Original Article

Effect of a novel quaternary ammonium silane based cavity cleanser FiteBac 2% K21 QAS in comparison with other cavity disinfectants on the bond strength of resin-modified glass ionomer cement

Thakur Veerandar Singh, Priyanka Sai Sattiraju, Shekar Kamishetty, Smitha Reddy, Priyendu Bhattacharjee, Aisha Habeeb

Department of Conservative Dentistry and Endodontics, Sri Sai College of Dental Surgery, Vikarabad, Telangana, India

Abstract

Background: The application of cavity cleansers for cavity disinfection can be a crucial step in the longevity of restorations. The objective of the present study was to compare the effect of the application of a new quaternary ammonium silane (QAS)-based cavity cleanser (2% K21 QAS), with other commercially available cavity disinfectants on the bond strength of resin-modified glass ionomer cement (RMGIC).

Materials and Methods: The buccal surfaces of 40 extracted premolars were trimmed to obtain a flat dentinal surface and were randomly divided into four experimental groups depending on the cavity cleansers used before restoration. Group 1: 2% chlorhexidine (CHX), Group 2: QAS (FiteBac 2% K21 QAS), Group 3: silver diamine fluoride-potassium iodide (Riva Star, SDF-KI), and Group 4: 3% hydrogen peroxide (H_2O_2). Then, a predetermined dimension of RMGIC restoration was bonded to the treated dentin surfaces. Following this, each sample was tested for shear bond strength (SBS) using a universal testing machine at a crosshead speed of 0.5 mm/min.

Results: Among the experimental groups, SDF-KI has shown the highest mean SBS, followed by 2% K21 QAS, and 2% CHX, which have shown almost comparable results. The 3% H_2O_2 group has shown the lowest values.

Conclusion: According to the results of the present study, 2% K21 QAS has the potential to be used as an effective cavity cleanser before the placement of RMGIC restorations. Since its application does not affect the bond strength of restoration, it can be successfully used as an alternative to CHX and SDF-KI.

Keywords: Cavity cleanser; cavity disinfectant; chlorhexidine; hydrogen peroxide; quaternary ammonium silane; silver diamine fluoride-potassium iodide

INTRODUCTION

Restorative procedures involve the removal of the infected dentin by means of cavity preparation to make space for the restorative materials. The success of these procedures

Address for correspondence:
Dr. Thakur Veerandar Singh,
Department of Conservative Dentistry and Endodontics,
Sri Sai College of Dental Surgery, Vikarabad, Telangana, India.
E-mail: veerubds86@gmail.com

Date of submission : 23.08.2023
Review completed : 22.09.2023
Date of acceptance : 23.09.2023
Published : 22.11.2023

Access this article online
Quick Response Code:
Website: https://journals.lww.com/jcde
DOI: 10.4103/JCDE.JCDE_145_23

How to cite this article: Singh TV, Sattiraju PS, Kamishetty S, Reddy S, Bhattacharjee P, Habeeb A. Effect of a novel quaternary ammonium silane based cavity cleanser FiteBac 2% K21 QAS in comparison with other cavity disinfectants on the bond strength of resin-modified glass ionomer cement. J Conserv Dent Endod 2023;26:688-92.

depends on the effective removal of infected dentin. Failure to mechanically remove the infected tooth structure leads to problems such as microleakage, postoperative sensitivity, secondary caries, and subsequent failure of the restoration. After the cavity preparation, only a small proportion of the teeth are sterile, according to histological and bacteriologic studies, and the bacteria left in the cavity preparation could persist for up to a year.[1] Therefore, disinfection of the cavity after the cavity preparation and before the placement of the restoration is considered vital.

A cavity disinfectant should demonstrate bactericidal and/or bacteriostatic properties while also being biocompatible, readily accessible, and easy to handle and apply during dental procedures. The ideal cavity disinfectant should combine strong antimicrobial action without interfering with the bonding of the restoration. Furthermore, it is expected to upgrade the durability of bond strength through the inhibition of matrix-derived enzymes. Today, with the availability of various cavity disinfectants on the market, the concept of cavity cleansing is gaining wider acceptance to avoid infection under restoration, which poses a great threat to the pulp.

Various agents that have been tested as cavity disinfectants are chlorhexidine (CHX) gluconate, sodium hypochlorite, hydrogen peroxide (H_2O_2), iodine-based solutions, ethylene diamine tetra-acetic acid-based solutions, and glutaraldehyde-based solutions.[2,3] Among all these, CHX has been the most widely used and has presented positive results in the majority of the studies.[2-5] On the other hand, a few studies reported undesirable results when using CHX, resulting in a decrease in bond strength and increased microleakage.[2,4] Besides, it has certain disadvantages, as it causes altered taste sensations and irritation to the oral mucosa.[6] K21 quaternary ammonium silane (QAS) is a novel biomaterial produced through the sol–gel process, known for its broad-spectrum antimicrobial effects. Apart from its ability to eliminate biofilms from dental tissues it also has the ability to inhibit protease enzyme and enhance resin-dentin bond strength. It has been tested in various applications in dentistry, including cavity disinfection.[7] There are no studies documented in the literature where QAS has been compared with other cavity cleansers. Hence, the purpose of the present study is to compare the effect of 2% K21 QAS with 2% CHX, silver diamine fluoride and potassium iodide (SDF-KI), and 3% H_2O_2-based cavity disinfectants on the shear bond strength (SBS) of resin-modified glass ionomer cement (RMGIC).

MATERIALS AND METHODS

Sixty intact, noncarious, nonrestored human premolars that were extracted for orthodontic reasons were selected for the study. Surface debridement was done with a hand scaler and later cleaned with a slurry of pumice and stored in distilled water until use. For sample preparation, teeth were embedded in self-cure acrylic resin, with only the crown portion visible. The buccal surfaces of all the teeth were sectioned with a diamond abrasive disc at slow speed through a plane parallel to the longitudinal axis of the tooth at the level of the middle third to expose a flat dentin surface. The exposed tooth surface was then ground flat to make it even using 180-grit silicon carbide abrasive paper and then polished with 600-grit silicon carbide paper to standardize the smear layer.

Samples were randomly assigned into four experimental groups ($n = 15$) based on the cavity cleanser applied.

- Group I: The dentin surfaces were treated with 2% CHX cavity disinfectant (Bisco, Inc., Irving Park Rd., Schaumburg, USA) for 20 s and then rinsed with distilled water and air-dried for 5 s
- Group II: The dentin surfaces were treated with 2% K21 QAS (KHG FiteBac Technology, Marietta, GA, USA) for 20 s later rinsed with distilled water and air-dried for 5 s
- Group III: SDF-KI (Riva Star, SDI, Bayswater, Australia) SDF solution was applied to the dentin surface, and then KI was applied to the dentine surface, both using a standardized microbrush until the creamy white solution turned clear. The reaction products were washed off with copious amounts of distilled water and then blot-dried[8]
- Group IV: The dentin surfaces were treated with 3% H_2O_2 cavity disinfectant (Apple HealthCare, India) for 30 s and then rinsed with distilled water and air-dried for 5 s.

Later, in all the groups, the surface was conditioned with 10% polyacrylic acid (GC Corporation, Tokyo, Japan) for 20 s using a cotton pellet and rinsed thoroughly with water. Samples were then dried by gently blowing with an air syringe. RMGIC (Fuji II LC, GC Corporation, Tokyo, Japan) was manipulated as per the manufacturer's instructions and packed into a cylindrical-shaped plastic matrix of 2 mm height and 4 mm internal diameter held onto the center of the treated dentinal surface and then cured for 30 s using light-emitting diode curing light. The samples were stored for 24 h at a temperature of 37°C and 100% humidity before the bond strength measurements.

Samples were then positioned into a positioning jig of the Universal Testing Machine (Fuel Instruments and Engineers Pvt. Ltd., Maharashtra, India) to measure the SBS using a crosshead speed of 0.5 mm/min. A blunt, flat chisel was used to deliver the shear force. The values of SBS were obtained in MPa.

Statistical analysis

The mean and standard deviation of the SBS in each group were calculated. Statistical analysis was done using SPSS

(Statistical Package for Social Sciences) version 25 software [IBM Corp, Armonk, N.Y., USA]. Descriptive statistics, Kruskal–Wallis ANOVA, and Bonferroni's *posthoc* test were performed. The confidence interval was set at 95%. $P < 0.05$ was considered statistically significant.

RESULTS

In the present study, Group–III (SDF-KI) has shown the highest mean SBS values amongst all the groups which are 7.26 MPa followed by Group–II (2% K21 QAS) and Group–I (2% CHX) which had a mean value of 5.93 MPa and 5.48 MPa, respectively. Group–IV (H_2O_2) has shown the least mean SBS values among all groups, which is 3.92 MPa. The tabular and graphical representation of data are shown in Table 1 and Graph. 1, respectively. There is a statistically significant difference in mean SBS values among all the groups. Further *post hoc* analysis with pairwise comparisons using Bonferroni correction revealed that the mean SBS values of Groups II and III were significantly greater than that of Group IV, respectively.

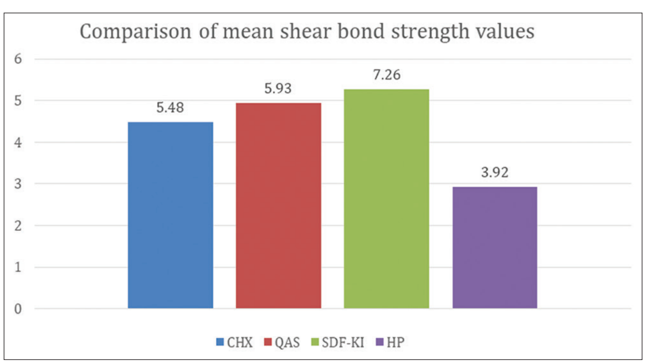
DISCUSSION

The use of cavity disinfectants may reduce or eliminate the bacteria in the cavity preparations and might increase the success and longevity of the restorations. Their effectiveness is contingent not only on their inherent characteristics but also depends on the substrate type, adhesive system, and restorative material. Therefore, these agents might interfere and affect the bonding ability of the adhesive restorative materials to the tooth. Several antimicrobial agents are tested and used as cavity cleansers. Recently, a novel cavity cleanser based on QAS has been introduced and there are very few studies documented about it. Therefore, the present study aimed to compare the effect of the application of this new cavity disinfectant with other commercially available cavity cleansers on the bond strength of RMGIC.

Table 1: The mean shear bond strength values with standard deviation and Bonferroni's *post hoc* correction

Group	Bond strength		*P*	*Post hoc* analysis
	Mean	SD		
Group 1 - CHX	5.48	2.17	0.007	QAS, SDF-KI > H_2O_2
Group 2 - QAS	5.93	2.15		
Group 3 - SDF-KI	7.26	2.89		
Group 4 - H_2O_2	3.92	2.19		

SD: Standard deviation, CHX: Chlorhexidine, QAS: Quaternary ammonium silane, SDF-KI: Silver diamine fluoride-potassium iodide, H_2O_2: Hydrogen peroxide



Graph 1: Comparison of mean shear bond strength values. CHX: Chlorhexidine, QAS: Quaternary ammonium silane, SDF-KI: Silver diamine fluoride-potassium iodide, HP: Hydorgen Peroxide

The choice of restorative material makes a tremendous impact on the clinical success of a restoration. RMGIC due to its predominant biocompatibility, chemical adhesion, anticariogenic property, and lower moisture sensitivity has been supported to be utilized as a liner underneath composite resin rebuilding efforts in deep caries management.[9] The resin component of RMGIC forms a hybrid layer with dentin to aid in adhesion. Hence, any procedures, such as disinfection, can cause changes in the dentinal surface and potentially alter the bond strength of RMGIC to the dentin. Therefore in this study, macro-SBS testing was used to assess the effect of different cavity disinfectants on the bonding of RMGIC as it is a quick, effective, and easy method.

Riva Star is the only commercial product of silver diamine fluoride and Potassium iodide. Since its introduction, it has been available for clinical usage as a desensitizing agent or a cavity cleanser. In the present study, Riva Star has shown the highest mean SBS values among all the groups. These results were similar to the previous study documented in the literature by Gupta *et al*.[10] Literature reveals several possible hypotheses for the hastened increase in the bond strength of RMGIC. The carboxylic acid of RMGIC may bond to the silver phosphate and silver iodide precipitates that are clogged in the dentinal tubules as a result of the reaction between the tooth surface with SDF and SDF with KI, respectively.[11,12] Improved bond strength can also be a result of the formation of fluorapatite and hydroxyl apatite on the exposed organic matrix.[11] The antimatrix metalloprotease effect of SDF may have reduced collagen breakdown and encouraged remineralization, which could have enhanced the chemical binding of GIC to the collagen fibrils.[13,14,15]

CHX is a widely used cavity cleanser. It is a bisbiguanide, a broad-spectrum antimicrobial agent used available in many forms such as solutions, gels, and sprays. It is shown to disinfect dentinal tubules and is absorbed into the dentin. It is relatively nontoxic and has residual action with less potential for adverse effects. Previous studies done by Cunningham and Meiers *et al*.[9] and Sekhar *et al*.[16] have documented that when CHX was used as a cavity cleanser before RMGIC restoration, it did not deteriorate its bond strength to dentin; in fact, it was slightly enhanced. Therefore, in the present study, 2% CHX cleanser was used in one of the groups. An increase in bond strength could be attributed to the fact that CHX has anticollagenolytic activity due to its inhibitory effect on matrix metalloproteinases (MMPs). MMPs in dentin play a role in the degradation of the unprotected collagen fibrils in the hybrid layer. The resin component of RMGIC is thought to form a hybrid layer to aid in adhesion with dentin. Therefore, MMP inhibitors, such as CHX, can play a role in enhancing the bond strength of RMGIC to dentin. Contrary to this, a few studies claimed that using CHX led to negative results, including a reduction in resin-dentin bond strength and increased microleakage.[4]

Quaternary ammonium silane is a novel antibacterial biomaterial that has been synthesized and used in dentistry to eliminate the biofilm from dental tissues. It possesses broad-spectrum antimicrobial properties, primarily acting through contact killing, disrupting bacterial cell membranes, inhibiting the Sortase-A enzyme, and causing osmotic changes in cells. It has been extensively tested in various applications, such as cavity disinfection, endodontic irrigation, intracanal medicament, and nano-drug delivery.[7] Recently, a commercial product based on QAS named FiteBac K21 QAS antimicrobial cavity cleanser was introduced. It has a 2% K21 QAS aqueous ethanol solution. It clears away debris in carious lesion preparations and penetrates exposed dentin tubules. Restorative adhesives can firmly adhere to the cleaned dentin surfaces while also acting on several microorganisms present at the restoration site because of this action. *In vitro* studies have shown its ability to effectively act on the following microorganisms: *Streptococcus mutans*, *Actinomyces naeslundii*,[17] *Lactobacillus acidophilus*,[18] *Enterococcus faecalis,* and *Candida albicans*.[19] Besides, studies have shown that K21 QAS inhibits MMP-9 and Cathepsin-K, improves infiltration of adhesive monomers into acid-etched dentin, and does not negatively impact adhesive bond strength to dentin.[17,20,21] Because of its proven antimicrobial action recently, it has also been implicated for usage as an alternative intracanal medicament.[19]

The K21 QAS cavity cleanser group had the second-highest mean SBS values, according to the study's findings. The reason for the increase in bond strength when QAS is used may be explained by the interpenetrating network that developed between the networks of condensing polysiloxane and methacrylate resin during the polymerization of the adhesive resin blend. QAS increases the hydrophobicity of acid-etched dentin by changing its surface energy due to its long hydrocarbon chains, which improves the wetting of the demineralized dentin matrix and infiltration of the adhesive monomers.[20] Besides, there is a consumption of water during the QAS's hydrolysis of the silanol groups, allowing resin infiltration and adhesive polymerization to improve. Reducing residual water within the demineralized dentine matrix is likely to facilitate adhesive resin infiltration and polymerization, resulting in better encapsulation of the collagen fibrils, increased mechanical properties of the adhesive layer, and improved bond durability.[20] Therefore, combined anticollagenolytic and antimicrobial action of QAS can be valuable in preventing the degradation of resin dentin bonds and the formation of secondary caries.

The lowest SBS values were seen in the H_2O_2 group. These results are in accordance with previous studies by Ercan *et al*.[22] and Reddy *et al*.[23] where resin-bond strength declined when composite resins with different bonding systems were used. This is because the collagen matrix and dentinal tubules may have retained some amount of H_2O_2 that eventually decomposed into oxygen and water. This liberated oxygen may prevent resin from penetrating the etched dentin or prevent resins from curing.

CONCLUSION

Within the limitations of the present study, 2% K21 QAS has the potential to be used as an effective cavity cleanser before the placement of RMGIC restorations. Since its application does not affect the bond strength of the restoration, it can be successfully used as an alternative to CHX and SDF.

Acknowledgment

The authors are thankful to Mr. Kirk Kimmerling founder/chairman of KHG Chemical and FiteBac, Marietta, Georgia, USA, for providing FiteBac K21 QAS cavity disinfectant for the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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