Porcelain Primer), a universal adhesive (G-Premio Bond), and a microhybrid resin composite (Charisma Smart). In the control group, the restorations were repaired using the universal adhesive and the resin composite without silane coupling agent application. The repaired restorations were blindly assessed by two calibrated examiners using modified USPHS criteria at baseline, 6 months, 1, and 2 years. The data were analyzed using non-parametric tests ($p = 0.05$).

Results After 2 years, 80 repaired class II restorations were evaluated. No restoration of either the control or silane-treated group failed. After 2 years, there were no statistically significant differences between the experimental and control groups ($p > 0.05$). The differences in surface roughness were observed in each group over time ($p < 0.05$). There were no variations in other criteria over time ($p > 0.05$).

Conclusion There was no significant effect of the silane coupling agent on restoration repair survival.

Clinical relevance The repair of localized defects of the posterior composite restorations either with or without silane application is a conservative treatment option that may increase the clinical success of these restorations.

Keywords Repair · Resin composite · Retrospective · Silane · Universal adhesive

Introduction

Because of the increase in patient esthetic demands and improvements in the mechanical properties of resin composites, they have frequently become the material of choice for directly restoring posterior teeth besides anterior teeth. Although materials with improved physical properties, such as high fracture and wear resistance, are available, posterior composite restorations may fail [1]. The clinical durability of composite restorations is influenced by some factors, including patient characteristics, material selection, technique, and operator experience [2]. It has been reported that the annual

failure rates of the posterior composite restorations were between 1 and 3% over periods of at least 5 years [2, 3]. The most frequent reasons for the failure of restorations are marginal fractures in the early stages and recurrent caries in the later stages [1, 3].

When the posterior composite restorations fail, the defective restorations are commonly treated with two options: repair or replacement [4, 5]. The replacement, which involves complete removal of the restoration, is time-consuming, costly, and not a conservative treatment option. During cavity preparation, the sound tooth structure may be removed, thus increasing the risk of pulpal damage [6]. The repair is described as restoring the defective part of restoration, leaving the intact part of the restoration in place [7, 8]. The repair has a lower risk of complications, such as loss of sound tooth substance and pulpal damage since it requires limited tooth preparation [9]. Moreover, the repair

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of defective composite restorations improves the clinical quality and longevity of restorations [5, 9–12].

While replacement of failed composite restorations was a more preferred treatment option in earlier times, repair has become more popular today due to the advances in adhesive technologies [4, 8]. For successful repair, a durable adhesion has to be promoted between the old composite restoration and the new resin composite [6, 7]. A variety of surface conditioning techniques based on physical and chemical adhesion principles have been developed to obtain an adequate and durable bond strength between the resin composite surfaces [13–17].

The most frequently used physical conditioning methods are aluminum-oxide sandblasting, bur roughening, and etching with hydrofluoric acid [13, 15, 17]. Different surface roughening procedures have been tested in laboratory studies, but any standardized physical roughening methods are not available [7, 14]. The chemical pretreatment methods involve using silane coupling agents and different adhesives [6]. Adhesive application after roughening procedures is needed to provide a chemical bond between old and fresh resin composites [16–19]. However, there are contradictory results regarding the effect of silane application before adhesive on the repair bond strength. Some studies concluded that the silane application increased the repair bond strength [16, 20–22], and others reported that it was ineffective for improving repair bond strength [15, 23, 24].

Several laboratory studies are available related to the repair bond strength of resin composites. However, there is

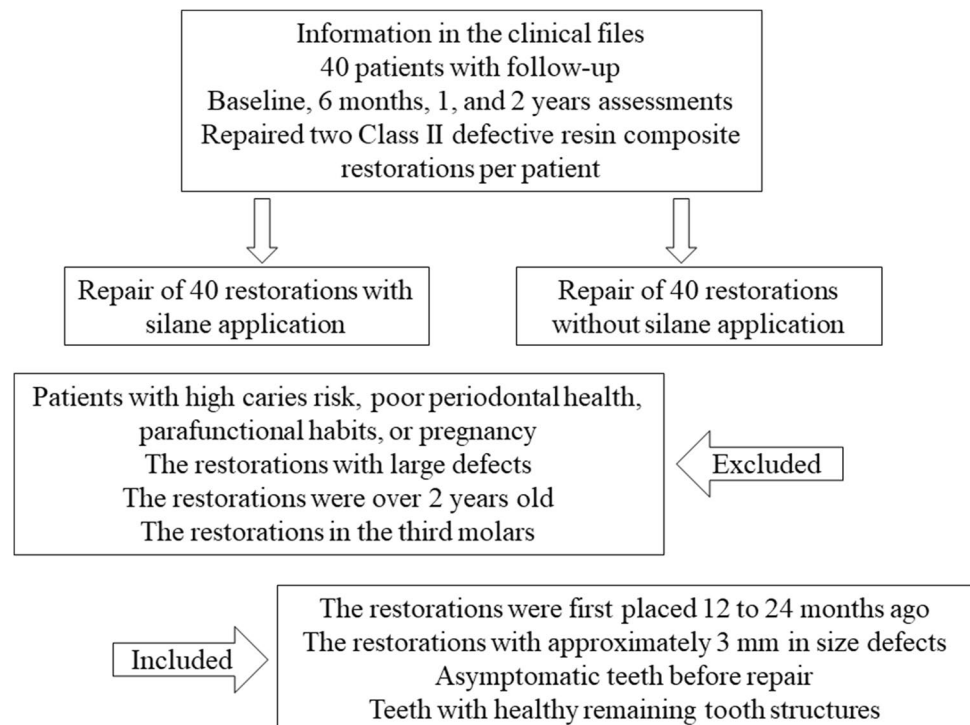
no agreement concerning the most efficient repair technique [6–8]. There are also no clinical studies that investigate which repair technique is more clinically effective. It is recommended that after roughening procedures, the application of silane is performed first, and then, the adhesive is applied [6]. The clinical performance of repairs has been previously investigated in clinical trials. In these studies, adhesive procedures were applied without silane after removing the defective part of the old restorations using diamond burs [10–12, 25, 26]. Nonetheless, clinical studies regarding the effectiveness of silane application in repair are still missing.

Therefore, this study aimed to evaluate the clinical effectiveness of silane application in the repair of defective composite restorations. The null hypothesis of this study was that the use of silane before adhesive application would not affect the clinical longevity of repaired defective composite restorations.

Materials and method

The study design and protocol were approved by the local ethics committee (2021/127). In this retrospective study, the patient record files of 40 patients with a mean age of 34.8 years (range 22–45) comprising both females (47.5%) and males (52.5%) were used for collecting data. The patients were treated for the repair of two defective class II composite restorations and visited the clinical practice for regular check-up visits (Fig. 1). The defective restorations were

Fig. 1 Flowchart of the study, number of repaired restorations, exclusion, and inclusion criteria



scored at least Bravo according to Modified United States Public Health Service (USPHS)/Ryge clinical criteria by two calibrated operators (Table 1). The restorations were clinically determined to be suitable for repair according to the modified USPHS/Ryge criteria, as reported in previous studies [9, 10, 25]. The patients were treated by the same experienced operator between January and December 2018 due to the repair of two class II resin composite restorations and reviewed at 1-week, 6-months, 1-year, and 2-year recall. Those patients with high caries risk, poor periodontal health, parafunctional habits, or pregnancy were already excluded. The restorations with large defects caused by recurrent caries lesions and marginal fractures were not included. Those teeth were asymptomatic before the repair treatment. The remaining tooth structure was healthy and in good condition for the adhesion of the new resin composite. In the experimental group, the defective restorations were repaired with silane coupling agent application beforehand. In the control group, the repair was performed without silane coupling agent application. All teeth had proximal contact with adjacent teeth and were in occlusion. A total of 40 pairs of restorations was considered to be adequate and comparable with previous studies [9, 10, 12, 25, 27]. For this study, approximately 80 patients admitted for treatment were examined according to inclusion and exclusion criteria (Fig. 1). The 40 patients were treated with the repair of two defective class II composite restorations. The repaired restoration with silane coupling agent application created the experimental group as the other restoration generated the control group.

Clinical repair procedure and evaluation

The operator distributed the restorations to one of two treatment groups, experimental or control groups, by randomization. The randomization of the experimental or control group was performed using a table of random numbers for each patient before the operative procedure. Local anesthesia was applied to the patient. The operative field was isolated with a rubber dam before the restorative procedures. The defective surfaces of the restorations were removed using a high-speed handpiece and diamond burs (MANI, Tochigi, Japan) under water cooling. The existing demineralized and soft tooth tissues were included in the cavity preparation. The thin metallic matrixes (Tor VM, Moscow, Russia) and wooden wedges (KerrHawe, Bioggio, Switzerland) were used during the restorative procedures. In the experimental group, the surfaces of old restorations and enamel margins were etched with 37% phosphoric acid gel (Scotchbond Etchant Gel; 3M ESPE St Paul, MN, USA) for 30 s. After water-rinsing and air-drying, a silane coupling agent (Porcelain Primer; Bisco, Schaumburg, IL, USA) was applied to the restoration surface. Then, a universal adhesive (G-Premio Bond; GC, Tokyo, Japan) was employed on the tooth and restoration surfaces and light-cured. The preparation field was restored using a microhybrid resin composite (Charisma Smart; Heraeus Kulzer, Hanau, Germany). All of the materials were used according to the manufacturer's instructions (Table 2). In the control group, the surfaces

Table 1 Modified USPHS criteria for direct clinical evaluation

Category	Rating	Criteria
Marginal adaptation	Alfa (A)	Restoration adapts closely to the tooth structure; there is no visible crevice
	Bravo (B)	There is a visible crevice, the explorer will penetrate, without dentin exposure
	Charlie (C)	The explorer penetrates into a crevice in which dentin or the base is exposed
Anatomical form	Alfa (A)	Anatomic form ideal
	Bravo (B)	Restoration is under contoured, without dentin, or base exposure
	Charlie (C)	Restoration is under contoured, with dentin or base exposure; anatomic form is unsatisfactory; restoration needs replacement
Marginal discoloration	Alfa (A)	No marginal discoloration
	Bravo (B)	Minor marginal discoloration without staining toward the pulp, only visible using a mirror and operating light
	Charlie (C)	Deep discoloration with staining toward the pulp, visible at a speaking distance of 60 to 100 cm
Surface roughness	Alfa (A)	As smooth as the surrounding enamel
	Bravo (B)	Rougher than surrounding enamel; improvement by finishing is feasible
	Charlie (C)	Very rough, could become anti-esthetic and/or retain biofilm; improvement by finishing is not feasible
Postoperative sensitivity	Alfa (A)	No postoperative sensitivity
	Bravo (B)	Short-term and tolerable postoperative sensitivity
	Charlie (C)	Long-term or intolerable postoperative sensitivity; restoration replacement is necessary
Secondary caries	Alfa (A)	No active caries present
	Bravo (B)	Active caries is present in contact with the restoration

Table 2 The materials, chemical composition, and application procedure

Material	Composition	Application procedure
G-Premio Bond (GC, Tokyo, Japan) Lot no: 1903122	10-MDP, 4-MET, dimethacrylate resins, photo-initiator, butylated hydroxytoluene, acetone, water	1. Apply the adhesive and wait for 10 s 2. Dry thoroughly with maximum air pressure for 10 s 3. Light-cure for 10 s
Porcelain Primer (BISCO, Schaumburg, IL, USA) Lot no:1800003839	3-(Trimethoxysilyl)propyl-2-methyl-2-propenoic acid, ethanol, acetone	1. Apply 1 thin coat to surface and allow to dwell for 30 s 2. Dry with an air syringe
Charisma Smart Composite (Heraeus Kulzer, Hanau, Germany) Lot no: K010516	Bis-GMA, barium aluminum fluoride glass, silicon dioxide	1. Apply the material in thin layers (max. 2 mm) 2. Polymerize the material using a light-curing unit with a light output of 1550–550 mW/cm ²

Composition as provided by the manufacturers: *10-MDP*, 10-methacryloyloxydecyl dihydrogen phosphate; *4 MET*, 4-methacryloxyethyl trimellitate; *Bis-GMA*, bisphenol-glycidyl methacrylate

of restorations and enamel margins were etched with the phosphoric acid gel for 30 s. After water-rinsing and air-drying, the same universal adhesive was applied to the tooth and restoration surfaces and light-cured. The preparation field was restored with the microhybrid resin composite without silane coupling agent application. After the occlusion checking and contouring, the polishing was done using a polishing system (OneGloss; Shofu, Kyoto, Japan) at a rotation speed of between 3000 and 10,000 revolutions per minute with intermittent water spray. Figures 2, 3, and 4 illustrate clinical photographs of the repair treatment.

The restorations were assessed at baseline (1 week after repair of the restorations) and after 6 months, 1, and 2 years by the following parameters according to modified USPHS/Ryge criteria as in the previous studies [9, 10, 12, 25, 27]: marginal adaptation, anatomic form, marginal discoloration, surface roughness, color match, and secondary caries. Two examiners independently evaluated all repaired restorations by direct observation, using a plane mirror and a WHO model explorer. Cohen's kappa coefficient between evaluators at all evaluation times was over 0.90, which reveals a strong coherence between the evaluators. All restorations received a clinical rating of Alfa, Bravo, or Charlie.

Statistical analysis

The SPSS program (Statistical Package for the Social Sciences version 20.0; SPSS, Chicago, IL, USA) was used to analyze the data. The dependent variable was the percentage of Alfa, Bravo, or Charlie ratings. The differences between the groups for marginal adaptation, marginal discoloration, and surface roughness at 2-year recall were determined by the Mann-Whitney *U* test. The Wilcoxon test was used to evaluate the variations in these clinical parameters over time. The statistical significance level was set at 0.05 for all analyses.



Fig. 2 A defective composite restoration in the lower molar

Results

The main reason for the repair in the restorations was initially a loss of anatomic form due to marginal defects. During the 2-year follow-up, 80 repaired class II restorations

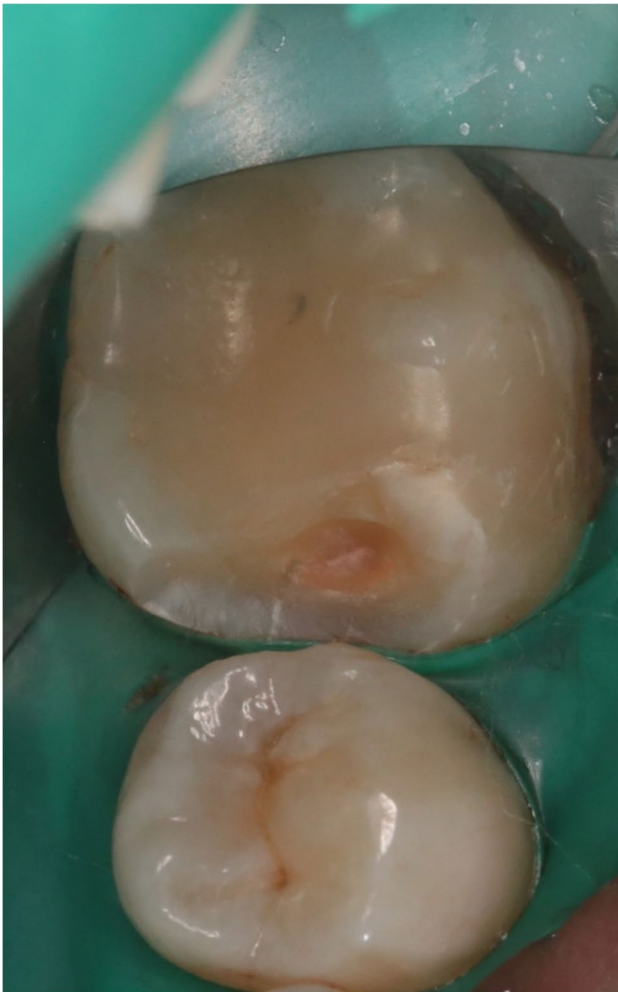


Fig. 3 Cavity preparation under rubber-dam isolation for repair treatment

were evaluated. The distribution of the restored teeth is displayed in Fig. 5. No participants reported any postoperative symptoms at the evaluation times. No carious lesions observed were found contiguous with the restorations. No failure was observed in any of the repaired restorations. The frequencies of Alfa, Bravo, and Charlie ratings in each group at all evaluation periods are shown in Table 3. After 2 years, Bravo ratings were observed for marginal adaptation, marginal discoloration, and surface roughness. There were no statistically significant differences in the ratings between the experimental and control groups at 2-year recall ($p > 0.05$). No significant differences were found in the criteria over time, except for surface roughness ($p > 0.05$). There was a statistically significant difference in surface roughness in each group comparing the baseline and 2-year recall ($p_{\text{experimental}} = 0.014$ - $p_{\text{control}} = 0.025$).



Fig. 4 The repaired composite restoration after treatment immediately

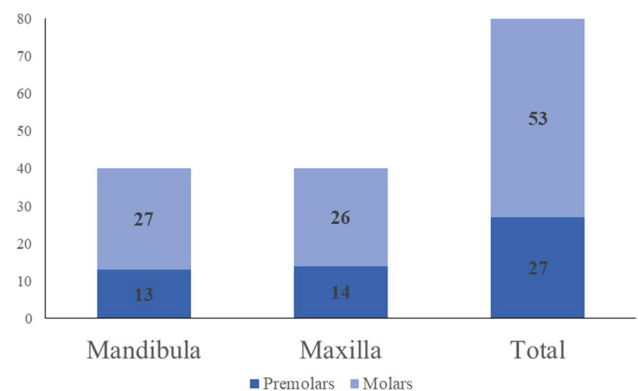


Fig. 5 Distribution of the repaired restorations based on teeth

Discussion

Repair of defective composite restorations is a less invasive treatment than replacement. When repair is performed, the

Table 3 Frequency of Alfa, Bravo, and Charlie ratings at baseline, 6-month, 1-, and 2-year periods according to the groups (%)

		Silane applied group				Silane non-applied group			
		Baseline	6 m	1 y	2 y	Baseline	6 m	1 y	2 y
Marginal adaptation	Alfa	100	100	100	97.5	100	100	100	95
	Bravo	0	0	0	2.5	0	0	0	5
	Charlie	0	0	0	0	0	0	0	0
Anatomical form	Alfa	100	100	100	100	100	100	100	100
	Bravo	0	0	0	0	0	0	0	0
	Charlie	0	0	0	0	0	0	0	0
Marginal discoloration	Alfa	100	100	100	95	100	100	100	92.5
	Bravo	0	0	0	5	0	0	0	7.5
	Charlie	0	0	0	0	0	0	0	0
Surface roughness	Alfa	100	100	100	85	100	100	100	87.5
	Bravo	0	0	0	15	0	0	0	12.5
	Charlie	0	0	0	0	0	0	0	0
Postoperative sensitivity	Alfa	100	100	100	100	100	100	100	100
	Bravo	0	0	0	0	0	0	0	0
	Charlie	0	0	0	0	0	0	0	0
Secondary caries	Alfa	100	100	100	100	100	100	100	100
	Bravo	0	0	0	0	0	0	0	0

annual failure rate (AFR) of posterior composite restoration decreases, and the longevity of restorations improves [5, 9, 28]. The longevity of restorations is beneficial for patients and dentists, moreover for the reduction of the cost of dental restorations. Repair is mainly indicated in the case of localized shortcomings, such as severe marginal staining, recurrent caries without deep undermining caries, marginal fracture of restorative material, chipping or partial fracture of restorative material, marginal breakdown of enamel, erosive/abrasive loss of tooth structure at the restoration margin, wear of the restoration, and minor cuspal fracture [8].

It has been reported that the remaining parts of the original restoration showed a higher success rate than the repaired part, and the failures were related to insufficient bonding [5]. To obtain optimal repair bond strength, several repair protocols have been developed and assessed in laboratory studies [14–17]. Mechanical retention is crucial to obtaining reliable repair bond strength [13, 17, 21]. Roughening with a diamond bur, air-abrasion with aluminum oxide powder, and etching with hydrofluoric acid are commonly tested mechanical surface treatment methods [13, 15, 17, 21, 22]. However, none of the surface treatment procedures can be recommended as a universally applicable repair technique [14]. Intraoral use of hydrofluoric acid has risks because of its hazardous effects on oral soft tissues [15, 20]. Previous studies concluded that alumina sandblasting showed higher repair bond strengths than roughening with diamond burs [15, 17, 21]. Nevertheless, using diamond burs is an easily applicable roughening method in clinical practice [29].

The effect of silane application on repair bond strength has not fully been explained [25]. There are no clinical trials that have assessed the effectiveness of silane application on the repair of the composite restoration. In the present study, the effect of silane application on the clinical longevity of repaired defective composite restorations has been investigated. This study is the first to investigate the clinical efficacy of silane application in the repair of posterior composite restorations. After 2 years, the current study found no statistically significant differences between the groups for the clinical parameters. The null hypothesis that the use of silane before adhesive application would not affect the clinical longevity of repaired defective composite restorations was confirmed. In previous studies regarding the clinical performance of repaired composite restorations, no silane agents were used before adhesives, and acceptable clinical results were observed [10–12, 25, 26].

It has been reported that silane application provided higher repair bond strength when followed by adhesive application [16, 21, 22]. The silane may improve the wettability of the adhesives on the irregular surfaces, thus facilitating the infiltration of adhesives into the irregularities [16]. Furthermore, the silane application may promote the development of covalent bonds between the monomers in the adhesive system and the inorganic filler particles of the resin composite [30]. Silane coupling agents are molecules with two functional groups: silanol and methacrylate groups [6]. The reactive silanol groups react with the inorganic filler particles of the old resin composite and create siloxane bonds between these filler particles and the methacrylate groups in the adhesive [16]. The methacrylate

groups of silane form covalent bonds between the adhesive and the fresh resin composite when the fresh resin composite is polymerized [6, 16]. However, the microstructure of the resin composite, the amount of surface roughness, and the number of filler particles present on the old composite surface might influence the effects of silane [15, 30]. In the current study, the use of silane did not show any beneficial effect over the 2-year time. It may have been caused by the type of resin composite, the roughening procedure, the age of the repaired restorations, and the length of the study.

The utilization of an intermediate adhesive resin plays a critical role in achieving reliable and durable repair bond strengths [17–19, 22, 23]. The use of an adhesive resin improves the wettability of the old resin composite surface when the fresh resin composite penetrates and provides a chemical bond between the original and the fresh resin composite [19]. The adhesive type might influence the repair bond strength depending on its composition [16, 22]. 10-MDP monomers in the adhesive content might promote high repair bond strength by providing additional chemical bonding [22]. 10-MDP is a functional monomer that has a high chemical bonding capacity [22]. In the current study, a 10-MDP containing universal adhesive was used. Universal adhesives may be used in different direct and indirect restorative applications of resin composites, besides dental ceramics and alloys [22]. It has been reported that universal adhesives showed reliable clinical performance when they were applied in etch-and-rinse and selective-etch modes [31]. Previous studies have reported stable and reliable repair bond strength using universal adhesives [22, 23]. Although some universal adhesives have an organosilane agent in their composition, the effectiveness of the silane content of universal adhesives is not consistent [22–24].

The clinical performance of repair is affected by different factors, such as the size of the initial restoration, patients' bearing risks, the location of the tooth, removable partial dentures, and previous endodontic treatment [5, 12]. In the present study, the marginal defects and loss of anatomical form were the main reasons for repairing restorations. The defect size in the restoration was approximately 3 mm. The cavity preparation was performed so that one wall was on the resin composite and the remaining walls were on the enamel. Due to the superficial cleaning capacity of phosphoric acid [14] and increasing the bond strength of universal adhesives, acid etching with phosphoric acid was performed on the old composite restoration surfaces and healthy tooth tissues where the new restoration will be bonded.

Calibration between evaluators is crucial in the clinical evaluation of restorations [32]. In the current study, the kappa test showed good agreement between the evaluators. Six modified USPHS criteria, including marginal adaptation, anatomic form, marginal discoloration, surface roughness, postoperative sensitivity, and secondary caries, were used to

assess the clinical performance of repaired composite restorations since enabling comparison with previous repair studies [9, 10, 12, 25, 26]. The USPHS criteria are widely used to assess the clinical performance of restorations because they may be easily applied and provide an opportunity to compare the results with previous studies [25]. Nevertheless, the criteria may have limited sensitivity since they provide very general information. The criteria may cause a misconception of the results as indicating good clinical performance in short-term clinical trials because any changes over time are not easily detected since limited sensitivity in short-term clinical studies [27, 33]. In the current study, there were no statistically significant variations in the criteria over time, except for surface roughness ($p > 0.05$). After 2 years, the surface roughness ratings in each group were different compared to the baseline results ($p < 0.05$). The surface roughness is related to the properties of resin composites, such as the filler type, filler shape, filler size, the distribution of the filler particles, and the type of resinous matrix, not bond strength [27].

The present study evaluated the 2 years of data obtained from the repaired defective composite restorations. During the 2-year observation period, the evaluated restorations remained stable and unchanged. It may have resulted from the short observation period reported in this study because this time might have been insufficient for the development of new defects or caries. The exclusion criteria might influence these results. The longevity of posterior composite restorations is generally related to several factors, including tooth type and location, operator, and socioeconomic, demographic, and behavioral elements. The properties of a material may have a minor effect on the longevity of restorations [2]. In the current study, some participants were excluded due to high caries risk, poor periodontal health, parafunctional habits, or pregnancy. The findings are in agreement with previous studies that assessed the clinical longevity of repaired defective composite restorations [11, 25, 33, 34]. Nonetheless, different patient profiles might affect the results of this study.

The different resin composites may be used as filling or as repair materials. In repair procedures, it is advisable but not compulsory to combine identical resin composites [35]. The age of the included defective restorations was retrieved from the dental records. The restorations that were first placed 12 to 24 months ago were repaired. It is in agreement with previous studies [11, 25, 33]. Aging might influence the clinical performance of repair due to a decrease in the number of available vinyl groups for cross polymerization [7, 10, 25]. Moreover, the age of the repaired restoration may alter the effect of the silane coupling agent on the repair.

This study was based on data from a faculty of dentistry hospital of one experienced dentist who specialized in restorative dentistry. The main limitation of this study is

the evaluation of a low number of clinical files based on inclusion and exclusion criteria. Furthermore, the evaluation period of restorations is limited to 2 years. More restorations must be evaluated in clinical trials with longer observation periods to confirm these findings.

Conclusion

Within the limitations of the present study, although the long-term results are not yet available, it might be concluded that the defective posterior composite restorations with a defect size of 2–3 mm in diameter might be repaired by roughening with a diamond bur, etching with %37 phosphoric acid, and the use of a universal adhesive with or without the silane application beforehand. The repair of localized defects might be a conservative and suitable treatment to increase the longevity of posterior composite restorations. Favoring repair over replacement could save more time for dentists to treat defective posterior composite restorations and save money for the healthcare system.

Declarations

Ethical approval The Medical Ethics Committee of Süleyman Demirel University reviewed and approved this study under protocol number 2021/127.

Informed consent For this type of study, formal consents were collected.

Conflict of interest The authors declare no competing interests.

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