Original Research

Efficacy of NovaMin- and Pro-Argin-Containing Desensitizing Dentifrices on Occlusion of Dentinal Tubules

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Abstract

Introduction: Dentin hypersensitivity is a commonly occurring condition characterized by short, sharp pain arising from the exposed dentine in response to stimuli. **Materials and Methods:** Seventy extracted human permanent molars were selected and divided into four groups. The photomicrographs of the surface from the center of each dentinal block were obtained using a scanning electron microscope. The objective of this study was to evaluate the ability of three desensitizing dentifrices – SHY-NM (NovaMin), Sensitive Pro-Relief (8% arginine and calcium carbonate) and Thermoseal (10% strontium chloride) – for dentinal tubule occlusion using a scanning electron microscope. **Results:** All of the desensitizing dentifrices evaluated, SHY-NM showed the highest percentage of tubular occlusion (95.58%) followed by Sensitive Pro-Relief (89.90%). The least amount of tubular occlusion was shown by Thermoseal (86.12%). **Conclusion:** NovaMin-containing toothpaste, SHY-NM, showed maximum tubular occlusion and it appears to be a promising desensitizing dentifrice.

Keywords: Dentin hypersensitivity, novamin, pro-argin, tubular occlusion

Introduction

For well over a century, there has been a cognizance that sensitivity – a painful condition of the teeth – is a serious problem. Dentin hypersensitivity is defined as, 'Short sharp pain arising from exposed dentin in response to various stimuli typically thermal, evaporative, tactile, osmotic or chemical and cannot be ascribed to any other form of dental defect or disease'.[1]

The reported prevalence of dentin hypersensitivity varies from 4 to 74%.[2] The cause of the condition is multifactorial and can manifest when dentin is exposed due to the loss of enamel or cementum, which occur because of excessive tooth brushing, poor oral hygiene, post-periodontal therapy, faulty occlusal contact, exposure to chemical products, medication, drugs or endogenous acids, as a side effect of bleaching.[3,4]

A wide array of treatment modalities are available for the management of dentin hypersensitivity such as desensitizing toothpastes, varnishes, fluoride iontophoresis, LASERs and remineralizing agents. However, desensitizing dentifrices are the most widely used and accepted. Recently, NovaMin- and Pro-Argin-containing toothpastes, which claim to reduce dentinal hypersensitivity, have become commercially available.

The use of bioactive glass in the form of NovaMin has been advocated for the treatment of dentin hypersensitivity. The active ingredient is the inorganic chemical calcium sodium phosphosilicate ($CaNaO_6PSi$).[4] It is a biocompatible material with osteogenic potential. Gillam *et al.* demonstrated that bioglass could occlude dentinal tubules.[5] The bioactive glass reacts with saliva depositing hydroxycarbonate apatite (HCA) within the demineralized collagen fibrils and, thereby, occluding dentinal tubules. Scanning electron microscope (SEM) analysis has shown that application of bioglass results in the formation of an apatite layer, which occludes the dentinal tubules.[6]

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Aims and objectives

The aim of this *in-vitro* study is to evaluate and compare the ability of three over-the-counter desensitizing toothpastes – SHY-NM, Sensitive Pro-Relief and Thermoseal – on dentinal tubule occlusion using a scanning electron microscope.

Materials and Methods

Seventy well-formed, non-carious, intact, extracted human permanent molars, free of wasting diseases, were selected for the study. Teeth having developmental defects, fractures, craze lines, wasting diseases, caries or restorations were not included.

The teeth were thoroughly cleaned and stored in 0.5% thymol at 4°C prior to their use. A modified dentin disc model similar to that proposed by Gillam *et al.* was used.[5] The teeth were sectioned with a diamond disc mounted on a slow-speed water-cooled handpiece. The first cut was made perpendicular to the long axis of the tooth above the cement–enamel junction, and the second cut was made parallel to the first to remove all the coronal enamel to expose the flat dentin surfaces to obtain 3-mm thick dentinal blocks. The surrounding enamel of the blocks was cut off creating specimens measuring 5 mm × 5 mm × 3 mm [Figure 1]. Seventy such dentinal blocks were obtained free of enamel and pulpal exposure, which were subsequently embedded in acrylic resin.

The surface of each dentin block was polished with 600-grit silicon carbide disc for 30 s to create a standard smear layer. The smear layer was subsequently removed by applying 17% EDTA solution (Pulpdent, USA) onto the dentin blocks for 5 min to ensure the patency of the dentinal tubules, following which they were rinsed with distilled water.

The specimens were then randomly distributed into the following four groups [Table 1]:

Group 1–distilled water (control) ($n = 10$);
Group 2–SHY-NM toothpaste ($n = 20$);
Group 3–Sensitive Pro-Relief toothpaste ($n = 20$);
Group 4–Thermoseal toothpaste ($n = 20$).

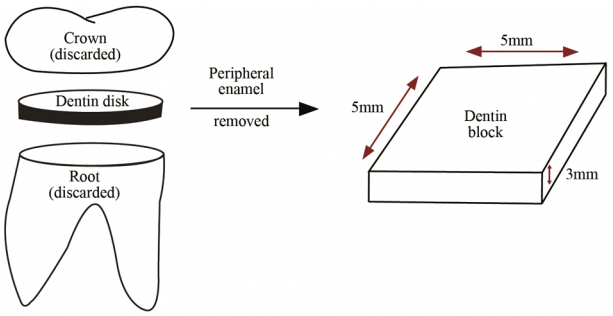

Figure 1: Schematic presentation of the preparation of a dentin block

The specimens from Group 1 were brushed with distilled water, and those from Groups 2–4 were brushed with undiluted toothpaste (approximately 1 g) using a pressure-sensitive powered toothbrush (Oral B smart series 3000). The brush was oriented such that the bristles were perpendicular to the dentin surface to be brushed. Each dentin disc was brushed for 2 min per session. After each brushing session, the specimens were washed with distilled water for 30 sec and kept in artificial saliva. Artificial saliva was prepared in the Department of Biochemistry, and it contained 1.5 mmol/L $CaCl_2$, 50 mmol/L KCl, 0.9 mmol/L KH_2PO_4 and 20 mmol/L Tris (buffer). The pH was adjusted to 7.4.

The specimens immersed in artificial saliva were stored in a beaker shaker machine at room temperature until the next brushing session. This procedure was repeated for seven consecutive days.

Scanning electron microscope analysis

The specimens were washed in distilled water and dried. The specimens were then sputter coated with gold for 5 min using fine coat ion sputter (JEOL, JFC-1100, Japan). The photomicrographs of the surface from the centre of each dentinal block were obtained using a scanning electron microscope (Fei QUANTA-200, Eindhoven, Netherlands). Photomicrographs were taken at 20 kV and at 1000× magnification.

The percentage of occluded tubules for each photomicrograph was calculated as:

$$\frac{\text{Number of occluded tubules}}{\text{Total number of tubules}} \times 100.$$

The data were analyzed Using SPSS by one-way analysis of variance (ANOVA) followed by Tukey's posthoc test.

Results

The photomicrographs of the dentinal specimens from Group 1 showed patent dentinal tubules [Figure 2], and those from Group 2 showed uniform occlusion of majority of the dentinal tubules [Figure 3]. The photomicrographs of the specimens from Group 3 showed either a complete occlusion or narrowing of the tubular lumen [Figure 4], whereas those from Group 4 showed a partial occlusion of the tubule with a large number of open tubules [Figure 5].

Table 1: Tested desensitizing dentifrices

Dentifrice	Manufacturer	Active ingredient
SHY-NM	Group Pharmaceuticals Ltd	Calcium sodium phosphosilicate
Sensitive Pro-Relief	Colgate Palmolive Ind ia Ltd	Calcium carbonate, arginine bicarbonate
Thermoseal	ICPA	Strontium chloride hexahydrate

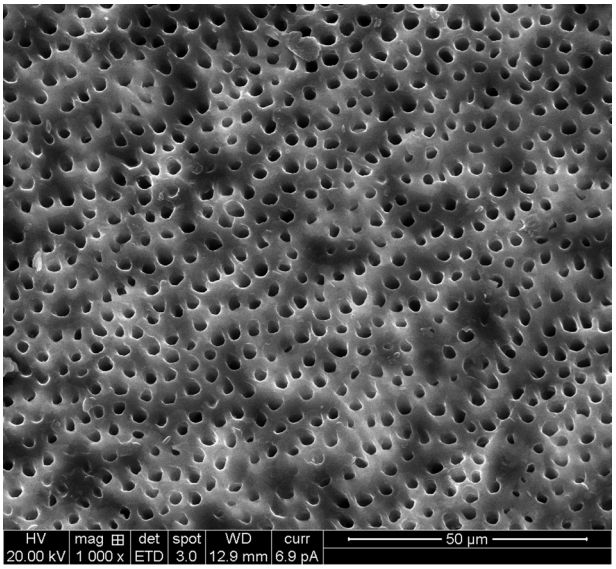

Figure 2: Photomicrograph of a specimen from Group 1–distilled water (control)

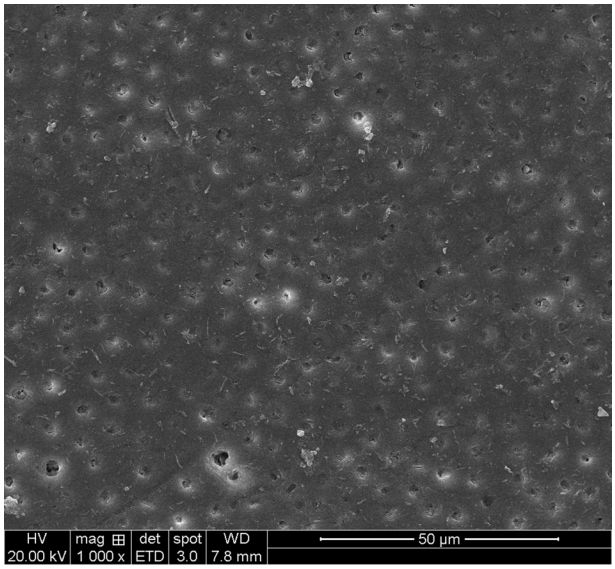

Figure 3: Photomicrograph of a specimen from Group 2–SHY-NM

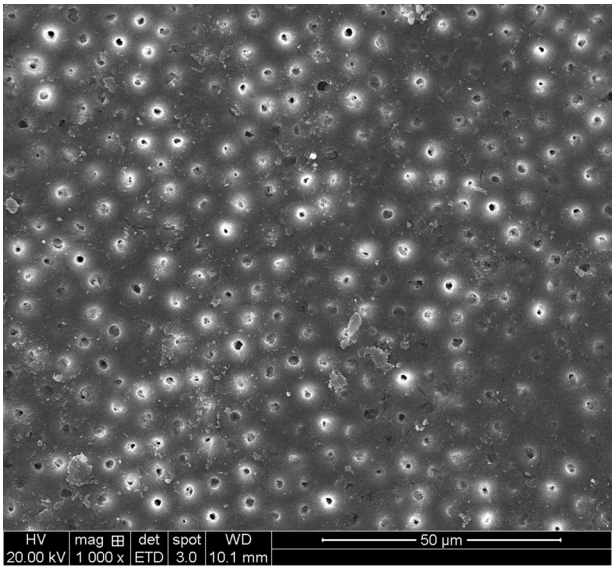

Figure 4: Photomicrograph of a specimen from Group 3–Sensitive Pro-Relief

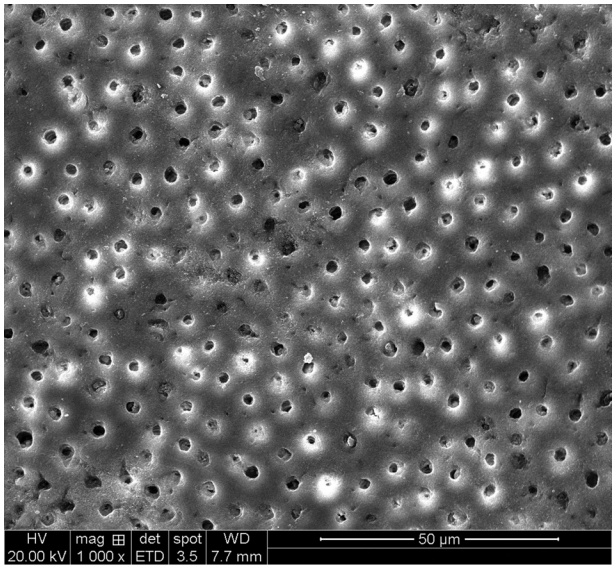

Figure 5: Photomicrograph of a specimen from Group 4–Thermoseal

The data were statistically analyzed with one-way analysis of variance (ANOVA) followed by Tukey's multiple post hoc test for pairwise comparison of the four groups with respect to the percentage of occluded tubules ($P < 0.05$) [Table 2].

This study showed that the number of occluded tubules in all the experimental groups (Groups 2–4) was significantly higher than in the control group (distilled water) ($P < 0.05$), as shown in Table 3.

Of all the desensitizing dentifrices, NovaMin-containing toothpaste, SHY-NM, was found to be the most effective, demonstrating 95.58% of tubular occlusion, followed by Pro-Argin-containing toothpaste, Sensitive Pro-Relief (89.90%). The least tubular occlusion was shown by strontium chloride containing toothpaste, Thermoseal (86.12%) [Table 3].

Table 2: Mean, standard deviation and standard error of the percentage of occluded tubules in the four groups

Group	Mean	Standard deviation
Control	0.991	0.266
SHY-NM	95.582	2.240
Sensitive Pro-Relief	89.898	3.988
Thermoseal	86.115	4.592

Inter-group comparison showed significant difference among all the groups, that is, between SHY-NM and Sensitive Pro-Relief ($P = 0.0002$), SHY-NM and Thermoseal ($P = 0.0002$) and Sensitive Pro-Relief and Thermoseal ($P = 0.0056$) [Table 3].

Table 3: Pairwise comparison of the four groups with respect to the percentage of occluded tubules by Tukey's multiple post hoc procedures

Group	Control	SHY-NM	Sensitive Pro-Relief	Thermoseal
Means	0.99	95.58	89.90	86.12
Std. dev.	0.27	2.24	3.99	4.59
Control	–			
SHY-NM	$P = 0.0002^*$	–		
Sensitive Pro-Relief	$P = 0.0002^*$	$P = 0.0002^*$	–	
Thermoseal	$P = 0.0002^*$	$P = 0.0002^*$	$P = 0.0056^*$	–

*$P < 0.05$, denotes statistical significance.

Discussion

Dentine hypersensitivity is a global clinical oral health problem. It has often been addressed as 'Mysterious Dentin' or 'an enigma?'[7] A wide plethora of methods have been used to treat or manage dentin hypersensitivity. Among at-home treatment modalities, over-the-counter desensitizing dentifrices appear to be the most realistic, practical and commonly used means. There are a wide array of dentifrices that are available over the counter, which often leads to confusion among patients as to which dentifrice to choose.

Various *in-vitro* as well as *in-vivo* methods have been used to determine the efficacy of the desensitizing products. Among *in-vitro* methods, SEM evaluation and the determination of fluid flow by hydraulic conductance are commonly used.

A modified dentin disc model similar to that proposed by Gillam *et al.* was used in this study. The dentinal tubule area was evaluated for occlusion by SEM at 1000× magnification.

The duration of relief provided by various desensitizing toothpastes is highly variable. There is a need for a material that will chemically react with the surface of dentin and intimately adhere to the tooth structure, thereby significantly reducing the possibility of reopening the dentinal tubules. Thus, NovaMin and Pro-Argin were evaluated for their efficiency in tubule occlusion.

Among all the desensitizing dentifrices tested in this study, NovaMin-containing toothpaste – SHY-NM – resulted in maximum tubular occlusion, 95.58%.

SHY-NM contains bioglass in the form of NovaMin. The active ingredient is the inorganic chemical calcium sodium phosphosilicate ($CaNaO_6Psi$). The use of bioglass paste for dentin hypersensitivity management was suggested by Lee *et al.* in 2005.[8] It was observed to produce considerable sealing depth in dentinal tubules with the potential of efficaciously prolonging the therapy.

The physical occlusion of NovaMin particles begins when the material is subjected to an aqueous environment. Sodium ions (Na^+) in the particles immediately begin to exchange with hydrogen cations (H^+ or H_3O^+) in the tooth. This rapid release of ions allows calcium ions (Ca^+) in the particle structure as well as phosphate ions (PO_4^{3-}) to be released from the material. This initial series of reactions occur within seconds of exposure to saliva, and the release of the calcium and phosphate ions continues as long as the particles are exposed to the aqueous environment.

A localized, transient increase in oral pH occurs during the initial exposure of the material because of its release of sodium. This increase in pH helps to precipitate the calcium and phosphate ions from the NovaMin particles, along with calcium and phosphorus found in saliva, to form a calcium–phosphate (Ca–P) layer. As the particle reactions continue and the deposition of calcium and phosphate complexes continues, this layer crystallizes into hydroxycarbonate apatite, which is chemically and structurally equivalent to biological apatite.

The combination of the residual NovaMin particles and the hydroxycarbonate apatite layer results in the physical occlusion of dentinal tubules, which relieves hypersensitivity.[9]

Thus, in this study, NovaMin-containing dentifrice, SHY-NM, showed maximum mean tubular occlusion at 95.58%.

The result obtained is in unison to a study conducted by Wang *et al.*, who proposed that bioglass-containing toothpaste (NovaMin) represented excellent occlusion effects after brushing treatment and artificial saliva immersion.[10] Similar results were also obtained in an *in-vitro* study conducted by Burwell *et al.*, who reported that NovaMin adhered to an exposed dentin surface and reacted with it to form a mineralized layer.[11]

On the basis of a randomized, controlled trial conducted by Neuhaus *et al.*, it was found that a single application of both fluoridated and non-fluoridated prophylaxis pastes containing 15% CSPS (NovaMin) provided a significant reduction of dentine hypersensitivity immediately after a single application, the efficacy of which lasted up to at least 28 days.[12]

Sensitive Pro-Relief contains arginine, an amino acid which is positively charged at physiological pH (i.e. pH 6.5–7.5), bicarbonate, which is a pH buffer, and calcium carbonate, which is a source of calcium. Kleinberg has suggested that arginine physically adsorbs onto the surface of the calcium carbonate *in vivo*, forming a positively charged agglomerate,

which readily binds to the negatively charged dentin on the exposed surfaces and within the tubules. Moreover, the pH of the arginine–calcium carbonate agglomerate is sufficiently alkaline to facilitate natural intervention through the deposition of calcium and phosphate from saliva and/or dentin fluid. The interaction of arginine and calcium carbonate *in vivo* triggers the deposition of phosphate, in addition to arginine, calcium and carbonate on the dentin surface and within the dentin tubules, thus occluding them.[13]

According to the results obtained in this study, Sensitive Pro-Relief toothpaste resulted in a mean tubular occlusion of 89.90%. SEM images showed either complete occlusion or narrowing of the tubular lumen. However, partially occluded tubules were counted as occluded, because, according to the Poiseuille–Hagen equation, the fluid flow rate is proportional to the fourth power of the tubule radius. Partial tubule occlusion may significantly reduce the fluid flow and the corresponding symptoms, thereby reducing dentin hypersensitivity.[14]

Energy dispersive X-ray (EDX) studies by Petrou *et al.* showed that dentin surface deposit and occluded tubule plug contained high levels of calcium and phosphate, as well as carbonate. The hydraulic conductance studies demonstrated that the occlusion provided by the arginine–calcium carbonate technology resulted in highly significant reductions in dentin fluid flow, and that the tubule plug was resistant to normal pulpal pressure and acid challenge.[15]

Similar results from a 12-week clinical trial, which used tactile and air-blast stimuli to determine sensitivity, showed that the 8% arginine-containing prophylaxis paste (for in-office treatment) was significantly more effective in reducing sensitivity than a control paste (Nupro® pumice prophylaxis paste), within 4 weeks.[16]

Thermoseal-containing 10% strontium chloride hexahydrate was included in the study, as strontium chloride has been widely used as a desensitizing agent.[17]

Strontium chloride acts by bicolloidal binding.[18] After application of strontium chloride on the exposed dentin surfaces, strontium replaces calcium in the hydroxyapatite layer due to the similar chemistry of these elements followed by recrystallization of strontium within the tubules, thereby causing tubular occlusion.[19]

In this study, Thermoseal demonstrated a mean tubular occlusion of 86.12%. SEM images of the specimens brushed with Thermoseal demonstrated significantly greater number of the tubular orifices that were unoccluded as compared to the other tested dentifrices.

In this study, on comparing SHY-NM with Sensitive Pro-Relief, SHY-NM showed a better tubular occlusion, 95.58%, when compared with Sensitive Pro-Relief, which resulted in 89.90% of mean tubular occlusion; this difference was statistically significant ($P = 0.0002$). Similar results were also obtained by Parkinson and Willson,[20] and Sauro *et al.*[21]

The limitations of this study are that the depth of occlusion and the mineral content of the occluded tubules were not evaluated. Moreover, the acid resistance of the occluded tubules when subjected to an acidic challenge should also be evaluated.

Conclusion

(1) All three desensitizing dentifrices – SHY-NM, Sensitive Pro-Relief and Thermoseal – demonstrated varying degrees of tubular occlusion.
   (a) SHY-NM – 95.58% of mean tubular occlusion;
   (b) Sensitive Pro-Relief – 89.90% of mean tubular occlusion;
   (c) Thermoseal – 86.12% of mean tubular occlusion.
(2) However, the new NovaMin-containing toothpaste – SHY-NM – resulted in better tubular occlusion, and thus, its use could be indicated for the management of dentin hypersensitivity.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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