Evaluation of the Effect of Water on the Flexural and Shear Strength of Silorane and Methacrylate-based Composites; A Review of Long-term Studies

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Abstract

Objective: Due to the importance of the effect of water on the structure of composites, in the present systematic review, the effect of water on the flexural and shear strength of silorane and methacrylate-based composites was investigated.

Method: Research articles published in English and Farsi were searched using the relevant terms in PubMed, Web of Science Core, POPLINE, EMBASE, Scopus, CINAHL, PsycINFO, International Bibliography of Social Science, and DoPHER databases. In the initial search, 2345 records were obtained. At the next stage, 1482 records were deleted due to duplication, and all articles that did not meet the inclusion criteria or were inappropriate due to indirect relevance to the topic (739 records) were removed. Then, the full-text of 124 articles was reviewed. Finally, 7 studies that met all inclusion criteria were selected for this review study.

Results: Based on the inclusion criteria, 7 studies were selected and examined in more detail. In 3 papers, only one composite (methacrylate-based) was investigated. In all but one of these studies, following water uptake over time, a reduction in the shear or flexural strength of the composites was reported. In four other articles, the effect of water on shear or flexural strength in both types of silorane and methacrylate-based composites was investigated. Examination of the results of these papers showed that although they indicated a reduction in mechanical forces for both composites, the rate of reduction was higher for methacrylate-based composites compared to silorane-based composites.

Conclusion: Although there was a decrease in shear or flexural strength of both types of composites, silorane-based composites demonstrated a lower rate of reduction in these forces compared to methacrylate-based composites. Therefore, it can be concluded that following water absorption, the mechanical properties of silorane-base composites change less than methacrylate-based composites.

Keywords: Flexural Strength, Shear Strength, Composite, Silorane, Methacrylate.

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INTRODUCTION

Resin composite restorative materials were first introduced to dentistry in the mid-1960s (1), and are now the most common tooth-colored restorative materials used for cosmetic purposes (2). These common composites usually consist of a methacrylate-based resin matrix (25-25% volume) and fillers made of glass or ceramic (70-75% volume) and a matrix-filler adhesive (3). Since the development of these composites, several changes have been made to reduce their limitations such as mechanical defects, polymerization shrinkage, and degradation in the oral environment (4). These disadvantages of resin-based restorative materials make the tooth susceptible to post-restoration allergies, bacterial infiltration into the created space, and secondary caries (5). To eliminate the most important defect of ordinary composite resins, which is their polymerization shrinkage, Silorane-based composite resins were introduced to the market (6). Silorane is obtained from the reaction of oxirane and siloxane molecules (7). Polymerization shrinkage and loss of marginal integrity in restorations using methacrylate-based composites are related to the free radical addition polymerization reaction and can lead to adverse effects on bonding to the tooth structure with marginal staining, microleakage, and repeated decay. However, silorane-based composite is polymerized with cationic ring-opening polymerization due to the presence of oxirane monomer and therefore can be useful to overcome the shrinkage caused by methacrylate-based composites (8). On the other hand, silorane-based composite resins have more hydrophobicity due to siloxane, which consequently leads to less bacterial adhesion compared to methacrylate-based resins (6, 7). Polymerization shrinkage in silorane-based composites is reduced to less than 1%, while in methacrylate-based composites the shrinkage rate is 1.81 to 2.19% (10). The stability of composites in the clinical environment depends on their durability in an aqueous medium. Evidence suggests that silorane-based composites are stable and insoluble in simulated aqueous solutions of bio-liquids containing epoxide hydrolase, porcine liver esterase, or dilute hydrochloric acid (11). Degradation of the composite in the oral environment is the result of the infiltration of water molecules into the polymer chains, the release of residual monomers, and the weakening of secondary bonds, as well as the destruction of the filler-matrix interface (12). Therefore, due to the importance of the effect of water on the structure of composites, in the present systematic review, the effect of water on the flexural and shear strength of silorane-based and methacrylate-based composites was investigated.

Materials and Methods

Search strategy and selection of articles

Related research articles published in English and Persian were found by searching the relevant terms in the databases of PubMed, Web of Science Core, POPLINE, EMBASE, Scopus, CINAHL, PsycINFO, International Bibliography of Social Science, and DoPHER. Initially, one of the researchers generated the terms needed for the search, and then the terms were reviewed by all the authors. Search terms that were used for selecting the articles included "water", "composite", "silorane-based", "methacrylate-based", "flexural strength" and "shear strength". The combination of these words with the operators "and" and "or" was also examined. The Persian equivalent of all these words was also searched. There was no time limit for searching, and all articles related to the topic were reviewed.

Inclusion and exclusion criteria

Inclusion criteria included all articles in which one of the following was considered:

Effect of water on flexural strength, Effect of water on shear strength, Effect of water on silorane-based composites, and Effect of water on methacrylate-based composites. Exclusion criteria included articles in which the effect of any factor other than water on flexural or shear strength was investigated, articles in which composites other than silorane-based and methacrylate-based were studied, and articles in which the full text was not available. Also, data related to review studies and non-original articles were not extracted.

Screening and extraction of data

Two trained authors performed search strategies, and then they separately screened the titles and abstracts of the articles and selected the relevant studies based on their relevance to the objectives of this review study, the inclusion and exclusion criteria, and their quality. Abstracts of all articles were reviewed, and in cases where the article could not be deleted based on the title or abstract, the full text of the article was retrieved and evaluated. In the event of a discrepancy, the two researchers thoroughly reviewed the article and reached a consensus, citing reasons for including or deleting the article.

In the initial search, 2345 records were obtained. At this stage, 1482 records were deleted due to duplication, and all articles that did not meet the inclusion criteria or were inappropriate due to irrelevancy (739 records) were removed. Then, the full-text of 124 articles was reviewed. The complete review led to the final selection of 7 studies that met all inclusion criteria. The method of presenting the topics, including analysis and interpretation, determination of the purpose of the study, and collection of the findings, was based on the preferred reporting items for systematic reviews and meta-analyses (PRISMA) (Figure 1).

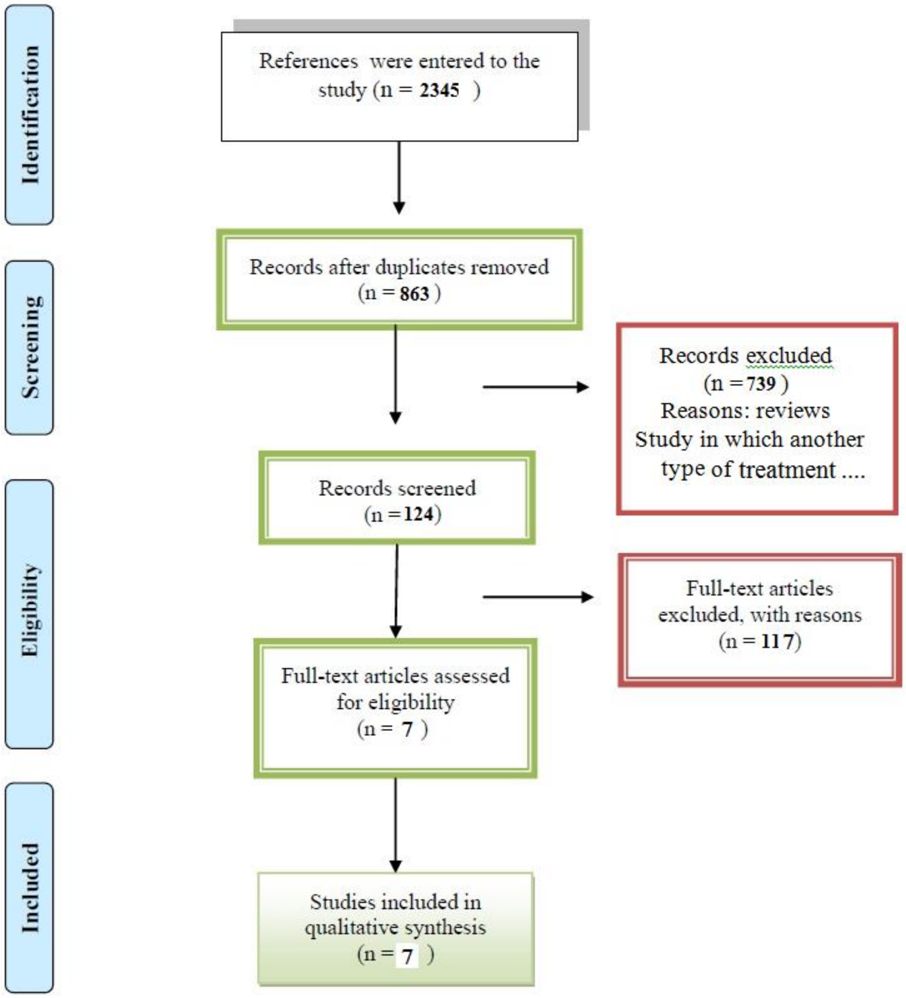

Figure 1: Diagram of the selection of reviewed articles

Results and Discussion

Based on the inclusion criteria, 7 studies were selected and further reviewed, the results of which are shown in Table 1. Based on the data extracted from this table, only one type of composite was studied in 3 articles (42.85%) and both types of the composites were studied in 4 articles (57.14%). Also, in 42.85% of the articles (3 articles), shear strength and in 57.14% of them, flexural strength was studied. The maximum immersion time was 2 years and the minimum study duration was 5 minutes.

Table 1: Summary of reviewed articles

Author(s) and year	Objective	Type of composite	Type of strength investigated	Details of the experiment	Results
Jacobsen and Siiderholm, 1995 (13)	Evaluation of the effects of different solvents (water or acetone) on the bond strength of dentin primers based on hydroxyethyl methacrylate (HEMA)	Resin combination consisting of HEMA (37.1%), Bis-GMA (61.9%), camphorquinone (0.3%), and dimethyl aminoethyl methacrylate (0.675%)	Shear bond strength was assessed using the universal testing machine at a velocity of 0.5 mm/minute	Immersion in water and acetone at 37 ° C for 30 days	Significantly higher shear strength was observed in both acetone groups (22.2 and 21.5 MPa for 30 and 120 seconds, respectively) compared to the two water groups (7 and 16.2 MPa for 30 and 120 seconds, respectively) Improved bond strength was observed in water-

					based primers as opposed to acetone-based primers by increasing priming time
Ferracane et al, 1998 (14)	Investigation of the long-term effect of aging in water on the physical properties of experimental composites with systematically controlled differences in degree of conversion (DC), filler volume fraction (Vf) and percentage of fillers treated with silane	50% Bis-GMA and 50% TEGDMA	Evaluation of fracture toughness (KIc), flexural strength (FS), elastic coefficient (E) and stiffness (KHN) Using universal testing machine, at a speed of 0.254 mm/minute	Immersion in water at 37 ° C for 1 day, 6 months, 1 year, and 2 years	20 to 30% reduction of KIc after 6 months for all composites Reduction FS was reported in multiple composites after 6 months and in 2 years No reduction was observed in E for most composites reduction of stiffness was observed for most composites after 6 months but many of them return to their original level in 2 years Prolonged aging in water reduced KIc, regardless of the composition, but had little effect on other properties, indicating limited degradation of composites in water. In general, with the exception of composites A, B, C, and E, there was no long-term reduction in flexural strength due to aging in water for these composites.
El-Damanhoury et al, 2009 (15)	Evaluation of the effect of hydrolytic stability on the flexural properties of silorane-based composites	Filtek Silorane (SL) Premise (PR) Aelite LS (AL) Filtek Z250 (Z)	Water absorption, solubility, flexural strength Using a three-point bending device at a speed of 1 mm per minute	Immersion in water at a temperature of 37 ° C At intervals of 5 minutes, 1 hour, 24 hours, 1 week and 26 weeks	Less water absorption in AL than Z and negative solubility values for SL Decreased flexural strength in all materials except Silorane following 26-week immersion in water There is a strong inverse relationship between water uptake and FS for all materials except SIL Conclusion: Lack of negative effect on flexural properties due to hydrolytic properties of silorane-based composite compared to methacrylate-based composites
Zhang et al, 2013 (16)	Evaluation of the effects of water aging for 6 months on the bond strength of antibiofilm and dentin monomers of the new antibacterial dimethylaminododecyl methacrylate (DMADDM)	Scotchbond Multi-Purpose (SBMP) Primer and control adhesive (SBMP + 5% DMADDM ،SBMP + 5% DMADDM + 0.1% Nag ،SBMP + 5% DMADDM + 0.1% NAg with 20% NACP)	Shear bond strength was assessed using the universal testing machine at a velocity of 0.5 mm/minute	Immersion in water at 37 ° C for 1 day and 6 months	35% reduction in dentin bond strength at 6 months of immersion in water for control SBMP
El-Shamy and Ragab, 2014 (17)	Determination of the shear bond strength (SBS) of two composites bonded to enamel and dentin immediately (after one day) and after one month of water storage	Filtek-Z250 (Z250) Filtek-LS (LS)	Shear bond strength was assessed using the Universal Testing Machine	Immersion in water at a temperature of 37 ° C At intervals of 1, 2, 5, 7, 30 and 60 days (n = 10)	SBS in MPa for the enamel, immediately after immersion, was 18.4 (1.9) and 9.4 (1.3) for Z250 and LS, respectively; and after one month, this rate was 18.3 (1.6) and 9.2 (1/1) for Z250 and LS, respectively.

					Overall, the average SBS for the Z250 was higher than the LS. Substrate type and storage time had no significant effect on SBS.
Gushiken et al, 2014 (12)	Determining the correlation between biaxial flexural strength and weight gain due to water absorption in two commercial restorative composites, namely methacrylate-based and silorane-based	Filtek Z250 Filtek Silorane	biaxial flexural strength was assessed using the piston-on-three-ball instrument	Immersion in water at a temperature of 37 ° C At intervals of 1, 2, 5, 7, 30 and 60 days (n = 10)	Similar mass increase was observed for both composites and no changes were reported in days one to seven Gradual reduction of biaxial flexural strength in Filtek Z250 with increasing immersion time, and sudden decrease of this strength in Filtek Silorane between 30 to 60 days There was a statistically significant correlation between biaxial flexural strength and mass increase for both composites Conclusion: There was a linear relationship between strength and water absorption
Panahandeh et al, 2017 (11)	Evaluation of the effect of water storage on the flexural strength of low-shrinkage composites	Filtek Z250 Filtek P90 GC Kalore	Flexural strength was assessed using the piston-on-three-ball instrument	Immersion in water at a temperature of 37 ° C Investigation of variables immediately after processing, and at intervals at 24 hours, 1 week, 1 month, 6 months and 1 year after storage in wet and dry conditions.	There was a significant interaction among time, composite type, and storage conditions A significant reduction was reported in FS of all composites after 6 months and 1 year of storage in distilled water compared to dry conditions Conclusion: Filtek P90 showed the highest FS and GC Kalore had the lowest FS, after 1 year of storage in distilled water. The high strength of the Filtek Z250 was reduced significantly in one year, and its final value was lower compared to Filtek P90.

The results of the present systematic review showed that in three articles, only one type of composite (methacrylate-based) was investigated. In two of the reviewed studies, the effect of water on shear strength was studied and in one case, the effect of water on flexural strength was studied. In all but one of these studies, a reduction was reported in the shear or flexural strength of the composite following immersion in water. In 4 of the reviewed studies, the effect of water on shear or flexural strength was investigated in both types of silorane and methacrylate-based composites. Among these papers, the results of the study by El-Damanhoury et al. showed that there was a decrease in flexural strength of all methacrylate-based composites, while this decrease was not reported for silorane-based composites, and no negative effect was observed on the mechanical properties of this type of composite. While in the other 3 studies there was a decrease in the shear or flexural strength of both types of composites studied; however, distinct rates of reduction were reported for different composites. Based on the studies by Gushiken et al. and Panahandeh et al., although a decrease in the mechanical forces of both composites was reported, the reduction rate of methacrylate-based composites was higher than silorane-based composites. On the other hand, according to the study by El-Shamy and Ragab, the average shear strength of methacrylate-based composites was generally higher.

Preservation of the physical and mechanical properties of the composite is essential to ensure the long-term clinical success of the restoration (18). On the other hand, the long-term performance of any resin-based restoration material is greatly influenced by its reaction to the moist environment of the mouth (15). The reduction of mechanical properties of composites in water is mainly related to the adsorption of water by the polymers. It is hypothesized that water absorption softens the resin component of polymers by swelling the network and reducing the frictional forces between the polymer chains (14). Due to the hydrophobicity of silorane molecules, silorane-based resins are expected to show superior properties in aqueous media compared to methacrylate-based composites. On the other hand, it has been shown that methacrylate-based composites decompose as a result of water storage and lose their filler particles (11). Also, according to the results of the present systematic review, although there was a decrease in shear or flexural strength of both types of composites, silorane-based composites demonstrated a lower rate of reduction in these values, compared to methacrylate-based composites.

Soaking a composite in water leads to both rapid leaching of unbound molecules and slow absorption of water. Most water molecules occupy the free volume between the chains and the crosslinks as well as the micropores (14). Due to the polar properties of the resin molecules, water absorption occurs slowly. Reduction of the mechanical properties of the polymer matrix due to the absorption of water and the flow of the long-chain polymer can lead to the destruction of the matrix/filler bond, which is called the "plasticization" process (11). In the study by Ferracane et al., it was reported that when the composite network was saturated with water and subsequently softened, the structure of the composite stabilized and there was no further reduction in properties during the study period. This limited reduction in mechanical properties indicates that further degradation, such as filler/matrix surface hydrolysis or polymer matrix depression, may not be present or may not continue significantly when the composite is saturated and moist. This slow absorption of water to saturation is related to the fact that the refractive index and hardness of all composites decreased in 6 months and there was no further reduction after that (14). Panahandeh et al. showed that composites containing triethylene glycol dimethacrylate (TEGDMA), such as Filtek Z250, are further degraded in wet environments. Due to the increased flexibility of TEGDMA, the cross-linking density decreases. Also, in the 4-weeks period of this study, silorane-based composite Filtek P90 retained its integrity and mechanical properties better than methacrylate-based composites (11).

Also, in the study by Gushiken et al., the two composites tested showed different properties. The methacrylate-based composite, Filtek Z250, showed a gradual decrease in strength, while for the silorane-based composite, a statistically significant decrease in strength was observed only between 30 and 60 days. The results of this study showed a statistically significant correlation between the increase in mass due to water absorption and the decrease in strength of the two restorative composites, with different organic and inorganic compounds. This linear relationship was shown to be material dependent and stronger for dimethacrylate-based materials (Filtek Z250) compared to silorane-based composites (Filtek Silorane) (12). However, El-Damanhoury et al. reported that water uptake values for silorane-based composites (SIL) were lower compared to conventional methacrylate-based (Z) composites and low-shrinkage methacrylate-based (PR) composites (15) (15). Considering the fact that silorane is more hydrophobic than any methacrylate-based composite, it is predicted that it has less water absorption than other materials; However, in this study, silorane showed a higher rate of water absorption in comparison with AL. As a result, although silorane is a hydrophobic material, the nature of the polymerization reactions and the cationic end may cause more water absorption compared to methacrylate composites, but unlike methacrylate composites which lose their mechanical properties, this absorption induces no detrimental effects on the flexural properties of these composites (15). El-Shamy and Ragab also reported that Filtek-Z250 adheres better to enamel and dentin, in comparison with Filtek-LS, and the low shrinkage effect of Filtek-LS does not improve its shear bond strength to enamel or dentin (17). However, it should be noted that solvents and esterases in the oral cavity may have a more destructive and stable effect than water on the mechanical properties of composites (14).

Conclusion

The aim of this study was to investigate the effect of water on the flexural and shear strength of silorane and methacrylate-based composites. In general, the results showed that although there was a decrease in shear or flexural strength of both types of composites after immersion in water, silorane-based composites showed a lower reduction in these forces over time, in comparison with methacrylate-based composites. Therefore, it can be concluded that following water absorption, the mechanical properties of silorane-based composites are less altered than methacrylate-based composites.

Limitations of the Study

One of the main limitations of this review was the small number of studies that investigated the effect of water on the shear and flexural strength of silorane and methacrylate-based composites.

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