Evaluation of the permeability of five desensitizing agents using computerized fluid filtration

A Dundar, T Yavuz[1], H Orucoglu[2], L Daneshmehr[3], M Yalcin[4], A Sengun[5]

Departments of Restorative Dentistry, [1]Prosthodontics and [2]Endodontics, Faculty of Dentistry, Abant Izzet Baysal University, Bolu, [4]Department of Restorative Dentistry, Faculty of Dentistry, University of Inonu, Malatya, [5]Department of Restorative Dentistry, Faculty of Dentistry, University of Kırıkkale, Kırıkkale, Turkey, [3]Department of Preventive and Restorative Sciences, University of Pennsylvania School of Dental Medicine, Philadelphia, USA

Abstract

Objective: The aim of this study was to evaluate the permeability of five desensitizing agents using computerized fluid filtration (CFF) test method.
Materials and Methods: Sixty dentin discs of 500 ± 200-mm-thick were prepared from middle dentin of bovine incisors without exposed the pulp and then randomly divided into five groups (n = 12). The permeability of the discs was measured using the CFF test method before and after application of the following desensitizers: Admira Protect (Voco, Cuxhaven, Germany), Seal and Protect (Dentsply, Konstanz, Germany), Sensi Kill (DFL, Brazil), Systemp Desensitizer (Ivoclar Vivadent, Liechtenstein), BisBlock (Bisco, USA). Fluid movement measurements were made at 2-min intervals for 8 min, and a mean of the values obtained was calculated for each specimen. The results were analyzed using Kruskal–Wallis test and Wilcoxon signed ranks tests with a significance threshold of $P < 0.05$.
Results: There were no significant differences in permeability among desensitizing agents ($P > 0.05$); however dentin permeability was reduced in all groups ($P < 0.05$).
Conclusion: The *in vitro* fluid conductance of dentin discs were reduced by treating with these five desensitizing agents.

Key words: Dentin, desensitizer, permeability

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Introduction

Dentin is a porous, fluid-filled mineralized tissue including tubules which contribute to permeability.[1] Abrasion, attrition, erosion and gingival recession contribute to the loss of enamel and cementum, and, therefore, dentinal tubules become exposed to the oral environment.[2] When thermal, osmotic and mechanical stimuli such as tooth brushing, sweet and sour foods, hot or cold water are applied to exposed dentin, the patient feels a short sharp pain of stabbing nature which can be termed as “dentinalgia” and/or “dentine hypersensitivity.”[3,4]

Several theories have been proposed to explain the mechanism of dentine sensitivity. Of these, the most widely accepted theory is the so-called hydrodynamic theory of sensitivity. The hydrodynamic theory of dentine sensitivity states that movement of fluid within the dentinal tubules is the mechanism by which pain is experienced when exposed dentine is stimulated.[5]

To produce tubule occlusion and reduce the hypersensitivity, the most frequently used method is topical application of desensitizers. Although the exact mechanism of action of desensitizers is still not fully understood, currently used agents probably act by blocking the dentinal tubules through coating, or by altering the tubular content through

Address for correspondence:
Dr. A Dundar,
Department of Restorative Dentistry, Faculty of Dentistry, Abant Izzet Baysal University, 14000 Bolu, Turkey.
E-mail: aysedundar@ibu.edu.tr

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Table 1: Materials used in this study

Materials and manufactures	Ingredients	Lot number
Admira protect (Voco, Cuxhaven, Germany)	Bis-GMA, HEMA, BHT, acetone, ormocer	912484
Seal and protect (Dentsply, Konstanz)	Di- and trimethacrylate resins, PENTA, functionalized amorphous silica, photoinitiators, BHT, cetylamine hydrofluoride, triclosan, acetone	811000948
Sensi kill (DFL, Brazil)	Solution 1: Potassium phosphate dibasic, sodium fluoride, methylparaben, distilled water	8101380
	Solution 2: Calcium chloride, sodium benzoate, distilled water	
Systemp desensitizer (Ivoclar Vivadent, Liechtenstein)	Polyethylene glycoldimethacrylate, glutaraldehyde in an aqueous solution	L13934
BisBlock (Bisco, USA)	Oxalic acid	800009851

GMA=Glycidyl methacrylate; HEMA=Hydroxyethyl methacrylate; BHT=Butylated hydroxy toluene; PRNTA=Dipentaerythritol penta acrylate monophosphate

Table 2: Dentin permeability through dentin before or after desensitizer treatment

Groups	Dentin permeability			
	Before	After	Percentage change	
Admira protect	0.0017±0.0013	0.0011±0.0010	47.56±27.08	a
Seal and protect	0.00010±0.0005	0.0003±0.0002	51.39±22.95	a
Sensi kill	0.0004±0.0002	0.0002±0.0001	57.13±25.54	a
Systemp desensitizer	0.0007±0.0007	0.0002±0.0001	58.89±16.49	a
BisBlock	0.0003±0.0001	0.0001±0.000	57.53±22.69	a

Table 3: Dentin permeability through dentin before or after desensitizer treatment (Wilcoxon signed rank test table)

Groups	Dentin permeability			
	Before	After	*P*	
Admira protect	0.0017±0.0013	0.0011±0.0010	0.002	a
Seal and protect	0.00010±0.0005	0.0003±0.0002	0.002	a
Sensi kill	0.0004±0.0002	0.0002±0.0001	0.002	a
Systemp desensitizer	0.0007±0.0007	0.0002±0.0001	0.002	a
BisBlock	0.0003±0.0001	0.0001±0.000	0.002	a

coagulation, protein precipitation or creation of insoluble calcium complexes, or by direct interference of sensory nerve activity.[6] The fact that many of the agents used clinically to desensitize dentine are also effective in reducing dentine permeability tends to support the hydrodynamic theory.[7]

The aim of this study was to evaluate the permeability of five desensitizing agents using SEM and computerized fluid filtration (CFF).

Materials and Methods

Desensitizing agents

Five desensitizing agents were evaluated: Admira Protect (Voco, Cuxhaven, Germany), Seal and Protect (Dentsply, Konstanz) as light-curing type, Sensi Kill (DFL, Brazil) as calcium phosphate type, Systemp Desensitizer (Ivoclar vivadent, Liechtenstein) as protein precipitate type, and BisBlock (Bisco, USA) as oxalate type. The composition of each material is shown in Table 1.

Sample preparation and methods

The sound lower central incisors of bovines, which were the same age, were used in this study. Flat dentine surface was obtained from mesial or distal root surface using low-speed diamond saw (Isomet Buhler Lake, IL, USA) under water-cooling. Sixty dentin discs of 500 ± 200-mm-thick were prepared from middle dentin without exposing the pulp canal. Pulpal surface of dentine discs was signed. Then the discs were randomly divided into five groups with 12 discs for each group.

An *in vitro* fluid transport model was used to measure the fluid conductance through the desensitizers, following the protocol for hydraulic conductance evaluation reported by Pashley and Depew.[8] The samples were placed pulp-side upper in a split chamber device in which the plastic spacers containing the rubber "O" rings have a surface area of 1 mm^2 and fluid movement across the desensitizer-treated dentin was measured. The measurements of fluid conductance were done by following the displacement of an air bubble in a micropipette with a constant barrel (25 μL, 65 mm).

Many techniques are used for measurement of permeability such as the use of tracers (dye penetration), scanning electron microscopy (SEM) or fluid filtration.[9] The CFF method was introduced by Oruçoglu *et al*.[10] A CFF meter was used to determine fluid conductance in this study. This apparatus includes a computer-controlling mechanism and digital air pressure arrangement and is, therefore, different from the conventional method.[8] The movement of air bubble can be observed by laser diodes, and the reliability of this technique was previously reported by Oruçoglu *et al*.[10] This method allows for easy reading of the bubble movement, shortens the working time, and records minimal bubble movements.

Cross-correlation function method depends on light refraction at the starting and ending positions of an air bubble in a glass micropipette under a stable pressure. An infrared light passes through the micropipette. Two light-sensitive photodiodes are put on the opposite sites of the micropipette to detect any movement of the air bubble. All operations are controlled by PC-compatible software (Fluid Filtration 2003, Konya, Turkiye). During this procedure, a computer program, previously described by Oruçoglu *et al*.[10] was used [Figure 1].

Fluid conductance was measured at 2-min intervals for 8 min, and the mean of the values obtained was calculated for each specimen. The linear displacement of the bubble converted to a volume of liquid filtrated, and hydraulic conductance was expressed as microliters of water flow/min/cm^2/cm H_2O pressure (1.2 atm). The permeability of dentin varies considerably between and among different teeth.[11] Therefore, in this study, before performing the desensitizer tests, the discs were numbered, and the initial fluid conductance for each specimen was calculated. The data for each dentin disc were later used as its own control value.

Next, each desensitizing agents were applied on the outer dentin surfaces according to manufactures' recommendations [Table 1]. The discs were again placed into the split chamber device, and the fluid movement across the desensitizer-treated dentin was measured using the same CFF contrivance described earlier. The data were calculated for each specimen.

For SEM evaluations of the dentin-desensitizing agent interfaces, after performing the permeability tests, two specimens from each group were selected randomly. Specimens were coated with an additional layer of flowable resin composite (Clearfil Flow FX, Kuraray Medical, Tokyo, Japan). Then, the samples were embedded in a self-curing epoxy resin for 1-day, subsequently ground in the longitudinal direction with #600-grit SiC paper (English Abrasives, England) under running water and

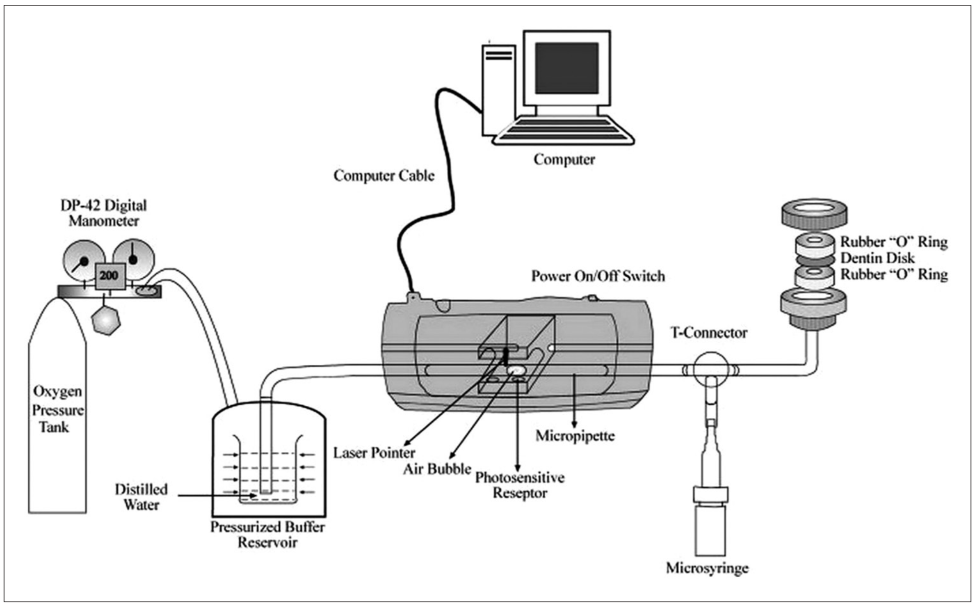

Figure 1: Diagrammatic representation of the apparatus used to measure dentin permeability

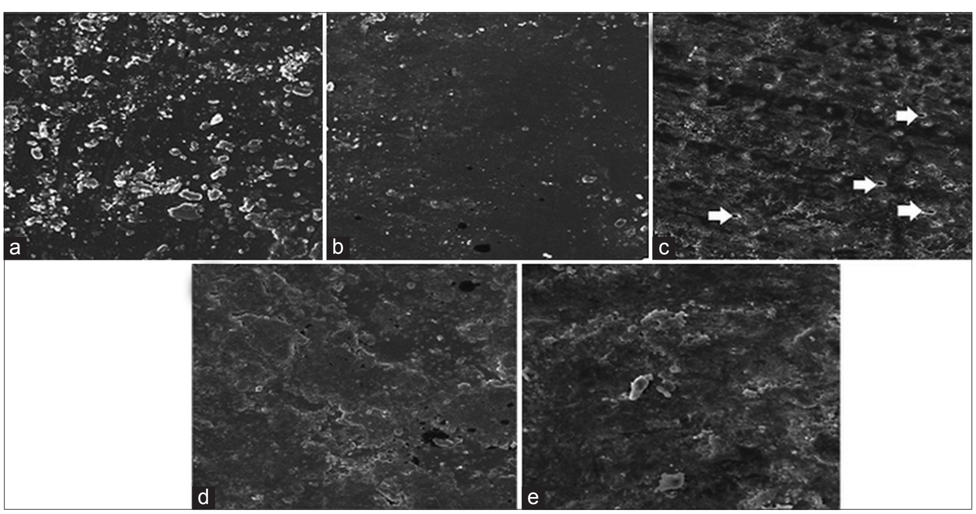

Figure 2: Representative scanning electron microscopy micrographs of the surface of dentin discs at ×2000 magnification. (a) Seal and Protect; (b) Admira Protect; (c) Systemp Desensitizer; (d) BisBlock; (e) Sensi Kill (arrows: Orifice of dentin tubules)

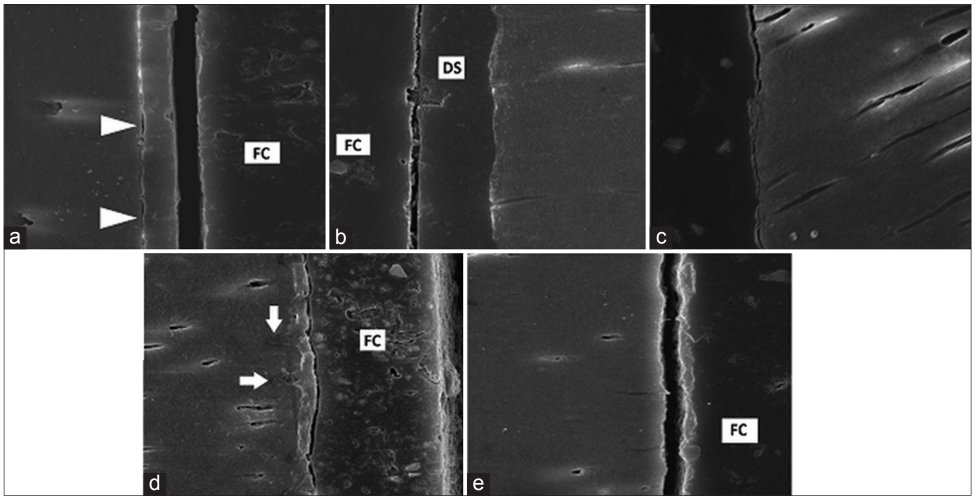

Figure 3: Representative scanning electron microscopy micrographs of interface of dentin discs at ×2000 magnification. (a) Seal and Protect; (b) Admira Protect; (c) Systemp Desensitizer; (d) BisBlock; (e) Sensi Kill (FC: Flowable composite; DS: Desensitizer; triangle: Separation of resin; arrow: Plugged dentin tubule)

finished with diamond pastes down to a 0.25 μm particle size. The samples were cleaned ultrasonically at each step for 10 min. The polished specimens were dried accordingly, sputter-coated and observed with the SEM.

Statistical analysis

The data were analyzed using the SPSS 17.0 software program for Windows (SPSS Inc., Chicago, IL, USA). Differences in dentine permeability among the desensitizing agents were tested using Kruskal–Wallis test.

Differences in dentine permeability through dentin before and after desensitizing agent treatment were analyzed using Wilcoxon signed ranks tests. All tests for statistical differences were conducted at the 95% confidence level were used.

Results

As a result of Kruskal–Wallis, statistical analysis showed no significant differences in permeability among desensitizing agents ($P > 0.05$) [Table 2]. Finding of Wilcoxon signed ranks tests demonstrated that dentin permeability was reduced in all groups ($P < 0.05$) [Table 3]. Admira Protect showed the lowest dentin permeability.

When the surface of dentin disc were scanned with SEM, it was observed that resin based desensitizers (Seal and Protect and Admira Protect) covered the dentin surface with maximum occluding effect. Most of the dentinal tubules were obliterated with a coat covered the surface [Figure 2a and b]. The surface treated with Systemp Desensitizer showed precipitation that closed most of the dentinal tubules and orifice of few dentin tubules were seen [Figure 2c]. In SEM images of BisBlock and Sensi Kill, orifices of dentin tubules were not observed [Figure 2d and e].

When the interfaces of samples were scanned, in resin groups dentin tubules were covered with Seal and Protect or Admira Protect [Figure 3a and b]. But the little separations of resin from dentin were shown in images of Seal and Protect [Figure 3a]. SEM observation of BisBlock showed plugged dentin tubules with potassium oxalate crystals [Figure 3d]. In SEM images of Systemp Desensitizer and Sensi Kill, orifices of dentin tubules were not seen [Figure 3c and e].

Discussion

Dentinal hypersensitivity has been associated with permeable dentin based on the hydrodynamics theory.[5] Several treatment modalities have been advanced to manage this problem, which based on the sealing of the dentinal tubules and the reducing of dentin permeability. In this study, we assessed the permeability of several desensitizer using CFF method and SEM analysis. It was noteworthy that all of the desensitizers reduced dentin permeability and the differences between materials were not significant.

Admira Protect is a light-curing desensitizer that contains 10–12% of a hydroxyethyl methacrylate/bisphenol A glycidyl methacrylate mixture and acetone. As it does not include chemicals to produce polymerization, the desensitizing effects of Admira Protect are thought to occur by precipitation of plasma proteins of dentinal fluid inside the tubules, thereby reducing fluid flow.[12] Although the dentin permeability was reduced, it could not seal permanently. A homogeneous layer is importance for an effective seal because any unsealed areas will allow water to penetrate.[13]

Another light-curing desensitizer Seal and Protect reduced the permeability in a similar manner with Admira Protect. The application of the pressure to the pulpal surface can be the result of tending to displace or lift the resin coating from the dentin. If the pressure had been applied to the bonded surface, it might have tended to assist resin sealing by compressing the coating onto the dentin.[13] In SEM image of Seal and Protect, the separation of the resin from dentin was shown in some areas [Figure 3a]. Nevertheless, the SEM images retrieved from Admira Protect and Seal and Protect showed a great sealing ability of the dentinal tubules [Figure 2a and b], consistent with the results of Abed *et al*.[14]

Sensi Kill as a calcium phosphate type desensitizer reduces the permeability occluding the dentin tubules by the deposition of calcium phosphate. The mineralized substances are deposited in and over the dentin tubules, resulting in a quick precipitation of amorphous calcium phosphate, which is rapidly converted into apatite.[15]

In the present study, BisBlock as oxalate type desensitizer reduced the dentin permeability in accordance with the results of Greenhill and Pashley.[16] Because of obstructive effect of potassium oxalate, it is mostly used in the treatment of dentin hypersensitivity.[17] Application of an acidic solution of oxalate to form small insoluble crystals of calcium oxalate within dentin tubules restricts fluid movement across dentin and has been used to desensitize dentin.[18] This product has two mechanisms for desensitizing dentin: It has the effect of occluding dentin, as a result of the potassium oxalate crystals creating plugs at the tubule entrances, and it reduces the neural action.[19] SEM observation of BisBlock supports this results thereby showing plugged dentin tubule [Figure 3d]. Another study[20] found that various potassium oxalate formulations decreased dentin permeability by approximately 75%, indicating the effectiveness of these products. No significant difference was found between BisBlock and Sensi Kill. Conversely, in another study, Sensi Kill presented a slightly better performance in reducing dentin hypersensitivity when compared to the oxalate type desensitizing agent.[15] The formulation of desensitizing agent and the method used may act an important role on results of the study.

In the present study Systemp Desensitizer was used as protein precipitate type desensitizer. According to its manufacturer, the polyethylene glycol dimethacrylate in Systemp Desensitizer triggers the precipitation of plasma proteins in the dentinal tubules. Glutaraldehyde which is the other content of Systemp Desensitizer is a cross-linking reagent capable of bonding to amine groups of proteins. Duran *et al*.[21] suggested that glutaraldehyde which is responsible for the occlusion of the tubules as an effect of glutaraldehyde on the serum proteins in the dentinal fluid. It was reasonable to assume that this fixative might react with and precipitates plasma proteins from the dentin tubular liquid by coagulation inside the tubules.[22] Lasers have also been used in the treatment of dentin hypersensitivity. Due to the occlusion ability of dentin tubules of high output power laser systems such as neodymium: Yttrium-aluminum-garnet, erbium: Yttrium-aluminum-garnet, and carbon dioxide, they can decrease or even eliminate dentinal pain.[23,24] But the treatment with laser was very costly methods advantages of desensitizing agents over laser.

However it is difficult to calculate the dentin permeability using *in vivo* studies, they demonstrate real results about dentin hypersensitivity. Within such limitations of this *in vitro* study, our findings implied that light-curing, calcium phosphate type, oxalate type and protein precipitate type desensitizers reduced the dentin permeability; however, there was no superiority to each other. Because desensitizers used in this study reduced the dentin permeability, it can be predicted that they can be used in the treatment of dentin hypersensitivity. Further comprehensive clinical studies are needed to assess the clinical potential of these desensitizers.

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