REVIEW

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Intraoral Repair of Dental Restorations with Resin Composite

Laden Güleç Alagöz[1], Aziz Çalışkan[2]

[1]Department of Restorative Dentistry, Final International University Faculty of Dentistry, Nicosia, North Cyprus
[2]Department of Restorative Dentistry, Near East University Faculty of Dentistry, Nicosia, North Cyprus

Abstract

Dental restorations suffer deterioration and degradation over time due to undesirable conditions; accordingly, their clinical life is reduced. The complete removal of defective dental restoration can lead to progressive cavity enlargement with unnecessary sound tooth tissue removal and weakening of the remaining dental tissue, which can lead to complicated treatment procedures, loss of vitality of the tooth, and result in an economic disadvantage. The repair approach, which provides the advantage of preserving a sound tooth structure by keeping tissue loss to a minimum level, has become an alternative to the replacement process. Today, there is not a clear consensus on selecting the appropriate treatment method from between the repair or replacement procedures. This review aims to provide information about the procedures to be applied when the repair approach is to be carried out, surface treatment methods and some of the results of studies on this subject which were carried out within the last 5 years.

Keywords: Composite resin, dental restoration repair, ceramics, CAD/CAM, surface treatment

INTRODUCTION

One of the most important principles of modern dentistry is minimally invasive interventions. Dentists should be cautious during the removal process in order to prevent unnecessary loss of sound tooth tissue.[1] Although their durability has been increased with improvements developed in recent years, dental restorations suffer deterioration and degradation due to undesirable conditions in the oral environment over time.[2,3] Localized secondary caries, localized defects, and defective restorations are amongst the most commonly encountered clinical observations in dental practice.[3]

For defective restorations, there are 4 options which can be carried out which were clearly defined in 2004 by Setcos et al.[4] In the presence of minor defects such as superficial staining which do not cause clinical disadvantages, only monitoring without treatment can be chosen. Refurbishment is the process done without damage to the tooth surface such as; recontouring the surface, removal of discoloration, removal of overhangs, sealing of small gaps, and pores without adding new restorative material (except bonding or glaze).[5] Repair is the treatment of localized defects that are clinically unsatisfactory by partially removing the defective part and adding new restorative material. Replacement is the process including the complete removal and rebuilding of defective restoration. While removing the restorative material, the portions that might appear to be clinically acceptable can also be removed. This application also can lead to a loss of dental tissues.[5,6]

Renovation of existing restorations is one of the most common clinical applications in dental practice. Studies have shown that almost half of the restorations performed in dental practice are replacements of restorations rather than new restorations. The complete removal of defective dental restoration approach can lead to progressive cavity enlargement with unnecessary sound tooth tissue removal. This can cause an acceleration in the restoration cycle accompanied by complicating the treatment process and even loss of tooth vitality.[3]

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ORCID IDs of the authors: L.G.A. 0000-0002-3440-3102; A.Ç. 0000-0003-1001-5946.

Address for Correspondence: Aziz Çalışkan
E-mail: aziz.caliskan@neu.edu.tr
ORCID ID: orcid.org/0000-0003-1001-5946

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Further disadvantages of replacements of restorations are that they are an expensive and time-consuming method.[7]

Repair of the restoration approach, which provides the advantages of preserving the sound tooth structure by keeping material loss to a minimum level, and reducing microbial adhesion to the damaged areas, is a viable alternative to the replacement process.[8,9]

Advances in adhesive technology, an integral part of the minimally invasive treatment approach, enable intraoral repair of defective indirect and direct restorations using composite resins so as to extend the longevity of the restoration.[3]

Advantages of repair instead of replacement of a restoration can be summarized as follows;[8,10]

- Preservation of dental remnant and reduction of tooth tissue loss

- Reduction of the risk of pulp damage

- No anaesthesia is needed unless the area to be repaired is large

- Reduction of the risk of iatrogenic damage

- Shortened treatment time

- Reduction of the cost of treatment

- Extension of the life cycle of restoration

- Protection against mercury vapours which may harm patients and dentists during the removal of amalgam restoration.

The results of the meta-analysis of Kanzow et al.[11] published in 2018 showed that although the repair process was taught in most schools, repair of partial defective restorations was preferred by only about two thirds of dentists. In Turkey, it was reported that the demographic differences of Turkish practitioners and the differences of the cases might affect the decision for repair or replacement. It was stated in that study that younger dentists preferred repair procedures more, but this difference with the older ones was not significant.[2] It is obvious that the repair approach, which causes less tooth tissue loss, should be preferred more in suitable indications. Additionally, to the best of our knowledge, there is no clear consensus on the best surface treatment method that should be used in the repair treatment protocol. Therefore, this review aims to provide information about the procedures to be applied when the repair approach is to be carried out and to present the surface treatment methods and results of many studies on this subject which were carried out within the previous 5 years.

Surface treatment methods: The prerequisites for repair protocols are applying the ideal surface treatment method for the existing restoration, and selecting an appropriate adhesive and restorative material.[7] Removing the superficial layer to expose a clean and high-energy surface and increasing the bonding area by creating irregularities are the two main purposes of surface treating the pre-existing adhesive restorations.[12] Surface treatment methods in the repair protocol investigated in the literature are; surface grinding with burs,[13] laser irradiation, surface etching with phosphoric acid and hydrofluoric acid and air abrasion with alumina particles as mechanical procedures, silane applications, and the use of adhesives as chemical procedures[7,13] and additionally tribochemical silica coating as both a mechanical and chemical procedure.[13] The purpose of these procedures is to increase the surface energy of the existing restorative material to be repaired and provide better wettability by the adhesive agents. There have been many investigations about the materials and techniques in the literature[9,12-14] but there is no clear consensus on a universal technique that should be used in repair protocols since there is a great variability in composition among different brands of resin composites.[7]

Air abrasion/sandblasting with Al_2O_3: Sandblasting is a surface roughening method based on direct sandblasting of the surface by an intraoral device that cleans the surface, increases the surface area used for bonding, and provides micromechanical retention by applying aluminium oxide particles to the restoration surface with a certain pressure.[15] Resin composite, amalgam, ceramic, or metal materials are abraded from a distance of approximately 10 mm for about 10 seconds by 30 to 50 µm aluminium oxide particles.[7]

Tribochemical silica-coating: Silica-coating or tribochemical surface conditioning provides micromechanical retention with aluminium oxide particles coated with a silicone-dioxide layer. The tribochemical silica-coating process strengthens the adhesion to the surface of silica-free material. This reinforcement is accomplished by bonding the silane coupling agent to the silica-coated layer formed on the substrate material.[7] The basic principle of the tribochemical silica-coating procedure is that mechanical energy causes chemical and physicochemical changes in the substance throughout the application.[16] Thus, the tribochemical coating can be used to increase both mechanical and chemical bonding. The CoJET (3M ESPE, Seefald, Germany) device is used in dentistry for this purpose.[13]

Bur abrasion: This method is based on the simple roughening of the restoration surface with diamond burs that are commercially available with different grit sizes. After the surface is abraded using diamond burs, macro mechanical retention is achieved through holes and undercuts.[17] It is claimed to be advantageous since it is an easy procedure to be applied and does not require additional equipment or chemical substances allowing it to be cost-effective. In one study, the effect of surface roughness and repair bond strength of three different grit sizes (medium, fine, extra-fine) were evaluated and all types of burs with different grit sizes increased the repair bond strength when compared to an untreated control group. Additionally, it was found that the difference among the grit-sizes affected the repair bond strength. Medium-grit-sized diamond bur showed the lowest repair bond strength while fine grit size achieved the highest repair bond strength.[17] Tınaztepe et al.[18] compared the shear bond strength values of three pre-treatment groups; diamond bur grinding, silica coating, and no treatment, for the repair of CAD/CAM resin nanoceramics with composite repair materials. After each surface pre-treatment group, they applied 4 different conditioning methods. The conditioning methods were as follows; Adper scotchbond multipurpose adhesive (3M ESPE, St. Paul, MN, USA), Scotchbond universal (3M ESPE), Ultradent silane (Ultradent, USA) + Adper scotchbond multipurpose adhesive (3M ESPE, St. Paul, MN, USA) and no conditioning. At the end of the study, they concluded that surface treatment followed by diamond bur grinding followed by silane and adhesive application is superior to the silica coating, and no treatment groups.[18]

Surface etching: Surface etching procedures are usually carried out with phosphoric or hydrofluoric acid in restorative dentistry. Etching with 30-40% phosphoric acid is used for both enamel and dentin tissue. Thus, the smear layer is completely removed; micro-porosity is obtained on the surface, and the bonding capacity increases.[19] Although phosphoric acid is effective in enamel and dentin, it has no direct effect on the surface characteristics of composite resins, ceramics, and metals.

Unlike phosphoric acid, hydrofluoric acid dissolves glass particles and exposes the crystalline matrix in ceramic causing increased surface roughness.[7,20] Enhanced wettability and surface energy are also provided by this process leading to increased bond strength. In cases of resin composite, the effect of hydrofluoric acid is highly dependent on the filler particle composition. Phosphoric acid with 37% concentration is not as adequately effective in removing silica as hydrofluoric acid. 4-10% concentration is recommended to obtain better bond strength for hydrofluoric acid.[20]

Laser irradiation: The application of laser irradiation on enamel surface leads to an irregular and rough shape with the effect of micro-explosions. The surface roughness that is realized is different from acid roughening. After the traditional method, a structure with boundaries of prisms is formed, while after laser irradiation different structural shapes with different sizes and depths are formed.[21] Er:Cr:YSGG (erbium, chromium: yttrium, scandium, gallium, garnet), Er:YAG (erbium: yttrium, aluminium, garnet), neodmium: yttrium, aluminium, garnet (Nd:YAG) and CO_2 (carbon dioxide) lasers are the types of lasers generally used for this procedure. It can be concluded from the studies in the literature that the type of laser used and the substrate material to be repaired are the two most important factors determining the efficiency of this surface treatment method.[16]

Silane coupling agent application: Silane coupling agents are important mediators for combining two dissimilar materials.[16] Silane is a primer with two functional groups, the silanol and the organofunctional groups increase the bond strength between organic and inorganic matrices.[7,14,16,22] The silanol group of silane bonds to the silica and/or alumina particles of the surface-treated substrate material[7,14] and the organofunctional group attaches to the methacrylate of the adhesive system.[14]

Adhesive agents: Adhesive systems have become more important with the repair approach. The content and application method of the adhesive system used for repair affects the success of the repair.[23] The adhesive systems can be divided into two: namely "*etch & rinse*" and "*self-etch adhesive*" systems according to their interaction with the dental substrate. *Etch & rinse* systems, which contain separate etching and rinsing, are classified as 3-step or 2-step depending on the combination of primer and adhesive resin separately or in a single bottle respectively.[24] Unlike *etch & rinse* systems, *self-etch* systems do not require separate etching and rinsing steps thanks to the monomers they contain. Thus, less application time and technical sensitivity as well as lower sensitivity in post-operative make these systems more user-friendly.[25] *Self-etch* adhesive systems are classified as "one-step" or "two-step" according to the number of clinical application steps.[24]

Universal systems can be used for bonding to both dental tissues and restoration materials thanks to the special monomers they contain. The most widely used is 10-Methacryloyloxydecyl dihydrogen phosphate (MDP) functional monomer, which apart from mechanical bonding, provides chemical bonding to restoration materials such as zirconia, while providing mechanical bonding as well as forming insoluble calcium salts in dental tissues. The compatibility of universal adhesives with resin-based systems has the advantage that they can be used in the cementation of indirect restorations. It is also stated that it can be used as a primer in zirconia, precious-nonprecious metal alloys, composite resins, and various silica-based ceramics. In this way, universal adhesives make it possible to bond to these surfaces without the need for separate agents.[26] In addition to being able to be used for adhesion of indirect restorations, universal adhesives can also be used to repair these restorations, and surface roughening is recommended by using burs or air-abrasion before adhesive application in order to increase bond strength. Some manufacturers have added silanes to universal adhesives to simplify the bonding protocol of glass-matrix ceramic restorations. Since bonding is adversely affected due to changes in the content added to the silane, a separate silane application before universal adhesive is recommended for optimal adhesion.[27]

The literature was searched electronically via the PubMed database using the keywords "repair, bond strength, composite resin, surface treatment" as MeSH terms. Original research articles published in English between 2015 to February 2020 were deemed eligible for inclusion. The titles and abstracts of all articles available as full text were carefully reviewed to eliminate those articles that were not within the scope of this review. If the focus of the article could not be determined exactly from the title and abstract, the full text of the article was examined. The surface treatment methods, materials and conclusions of the studies selected in accordance with the specified criteria for resin composites and ceramics, and CAD/CAM materials are indicated in Table 1 and Table 2 respectively.[1,9,13,14,20,22,28-50]

CONCLUSION

For composite repair, air abrasion and diamond burs can both be effectively used for surface roughening, however, the advantages such as ease of availability, lower cost, and reduced risk of damage to the patient make surface roughening with diamond burs preferable. After roughening, the debris on the surface should be removed with phosphoric acid and thus the surface energy should be increased. Micro-hybrid composite resins seem beneficial to be used as the repair material.

In the repair of ceramic restorations, after surface roughening with burs, it is recommended to use hydrofluoric acid if the ceramic material contains silica, and to apply tribochemical silica-coating to the surface if the ceramic does not contain silica. In the next step, by applying silane, both surface wettability and adaptation of the adhesive resin to the surface can be increased. The content of the composite resin as a repair material does not make a significant difference.

In the repair procedure, the application of an adhesive resin step seems to have a positive effect on the bond strength. Universal adhesives in adhesive systems stand out with their special functional monomers which can provide chemical bonding to some materials, for their ease of use and also due to the property that they can be applied as a thinner layer than other systems.

MAIN POINTS

- Repair of restorative materials, which are currently the preferred procedures in terms of minimally invasive approaches, should be performed with surface roughening procedures.
- In cases of composite repair, surface treatment with air abrasion or diamond burs can be effective. However, advantages such as ease of availability, lower cost, and reduced risk of damage to the patient make surface roughening with diamond burs preferable.
- In the repair of ceramic materials, the silica content of the material is important for the surface treatment to be preferred.
- Applications of adhesive resin systems have a beneficial effect on the repair of aesthetic restorative materials.

Table 1. Surface treatment methods used and conclusions of the studies on resin composites

Publication	Substrate	Repair Material	Surface Treatments	Adhesive	Silane	Conclusion
Kaneko et al.[28]	SRC, MRC	SRC, MRC	Al_2O_3	TE	+	Al_2O_3 + adhesive + silane application increased tensile repair bond strength of MRC. It showed higher repair ability than SRC.
Gupta et al.[20]	Nanofill RC	Nanofill RC	H_3PO_4, HF	TE	-	HF application was found to provide more effective shear bond strength than H_3PO_4.
Consani et al.[29]	MRC, SRC	MRC	Al_2O_3	TE	+	Higher tensile bond strength values were observed in MRC samples and greater percentage of adhesive failures in SRC samples.
Wendler et al.[1]	Nano-hybrid RC	Nano-hybrid RC	H_3PO_4, Bur abrasion, Al_2O_3, Tribochemical silica coating	UA, TE	-	Application of bonding system plays a key role in achieving reliable repair tensile bond strengths. Importance of surface treatment method plays a secondary role in bond strength.
Ahmadizenouz et al.[30]	Nanofilled-RC	Nanofilled-RC	H_3PO_4, HF, Laser irradiation, Bur abrasion, Al_2O_3	TE	+	All surface treatment methods showed similar and optimal repair bond strengths.
Arami et al.[31]	Giomer	Giomer	Laser irradiation, Bur abrasion, Al_2O_3	SE	-	The highest repair bond strength was observed in air abrasion group followed by laser and bur groups respectively.
Souza et al.[22]	Micro-hybrid RC	Micro-hybrid RC	HF, Al_2O_3	UA	+	Sandblasting with Al_2O_3 followed by application of a silane layer produced high micro-tensile bond strength after aging procedure up to 1 year.
de Jesus Tavares et al.[32]	Nanofill RC	Microhybrid, nanofilled bulk-fill RC	H_3PO_4, Bur abrasion	TE	-	The micro-shear bond strength of the RC repairs varies in accordance with the type of RC utilized, and roughening the surface is needed to increase the bond strength of these materials.
Kiomarsi et al.[33]	Microhybrid RC	Microhybrid RC	H_3PO_4, Laser irradiation, Bur abrasion	TE	+	Bur abrasion was found to be more effective than laser.
Kiomarsi et al.[34]	Microhybrid RC	Microhybrid RC	H_3PO_4, Bur abrasion	TE, UA	+	Surface preparation of aged RC by bur and application of UA can improve the repair bond strength of RC. Application of silane without adhesive was found to be unsuccessful in providing adequate bond strength. UA showed higher bond strength than TE.
Ghavam et al.[35]	Microhybrid nanohybrid RC, Giomer	Microhybrid nanohybrid RC, Giomer	H_3PO_4, Laser irradiation	TE	-	Laser irradiation + etching was found to increase the micro-tensile bond strength in all groups but giomer groups had a reduction in bond strength.
Altinci et al.[36]	Nanohybrid, Hybrid, Nanofill RC	Nanohybrid, Hybrid, Nanofill RC	Bur abrasion, Tribochemical silica coating	UA	+	UA application is a reliable method for composite repair. Sandblasting and silane application slightly increased the repair strength for all substrate types.
Kouros et al.[37]	Nanofilled RC, MBC, SRC	Nanofilled RC, MBC, SRC	H_3PO_4, Bur abrasion, Al_2O_3	SBA, TE	-	The most critical factor in repairing procedure is selecting the repairing material. Silorane was not a good option for repairing an aged RC.
Ayar et al.[38]	Bulk-fill RC, Conventional posterior RC	Bulk-fill RC, Conventional posterior RC	H_3PO_4, HF	TE	-	The combined application of HF acid etching and adhesive application was found to provide the effective shear bond repair strength.

Table 1. Continued

Publication	Substrate	Repair Material	Surface Treatments	Adhesive	Silane	Conclusion
Sismanoglu[13]	Nanofill RC	Self-adhering flowable RC	H_3PO_4, Al_2O_3, Tribochemical silica coating	UA	-	Acid etching followed by universal adhesive application obtained acceptable micro-tensile repair performance with flowable RC.
de Medeiros et al.[14]	Bulkfill RC, conventional RC	Micro-hybrid RC	H_3PO_4, Bur abrasion	TE, UA	+	Similar micro-tensile bond strength values among different adhesion protocols were observed. Comparable bond strength values are presented between repairs of bulk fill composites and conventional composites.
Kanzow et al.[39]	Conventional RC, Amalgam	Conventional RC	Bur abrasion, Al_2O_3, Tribochemical silica coating	TE, UA	-	Amalgam restorations may be repaired using RC, but the shear bond strength was lower than that obtained with RC. Amalgam repair with RC was suggested to be done with silica coating and application of a silane-containing adhesive.
Eren et al.[40]	Nanohybrid RC	Nanohybrid RC, Self-adhering flowable RC	H_3PO_4, Laser irradiation, Bur abrasion, Al_2O_3, Tribochemical silica coating	SE	+	Bur abrasion, silica coating and air abrasion with Al_2O_3 showed reliable shear bond strengths while laser abrasion was not recommended.

RC: resin composite, H_3PO_4: phosphoric acid etching, HF: hydrofluoric acid etching, Al_2O_3: aluminum oxide, MRC: methacrylate-based resin composite, SRC: silorane-based resin composite, SE: self-etch, TE: total-etch, UA: universal adhesive, SBA: silorane-based adhesive, Ni: nickel, Cr: chromium.

Table 2. Surface treatment methods used and conclusions of the studies on ceramic and CAD/CAM materials

Publication	Substrate	Repair Material	Surface Treatments	Adhesive	Silane	Conclusion
Neis et al.[41]	Feldspathic ceramic, leucite-reinforced glass-ceramic, lithium disilicate-reinforced glass ceramic	Nanofilled RC	H_3PO_4, HF, Bur abrasion, Tribochemical silica coating	TE	+	Effective surface treatment method varies depending on the type of ceramic. Suitable matches were: Feldspathic and leucite-reinforced ceramics-bur abrasion, lithium disilicate-reinforced ceramic- HF etching, leucite-reinforced ceramic -tribochemical silica-coating.
Wiegand et al.[42]	Polymer-based CAD/CAM material, MRC	MRC	Bur abrasion, Al_2O_3, Tribochemical silica coating	TE	+	Surface pre-treatment especially tribochemical silica coating was recommended for CAD/CAM polymers. Repair bond strength of CAD/CAM polymers was found to be weaker than RC.
Sadeghi et al.[43]	Feldspatic Porcelain	Micro-hybrid RC	HF,Laser irradiation	SE	+	Pre-treatment with HF acid was found to provide more effective shear bond strength than laser irradiation.
Yoo et al.[44]	Feldspatic porcelain, Ni-Cr metal alloy	Micro-hybrid RC	HF, Bur abrasion, Al_2O_3, Tribochemical silica coating	SE, TE	+	Al_2O_3 blasting application was suggested for repairing a fracture with exposed area of porcelain. Tribochemical silica coating was recommended if the fracture extended to the metal surface.
Duzyol et al.[45]	Lithium disilicate CAD/CAM, feldspar ceramic CAD/CAM, nanoceramic resin CAD/CAM	Nano-hybrid RC	HF, Bur abrasion, Al_2O_3, Tribochemical silica coating	UA	+	Lithium disilicate CAD/CAM materials require an etching procedure for repair. Surface treatments did not increase repair micro-tensile bond strength of feldspar ceramic CAD/CAM material while they reduced the bond strength of the nanoceramic resin group.
Subaşı and Alp.[46]	Aged-non-aged nanoceramic CAD/CAM	Nano-hybrid RC	Al_2O_3, Tribochemical silica coating	UA	-	For aged nanoceramic CAD/CAM restorations, Al_2O_3 blasting is recommended as a surface treatment method.

Table 2. Continued

Publication	Substrate	Repair Material	Surface Treatments	Adhesive	Silane	Conclusion
Tatar and Ural.[47]	Polymer infiltrated ceramic, nanoceramic CAD/CAM	Micro-hybrid RC	HF, Tribochemical silica coating	-	+	Each surface treatment increased shear-bond strength but air-abrasion with silica coating was found to be the best choice.
Ataol and Ergun.[48]	Lithium disilicate glass ceramic CAD/CAM, Yttrium-stabilized zirconium oxide ceramic CAD/CAM, Zirconia-reinforced lithium silicate glass ceramic CAD/ CAM	Nanofilled RC	HF, Laser irradiation, Al_2O_3	UA	+	Only Al_2O_3 blasting and HF etching provided satisfactory repair bond strengths for each CAD/CAM ceramic tested.
Silva et al.[9]	Hybrid ceramic CAD/CAM	Nanofilled RC	HF, Bur abrasion, Al_2O_3, Tribochemical silica coating	UA	+	Grinding with silicon carbide paper followed by the application of a universal adhesive system is the best option for repairing fractures of the hybrid ceramic CAD/CAM material
Arpa et al.[49]	Nanoceramic CAD/CAM block	Nanofilled RC	H_3PO_4, Al_2O_3, Tribochemical silica coating	UA, TE	+	Air-abrasion with Al_2O_3 or tribochemical silica coating followed by UA application is recommended.
Verissimo et al.[50]	Nanoceramic resin CAD/CAM, Hybric ceramic CAD/CAM, Glass ceramic CAD/CAM	Nanofill RC	HF, Bur abrasion, Al_2O_3, Tribochemical silica coating	UA, TE	+	In situ aging procedure reduced the repair shear bond strength of nanoceramic resin and polymer-infiltrated hybrid ceramic CAD/CAM materials. The best repair protocol for each restorative material differed, with bur-roughening+UA for nanoceramic CAD/CAM and acid etching+silanization recommended for hybrid ceramic and glass ceramic CAD/CAM.

RC: resin composite, H_3PO_4: phosphoric acid etching, HF: hydrofluoric acid etching, Al_2O_3: aluminum oxide, MRC: methacrylate-based resin composite, SRC: silorane-based resin composite, SE: self-etch; TE: total-etch, UA: universal adhesive, SBA: silorane-based adhesive, Ni: nickel, Cr: chromium.

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