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The Silorane-based Resin Composites: A Review

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Clinical Relevance

Silorane-based resin composites (SBRC) have been found to exhibit a decrease in polymerization shrinkage stresses and properties at least as good as that associated with methacrylate-based resin composites. This review summarizes the current literature on the SBRC to help the dental practitioner trying to make evidence-based decisions.

SUMMARY

This article aims to review the research done on the silorane-based resin composites (SBRC) regarding polymerization shrinkage and contraction stresses and their ability to improve the shortcomings of the methacrylate-based resin composites (MRBC). Special attention is given to their physical and mechanical properties, bond strength, marginal adaptation, and cusp deflection. The clinical significance of this material is critically appraised with a focus on the ability of SBRC to strengthen the tooth structure as a direct restorative material. A search of English peer-reviewed dental literature (2003-2015) from PubMed and MEDLINE databases was conducted with the terms "low shrinkage" and "silorane composites." The list was screened, and 70 articles that were relevant to the objectives of this work were included.

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INTRODUCTION

Current resin-based composite (RBC) restorations have become an essential part of everyday dental practice. This is due to the increase in patients' demand for esthetic restorations, along with greater emphasis on the preservation of sound tooth structure and the improvement of adhesive dentistry as a result of bonding mechanisms that can reinforce the remaining tooth structure. Resin-based composites have also been proven to have enhanced mechanical properties and abrasion resistance that have continued to improve since their introduction as dental restorations. This allows expanded use for posterior teeth with good longevity.

Polymerization shrinkage and the associated stress transmitted to the adhesive bond and the remaining tooth structure are the most important and clinically relevant problems associated with the methacrylate-based resin composites (MBRC).[1] Depending on the bond strength of the interface between the RBC and tooth structure, these shrinkage stresses can lead to clinical consequences, such as marginal gap formation and leakage, debonding at the restoration/tooth interface, cusp deflection, and microfractures of the tooth structure.[2,3] Consequently, several clinical strategies have been developed in order to overcome the problems associated with polymerization shrinkage, including the placement of low-modulus liners or bases and incremental placement of the RBC, in addition to modifications in light application, which is the so-called "soft-start" method.[4-6] However, conclusive data on the efficacy of these techniques and their relationship to increased technique sensitivity.

Consequently, research has focused on advances in material formulation that may improve the shortcomings of the MBRC, including reducing monomer percentage through the addition of inorganic fillers, utilizing multiple-sized filler particles, and utilizing prepolymerized filler particles.[7] However, changes in filler configuration offered only limited reduction in polymerization shrinkage.[8] Furthermore, researchers have begun to examine the ways in which the matrix and monomer chemistry can be modified. A novel monomer technology with unique polymerization characteristics to minimize polymerization shrinkage has been developed, the silorane-based resin composites (SBRC). The silorane matrix is formed by the cationic ring-opening polymerization of the silorane monomer. This is in contrast to the linear chain reaction of methacrylates, which is cross-linked via radicals. This change in composite chemistry and polymerization reaction resulted in a significant reduction in the polymerization shrinkage to a level less than 1.0% of the total volumetric shrinkage.[9] This is in comparison to the 2.6% to 7.1% associated with MBRC.[10] The reduction in polymerization shrinkage of SBRC often results in a significant decrease in polymerization shrinkage stresses,[11,12] lower microleakage scores,[13] improved marginal adaptation,[14] and reduced cusp deflection.[15] These benefits occur while maintaining comparable mechanical properties to those of MBRC.[16]

The objective of the present work is to review both experimental and clinical studies that were done on the SBRC in terms of polymerization shrinkage and contraction stresses, physical and mechanical properties, bond strength, cusp deflection, and fracture strength of teeth restored with SBRC. A search of English peer-reviewed dental literature (2003-2015) from PubMed and MEDLINE databases was conducted with the terms "low shrinkage composites" and "silorane composites." The list was screened, and 70 articles that were relevant to the objectives of this work were included.

POLYMERIZATION SHRINKAGE AND CONTRACTION STRESSES

Modern MBRC exhibit excellent esthetics and physical properties. However, their major drawbacks are polymerization shrinkage and its related polymerization stress. Most MBRC undergo contraction, which ranges from 2.6% to 7.1% as a result of the polymerization reaction.[10]

The use of alternative chemistries has been at the forefront of research and development for dental RBC for many years. The silorane molecule in SBRC presents a siloxane core with four oxirane (oxygen-containing) rings attached. Thus, these rings are opened during polymerization to bond to other monomers. The hydrophobic properties of the material are attributed to the siloxane molecules. Therefore, exogenous discoloration and water absorption are minimized. The oxirane rings are responsible for the physical properties and the reduced polymerization shrinkage. Furthermore, the opening of the oxirane ring causes a volumetric expansion that may compensate, to some degree, for the shrinkage resulting from molecular bonding.[17]

Weinmann and others[9] found that the volumetric shrinkage of SBRC is less than 1% of the volume. This finding concurs with those of other studies,[11,12,18] which found that the SBRC exhibited significantly lower polymerization shrinkage and polymerization stress than did the MBRC. However, polymerization stress is not determined by volumetric shrinkage alone but also by a number of other factors, including properties that are intrinsic to the material, such as the modulus of elasticity, the degree of cure, the coefficient of thermal expansion, and the silanization characteristics at the resin-filler interface.[19] This is in addition to clinical factors, such as the rate of cure and polymerization kinetics, the cavity configuration factor, and the compliance of the remaining tooth structure. In this respect, recent studies have evaluated these new materials in terms of polymerization stress, as well as other aspects involved in its development, in addition to shrinkage.

Boaro and others[17] compared a SBRC to a MBRC in terms of polymerization stress, volumetric shrinkage, elastic modulus, and reaction rate. The SBRC had high polymerization stress value (4.3 MPa) in spite of the low volumetric shrinkage (1.4 %). Thus, the authors[17] speculated that the high initial flexural modulus shown by the SBRC may explain its high polymerization stress value, in spite of the low volumetric shrinkage. This observation was also found in a study by Marchesi and others,[20] who reported that Filtek Silorane LS resulted in higher stresses (1.3 MPa) when compared to Tetric EvoCeram (0.95 MPa), which is a MBRC with lower elastic modulus. In addition, a low degree of conversion was observed in this study for the Filtek Silorane LS. This result has been hypothesized in other studies to result in slower polymerization that allows enough time for stress relaxation. However, Marcchesi and others[20] claimed that the cationic polymerization in the SBRC continues for extended periods of time at a slower rate. This may also lead to increased stresses over time.

Other studies[11,21] reported that the polymerization kinetics of SBRC are comparable to those of the MBRC. Moreover, Yamasaki and others[21] found that despite the different reaction mechanisms, P90 (SBRC) showed similar behavior to the MBRC regarding the kinetics of polymerization. However, it had lower polymerization stresses (2.6 MPa); this was explained by the ring-opening polymerization mechanism of silorane. In view of the above, the complexity of the interactions between factors that determine polymerization shrinkage and stress development should be highlighted more by future research. This is in a bid to quantify the polymerization shrinkage associated with the SBRC.

BOND STRENGTH

Most of the shrinkage stresses generated during polymerization of MBRC are generated as a result of the entire composite material being strained during the polymerization reaction through its adherence to the cavity walls. Contraction stresses will appear as tensile forces at the adhesive-tooth interface because the composite will attempt to shrink toward the bonded surface. Nevertheless, it will be constrained by the rest of the composite mass, which is also bonded to the opposite side. To relieve those stresses, the polymer matrix will attempt to flow to any free surface. In addition, localized interfacial failures or weaker bonded areas will provide sites for stress relief. If the local contraction stresses exceed the local bond strength, stress-relieving gaps might be formed.[1]

Therefore, for successful composite-dentin bonding and less debonding, either the bond strength between the cavity wall and dental adhesive must be higher than the shrinkage stress or the composite should exhibit low shrinkage stresses.[22] A study by Cho and others,[22] using the acoustic emission analysis technique to detect the debonding at the tooth-composite interface during composite curing, found that composites with lower shrinkage and slower polymerization reactions demonstrated fewer interfacial debonds during cavity restoration.

The SBRC comes with a two-step self-etch adhesive known as silorane system adhesive (3M ESPE, Seefeld, Germany). Consequently, it still boasts features of conventional methacrylate adhesives, especially with regard to its bonding mechanism to tooth tissue. However, it should be compatible with the highly hydrophobic silorane matrix. Transmission electron microscopy analysis of the interface complex of a SBRC bonded to enamel and dentin found that the two-step self-etch adhesive effectively bridged the hydrophilic tooth substrate with the hydrophobic silorane composite.[23] Moreover, the silorane adhesive system formed a hybrid layer of comparable thickness with that of methacrylate-based adhesives in scanning electron microscopy (SEM) analysis.[24]

Several studies concluded that there was no significant difference in shear bond strength to dentin between the SBRC and MBRC[25.26] or in the microtensile bond strength.[27-29] On the contrary, Khosla and others[30] found that the total etch system that is used with MBRC has a significantly higher shear bond strength value (13.4 MPa) than does the self-etch system of the SBRC (9.5 MPa).

Fernandes and others[31] found that MBRC yielded the highest bond strength values (26.3 MPa), regardless of the type of adhesive system used, when compared to the SBRC. Furthermore, Almeida and others[32] found that the MBRC showed superior performance regardless of the placement technique. Duarte and others[33] also found that SBRC shows compatibility only with its dedicated adhesive. Pucci and others[34] measured the microtensile bond strength of a SBRC to dentin after artificial aging of the specimens. They found that the surface treatment of dentin (laser or phosphoric acid) and the use of primer agitation improved the bond strength of the silorane adhesive system.

Furthermore, increasing the cavity configuration factor (C-factor) has been associated with progressive decrease in bond strength.[35] Isaac and others[36] found that a MBRC with total etch adhesive obtained higher bond strength (32.4 MPa) than did the SBRC (24.4 MPa) on a flat surface. On the other hand, no significant difference was found between both restorative materials in a Class I cavity (high C-factor) model. It was suggested that the adhesive system of the SBRC, although leading to lower bond strength mean values, is not subjected to the same stress at the bond interface since there is a lower degree of volumetric shrinkage of the composite.[36] Furthermore, El-Sahn and others[37] found that, unlike MBRC, the increase in the C-factor did not negatively affect the bond strength of the SBRC. Van Ende and others[38] found that the silorane two-step self-etch adhesive performed significantly better than the one-step self-etch adhesive in high–C-factor cavities regardless of the composite used.

It can be concluded that the reduction in the polymerization shrinkage associated with the SBRC is also associated with the improvement in bond strength values in cavities with high C-factor. Hence, this may be considered to be more clinically relevant than bonding to a flat surface.

CUSP DEFLECTION

Cusp deflection of teeth restored with the MBRC was found to be highly correlated with polymerization shrinkage.[39] The decrease in polymerization shrinkage associated with the SBRC has been associated with a decrease in cusp deflection. Palin and others[40] found a significant reduction in cusp deflection and microleakage of maxillary premolars restored with two experimental SBRC (2.5 and 6.0 μm) when compared with two conventional MBRC (16.5 and 20.6 μm). Moreover, their results correspond with those obtained by Bouillaguet and others,[41] who showed that a SBRC induced the lowest tooth deformation (3.5 μm) when tested against four MBRC. On the other hand, Tantbirojn and others[42] found that the low-shrinkage composites did not necessarily reduce coronal deformation.

Several studies[13,14,43-46] found that the SBRC was more efficient for cavity sealing than was the MBRC. In a study by Papadogiannis and others,[14] the SBRC showed better behavior than the MBRC in setting shrinkage and marginal adaptation with dentin. Santos and others[47] found that while the SBRC and MBRC had no significant difference in immediate push-out bond strength (8.0 and 9.8 MPa, respectively) and in marginal adaptation, the SBRC presented an increase in the mean push-out bond strength after six months of water storage (12.5 MPa). However, it should be mentioned that there was a high incidence of adhesive failures in the silorane restorations; thus, this may indicate a weak adhesive interface of the silorane adhesive system. This finding of failure pattern was observed in other studies as well.[27,38] In addition, a micro–Raman spectroscopy study by Santini and Miletic[24] demonstrated an intermediate zone of approximately 1 μm between the silorane primer and the bond. According to the authors,[24] this may be the weakest link in the failure mechanism of silorane restorations, and it requires further investigation.

MECHANICAL AND PHYSICAL PROPERTIES

The physical and the mechanical properties of the SBRC require further investigation. Some studies[16,48,49] showed inferior mechanical performance compared to the MBRC, while others[50-52] showed mixed or comparable mechanical properties. Generally, the physical and mechanical properties are directly influenced by the degree of conversion that is obtained during adequate polymerization.

The degree of conversion for the SBRC varies in the literature from 50% to 80%,[13,14,40,49] which may be explained by the distinct power densities and curing times selected in these studies. Boaro and others[48] reported a very low degree of conversion for a SBRC (30%), which explained its lower mechanical performance (flexural modulus, 9.1 GPa, and flexural strength, 111.0 MPa) compared to that of a nanohybrid MBRC.

Similarly, Ilie and Hickel[16] found that the macroscopically measured strength of the SBRC was comparable to that of most of the analyzed MBRC but was statistically lower than that of the nanohybrid MBRC. In a study by Lien and Vandewalle,[50] the SBRC (Filtek LS) showed an overall mixed mechanical performance. It had relatively high flexural strength/modulus (120 MPa/9 GPa) and fracture toughness (0.7 MPa $m^{1/2}$) but a relatively lower compressive strength (250 MPa) and microhardness (43 Kg/mm^2). The authors[50] related the lower microhardness of the SBRC to the reduced filler-volumetric fraction (55%). This is also in agreement with the work of Torres and others,[49] who found a low Knoop Hardness Number (41.7 Kg/mm^2) for a SBRC compared to those found in the literature for MBRC (60 Kg/mm^2).

On the other hand, other studies[51,52] showed that the SBRC was comparable to that of the regular micro-hybrid MBRC in terms of mechanical properties. Moreover, Zakir and others[53] found that the mechanical properties (fracture toughness and compressive strength) of Filtek Silorane increased considerably from day 1 to day 90. This was after incorporating 5% and 10% nano-hydroxyapatite crystals into the composite resin. The increase in the fracture toughness was attributed to the possible interruptions in the crack propagation by the hydroxyapatite crystals.

Surface roughness, water sorption, and solubility are essential to predicting the behavior of RBC restorations. The literature reports that the SBRC presents lower sorption, solubility values, and diffusion coefficient compared with MBRC; furthermore, SEM analysis showed no surface changes after one year of water storage.[48,54-56] The reduction in water sorption and solubility was attributed to the hydrophobic backbone of the silorane molecule. Siloranes were also found to be stable and insoluble in biological fluid simulants using aqueous solutions containing either epoxy hydrolase, porcine liver esterase, or dilute hydrochloric acid.[57] Moreover, Yesilyurt and others[58] found that the hardness and flexural strength of Filtek Silorane were not significantly affected by storage in food-simulating liquids compared to MBRC.

Several studies[59-63] have reported better color stability for SBRC compared to MBRC. However, Pires-de-Souza and others[64] found that the SBRC (P90) underwent greater alteration in color and higher surface degradation after accelerated artificial aging compared to MBRC.

FRACTURE RESISTANCE OF TEETH RESTORED WITH SBRC

The use of adhesive restorations has been recommended for reinforcing the remaining tooth structure after cavity preparation.[65] The SBRC has been suggested as an alternative to the MBRC to overcome the polymerization shrinkage problem and its consequences.

The number of studies that assessed the fracture resistance of teeth restored with SBRC is limited. However, the SBRC (Filtek P90) was not able to restore the fracture resistance of teeth with MOD cavities compared to a MBRC (Filtek P60).[66] Akbarian and others[67] found that there was no significant difference between SBRC and MBRC in MOD cavities. Similarly, Taha and others[68] found that SBRC restorations had no superior strengthening effect on endodontically treated maxillary premolar teeth with MOD preparations compared to MBRC, although both restorative materials modestly increased the fracture strength. On the other hand, Shafiei and others[69] reported that the SBRC revealed significantly higher strength for restored endodontically treated premolar teeth compared to that of MBRC, regardless of fiber insertion.

CLINICAL STUDIES

Silorane-based resin composites have been found by experimental studies[12,14,43,44,46,51,52] to exhibit properties that are at least as good as those of MBRC. However, these findings should be validated by clinical studies (Table 1).

In a randomized clinical trial, Schmidt and others[70] found better performance for MBRC (Ceram X) compared to Filtek Silorane. This is in terms of the marginal adaptation (occlusal and proximal) of 158 Class II restorations after one-year follow-up. They concluded that the reduction in polymerization shrinkage demonstrated in the laboratory was not clinically significant. The external validity of their study may be affected by the fact that it was conducted at a dental school by one dentist; therefore, the results of the study cannot by directly related to everyday dental practice.[70]

To overcome the subjectivity of the results obtained by one operator, Burke and others[71] conducted a practice-based cohort study to evaluate the performance of Filtek Silorane restorations. The two-year assessment of 100 Filtek Silorane restorations (30 Class I and 70 Class II) indicated satisfactory clinical performance with no complaints of postoperative sensitivity; this could be attributed to lower values of cusp deflection as a result of reduced polymerization stresses.

In a double-blind, randomized clinical trial, Goncalves and others[72] found that both SBRC and MBRC performed similarly. Both showed marginal discoloration and changes in surface texture at 18 months when compared with baseline. However, P60 (MBRC) performed better than Filtek LS (SBRC) in the marginal integrity criterion. This finding was in agreement with that of a randomized clinical trial[73] that reported no significant difference in the clinical performance of Filtek Silorane and Ceram X in Class I posterior restorations after two years.

In a three-year prospective randomized clinical study, Mahmoud and others[74] found insignificant differences in the overall clinical effectiveness of SBRC and MBRC in Class II restorations. Filtek Silorane showed excellent clinical performance that was comparable to that of Ceram X Mono when it was used to restore noncarious cervical lesions over a three-year period.[75] The findings from the previous studies were confirmed by a five-year randomized clinical trial,[76] in which the authors found no statistically significant differences between Filtek Silorane and Ceram X in terms of proximal contacts, anatomic form, fractures, or discoloration.

Yazici and others[77] found that P60 showed the best marginal adaptation compared with Filtek Supreme and Filtek Silorane. However, all restorative resins performed equally well in clinical

Table 1: *Summary of the Clinical Studies that Evaluate Silorane-based Resin Composites (SBRC)*

Study	Year	Duration	Type of Restoration (No.)	No,. of Patients	Materials Tested/Adhesive
Burke and others[71]	2011	2 y	Class I (30) Class II (70)	64	Filtek Silorane/Silorane System Adhesive
Schmidt and others[70]	2011	1 y	Class II (158)	72	Filtek Silorane/Silorane System Adhesive Ceram X /Xeno III
Baracco and others[80]	2012	1 y	Class I (38) Class II (37)	25	Filtek Silorane/Silorane System Adhesive Z250/Adper Scotchbond (XT) Z250/Adper Scotchbond (SE)
Goncalves and others[79]	2012	6 mo	Class II (100)	33	Filtek P90/Silorane Adhesive System Filtek P60/Adper SE Plus
Goncalves and others[72]	2013	18 mo	Class II (100)	33	Filtek P90/Silorane Adhesive System Filtek P60/Adper SE Plus
Efes and others[73]	2013	2 y	Class 1(100)	50	Filtek Silorane/Silorane System Adhesive Ceram X Duo
Mahmoud and others[74]	2014	3 y	Class II (156)	78	Filtek P90/P90 System Adhesive Quixfil/Prime &Bond NT
Popoff and others[86]	2014	2 y	Class I or II (100)	34	Filtek P90/P90 System Adhesive Filtek P60/Adper SE Plus
Walter and others [78]	2014	3 y	Class II (82)	31	Filtek LS/Filtek LS System Adhesive Tetric EvoCeram/AdheSE
Yaman and others[75]	2014	3 y	Class V noncarious (144)	24	Filtek Silorane/Silorane System Adhesive Ceram X Mono/Clearfil SE Ceram X Mono/XP Bond
Yazici and others[77]	2014	3 y	Class I (84)	28	Filtek Silorane/Silorane Adhesive System Filtek P60/Adper Single Bond 2 Filtek Supreme/Adper Single Bond 2
Schmidt and others[76]	2015	5 y	Class II (158)	72	Filtek Silorane/Silorane System Adhesive Ceram X/Xeno III

conditions during the three-year evaluation period. The SBRC Filtek LS also performed similarly to the MBRC (Tetric EvoCeram) in Class II posterior restorations over a three-year clinical service.[78]

Goncalves and others[79] found no significant difference in the short-term clinical performance of the proximal contacts of 100 Class II restorations restored with Filtek P90 compared with those restored with Filtek P60 over the course of six months. Baracco and others[80] found that Filtek LS performed similarly to Filtek Z250 (used with two different adhesive systems) over two years of clinical service; in addition, the marginal adaptation of restorations deteriorated over the evaluation period.

As a consequence of the progression of techniques and materials in adhesive dentistry, repair of preexisting restorations—instead of their complete replacement—has become part of everyday dental practice. *In vitro* studies[81-83] found that the repair methods used for MBRC can be applied for SBRC. For aged SBRC, repairs were considered successful after sandblasting (Al_2O_3) and adhesive application with either SBRC or MBRC.[84,85] A clinical trial by Popoff and others[86] showed that SBRC are clinically acceptable to repair failed conventional MBRC

Table 1: *Summary of the Clinical Studies that Evaluate Silorane-based Resin Composites (SBRC) (ext.)*

Study	Assessment Parameters	Results
Burke and others[71]	Retention of the restoration, lack of fracture, marginal integrity, secondary caries, gingival health, color match, stain resistance, surface quality	All restorations were found intact, without secondary caries; 97% of the restorations were rated optimal for anatomic form, 84% optimal for marginal integrity, 77% optimal for marginal discoloration, 99% optimal for color match, and 93% optimal for surface quality
Schmidt and others[70]	Marginal adaptation	Better performance for CeramX™ both occlusally (p=0.01) and proximally (p<0.01) compared to Filtek Silorane
Baracco and others[80]	Color match, retention, marginal adaptation, anatomic form, surface roughness, marginal staining, sensitivity, secondary caries	Filtek Silorane and XT had similar performance at 1 yr, SE had marginal staining, While XT had the best performance
Goncalves and others[79]	Proximal contacts	No significant differences were found between the two restorative materials
Goncalves and others[72]	Proximal contacts, fracture, marginal integrity, marginal discoloration, surface texture	No significant differences were found between the two restorative materials
Efes and others[73]	Anatomic form, marginal adaptation, surface texture, secondary caries, and postoperative sensitivity	No significant differences were found between the two restorative materials; no reports of sensitivity or secondary caries
Mahmoud and others[74]	Anatomical form, marginal adaptation, color match, marginal discoloration, surface roughness, secondary caries	No significant difference in the annual failure rate between the two composites (1.7% for Filtek P90 vs 1.2% for Quixfil)
Popoff and others[86]	Marginal adaptation, anatomic form, surface roughness, marginal discoloration, postoperative sensitivity, secondary caries	No significant differences were found between the two restorative materials
Walter and others [78]	Surface luster, surface staining, color stability and translucency, anatomic form, fracture and retention, marginal adaptation, wear, contact area, radiographic appearance, postoperative sensitivity, tooth vitality, recurrent caries, tooth integrity, periodontal response, adjacent mucosa, oral and general health	No significant differences were found between the two restorative materials
Yaman and others[75]	Retention, color match, marginal discoloration, anatomic form, marginal adaptation, surface texture, secondary caries, postoperative sensitivity	No significant differences were found among the restorative materials
Yazici and others[77]	Retention of restoration, marginal adaptation, marginal discoloration, loss of anatomic form, postoperative sensitivity and recurrent caries	All restorative resins performed equally well in clinical conditions during the 3-yr evaluation, with no significant differences, except for marginal adaptation, for which P60 showed superior results
Schmidt and others[76]	Marginal adaptation, marginal discoloration, proximal contact, anatomic form, fracture, secondary caries, hypersensitivity	No significant differences were found between the two restorative materials

restorations, but they did not demonstrate any advantage over MBRC.

Long-term clinical studies on the longevity of SBRC restorations are required. On the basis of the results of the previous studies, it seems reasonable to conclude that there is no evidence yet that the SBRC perform clinically better than do conventional MBRC.

CONCLUSIONS

Resin manufacturers have already done much toward significantly lowering volumetric shrinkage through the introduction of the SBRC. However, this review found that the attempt to reduce shrinkage by ring-opening polymerization is not yet conclusive in terms of efficacy. The reduced volumetric shrinkage of the SBRC did not have an advantage over the conventional MBRC in terms of clinical performance. Physical and mechanical properties of the SBRC and its ability to bond to dentin have been found to be comparable to those of the MBRC *in vitro*. However, SBRC showed lower values of water sorption and solubility compared to MBRC. Therefore, long-term clinical evaluations are required to fully assess the performance of this material.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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