

RESEARCH PAPER

In-vitro efficacy of nanoparticulate calcium sodium phosphosilicate in the obstruction of dentinal tubules

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ABSTRACT

Objective(s): The present study aimed to assess the in-vitro efficacy of nanoparticulate calcium sodium phosphosilicate mouthwash in the obstruction of dentinal tubules.

Materials and Methods: This in-vitro, study was conducted on 120 sections obtained from extracted human premolars, which were etched with citric acid for two minutes and rinsed with distilled water. Afterwards, the sections were randomly divided into two groups (60 per each) of nanoparticulate and regular mouthwash. In addition, each group was divided into six subgroups of 10. In the nanoparticulate mouthwash subgroups, one subgroup (n=10) was evaluated using scanning electron microscopy (SEM). The remaining five subgroups were immersed in artificial saliva for different time periods and inspected using SEM. The control subgroups were exposed to regular mouthwash. The diameters and number of the open dentinal tubules were evaluated and compared using two-way analysis of variance (ANOVA).

Results: The mean number of the open dentinal tubules was significantly lower in the nanoparticulate mouthwash group compared to that of the regular mouthwash group at all the time intervals ($P<0.05$). Moreover, the mean diameters of the open dentinal tubules were significantly smaller in the nanoparticulate mouthwash subgroups at all the time intervals ($P<0.05$), with the exception of four-, six-, and 12-hour intervals.

Conclusion: According to the results, nanoparticulate mouthwash was more effective in the obstruction of dentinal tubules compared to regular mouthwash.

Keywords: Dentinal tubules, Dentin hypersensitivity, Mouthwash, Nanoparticulate calcium sodium phosphosilicate, Obstruction

How to cite this article

Aghayan Sh, Asaadi R, Bayandori Moghaddam AM, Bahmani R. In-vitro efficacy of nanoparticulate calcium sodium phosphosilicate in the obstruction of dentinal tubules. *Nanomed J.* 2020; 7(1): 65-72. DOI: 10.22038/nmj.2020.07.08

INTRODUCTION

Dentin hypersensitivity (DH) is a short, severe dental pain in response to touch, chemical, thermal, and osmotic stimuli caused by the denuding of the dentin, which often occurs due to abrasion, attrition, erosion or periodontal treatments [1, 2]. DH could also be caused by traumatic tooth brushing [3], poor oral hygiene [1] and supragingival and subgingival calculus removal [1]. Furthermore, factors such as chemical agents, medication therapy, esophageal reflux [4], and destructive occlusal contact (e.g., premature contact or tooth deformity) [1] could contribute

to DH. The prevalence rate of DH has been estimated at 4-74% in various populations, and its incidence is speculated to be higher at the end of the third decade of life [1]. The most commonly involved regions in DH are the cervical areas of the permanent canine and premolar teeth of both jaws [1]. Currently, the hydrodynamic theory has been well established to elucidate the mechanism of DH development [5]. Accordingly, the stimuli that cause intratubular fluid movement in the dentinal tubules in denuded areas could indirectly lead to severe pulpal pain [1]. Several professional in-office and at-home techniques are currently available to control DH. Desensitizing toothpastes and mouthwashes are available on the market, which could be used by patients at home or

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Note. This manuscript was submitted on September 11, 2019; approved on November 10, 2019

administered by clinicians in clinical offices. These treatments aim to obstruct the dentinal tubules in order to prevent the hydrodynamic movement of the intratubular fluid, thereby resolving DH. Toothpastes and mouthwashes are considered optimal for this purpose since they are easy to use and inexpensive and could be applied at home. Therefore, they are considered to be the most commonly used products for the treatment of DH [6]. Some available desensitizing mouthwashes contain compounds such as strontium chloride, potassium nitrate, sodium citrate, and sodium fluoride as their main desensitizing agents. However, the use of calcium sodium phosphosilicate for the treatment of DH is on the rise due to its presumably higher efficacy [7, 8].

Bioactive glasses are a group of mineralizing agents, which were introduced in 1970 for bone mineralization [10]. These agents could chemically bond to the bones and mainly contain calcium oxide, sodium oxide, phosphorous oxide, and silicate. NovaMin is a commonly used bioactive glass product for the treatment of DH. It is a ceramic containing amorphous calcium sodium phosphosilicate, which could be dispersed in water and obstruct the dentinal tubules [11]. However, this product contains macro-sized calcium sodium phosphosilicate particles (mean diameter: 90 μm), which may not be able to completely penetrate into the dentinal tubules. In a study, Young et al. evaluated the efficacy of NovaMin with various particle sizes, reporting that use of smaller particles resulted in the more rapid and higher quantity of the released calcium and phosphorous ions [12]. Although the mentioned study was performed on various sizes of macroparticles, it may be hypothesized that the conversion of macroparticles into nanoparticles resulted in the improved chemical properties and efficacy of the particles.

Recently, nanoparticulate toothpastes have become available on the market, with the manufacturers claiming that these toothpastes have optimal effectiveness in the treatment of DH [12-16]. Accordingly, Lee et al. conducted an *in-vitro* study and reported the superior efficacy of nano-carbonate apatite toothpaste compared to strontium chloride in the obstruction of dentinal tubules [17].

To the best of our knowledge, no studies have evaluated the efficacy of nanoparticulate calcium sodium phosphosilicate mouthwash in the

treatment of DH. Considering the need for further evidence in this regard and given the importance of this issue, the present study aimed to assess the efficacy of nanoparticulate calcium sodium phosphosilicate mouthwash in the obstruction of dentinal tubules.

MATERIALS AND METHODS

Preparation of the specimens

This *in-vitro*, experimental study was conducted on 60 human premolars, which had been extracted for orthodontic purposes. The study protocol was approved by the Ethics Committee of Islamic Azad University, Tehran Medical Branch (code: IR.IAU.DENTAL.REC.1396, 29). The sample size was calculated to be 10 per each subgroup using the Bonferroni formula and based on previous findings [17]. The teeth were selected *via* targeted sampling. The inclusion criterion of the study was extracted human premolars with no fractures or root caries. After sample collection, teeth were subjected to scaling and root planing using manual and ultrasonic techniques. The teeth were decoronated, and the apical third of the roots was cut. Afterwards, two sections (diameters: 5x5 mm) were prepared in the remaining root piece using a high-speed disc [18]. In total, 120 specimens were prepared for further experimentation. The specimens were etched using 6% citric acid for two minutes and rinsed with distilled water for one minute. Following that, the specimens were randomly divided into two groups (60 per each) of nanoparticulate and regular mouthwash *via* block randomization. At the next stage, calcium sodium phosphosilicate powder (NovaMin Technology Inc., PA, USA) was converted into the nanoparticulate form using a ball mill and through dispersion in an aqueous environment, along with ultrasonication [19]. Afterwards, a water-based mouthwash was prepared using nanoparticulate calcium sodium phosphosilicate, and regular calcium sodium phosphosilicate mouthwash was considered as control.

Preparation of the nanoparticulate calcium sodium phosphosilicate mouthwash

NovaMin was purchased from Denfotex and subjected to ball milling in order to produce NovaMin nanopowder. The mechanical alloying of the initial NovaMin powder was carried out using a planetary ball mill composed of a hardened steel vial and balls. The ball-to-powder weight

ratio and milling speed were set at 2.5 and 250 rpm, respectively, and the powder was milled for 210 minutes. The initial NovaMin and NovaMin nanopowder were inspected using scanning electron microscopy (SEM; XL 30, Philips) for the qualitative assessment of the particle size and shape. Following that, the dispersed solutions of NovaMin were prepared using deionized water and sonicated using an ultrasonic bath for 20 minutes. At the next stage, 10% w/v aqueous solutions of NovaMin containing the initial NovaMin or NovaMin nanopowder were compared in terms of the obstruction of dentinal tubules.

In-vitro efficacy assay of the synthesized nanoparticulate in the obstruction of dentinal tubules

Each group was divided into six subgroups of 10. In the nanoparticulate mouthwash group, the nanoparticulate mouthwash was applied to all specimens in the subgroups for two minutes. The mouthwash was applied using a cotton roll with brushing movements. The first nanoparticulate mouthwash subgroup (n=10) was evaluated using SEM, and the specimens in the remaining five subgroups were immersed in artificial saliva for two, four, six, eight, and 12 hours. Afterwards, the specimens in each subgroup were removed from the saliva and evaluated using SEM. In the control group (regular mouthwash), the same procedures were performed, with the exception that regular mouthwash was applied to the specimens. Following that, the specimens were gold-plated and evaluated using SEM (XL30; Philips, Netherlands).

It is notable that the operator measuring the number and diameters of the dentinal tubules using SEM was blinded to the group allocation of the specimens. Data analysis was performed in SPSS version 22 (SPSS Inc., IL, USA). The normality of the data on the number and diameters of the dentinal tubules was assessed using the Kolmogorov-Smirnov test. In addition, the equality of the variances was evaluated using the Levene's test.

Since the data had normal distribution and the equality of the variances was met, two-way analysis of variance (ANOVA) was used to compare the diameters and number of the dentinal tubules between the groups. Independent t-test was also employed to compare the nanoparticulate and regular mouthwash groups at each time interval.

RESULTS

The assessment of the specimens using SEM revealed that following scaling and root planing and before the application of citric acid, the surface of the specimens was covered with a smear layer, and none of the tubules could be observed (Fig 1-A). However, the application of 6% citric acid for two minutes resulted in the exposure of the dentinal tubules with variable numbers and diameters as revealed in the SEM micrographs (Fig 1-B).

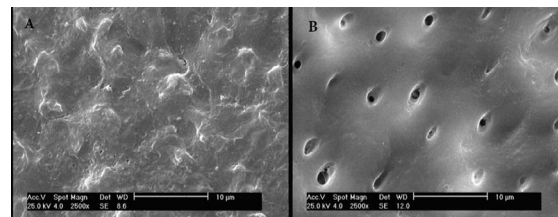


Fig 1. (A) SEM micrograph of tooth following scaling and root planing and before the application of citric acid; (B) SEM micrograph of tooth following scaling and root planing and after the application of citric acid

Assessment the number of the dentinal tubules

Table 1 shows the mean number of the dentinal tubules. The results of two-way ANOVA indicated that the number of the open dentinal tubules in the specimens that were subjected to nanoparticulate mouthwash for two minutes was 1.20 ± 0.92 , while this value was estimated at 10 ± 0.82 in the regular mouthwash group (Table 1; Fig 2). Furthermore, the results of t-test showed a significant difference between the groups in terms of the number of the dentinal tubules ($P < 0.05$) (Table 3).

Table 1. Number of open dentinal tubules in the two mouthwash groups at different time points

Time	Count of tubule	
	with nanoparticles	without nanoparticles
2'	1.20 ± 0.92	10.00 ± 0.82
2h	4.60 ± 0.70	10.80 ± 0.92
4h	9.30 ± 0.67	14.20 ± 0.63
6h	12.30 ± 1.16	15.40 ± 0.70
8h	16.40 ± 1.17	18.10 ± 0.99
12h	18.40 ± 0.84	19.50 ± 0.53

After two hours of immersion in artificial saliva, the mean number of the open dentinal tubules showed a significant difference between the

nanoparticulate and regular mouthwash groups ($P < 0.05$) (Table 2; Fig 3).

Table 2. Diameter of open dentinal tubules in the two mouthwash groups at different time points

Time	Diameter of tubule	
	with nanoparticles	without nanoparticles
2'	0.17±0.14	1.32±0.10
2h	0.87±0.06	1.38±0.08
4h	1.92±0.08	1.94±0.08
6h	1.97±0.06	1.92±0.08
8h	2.19±0.11	2.36±0.08
12h	2.66±0.08	2.59±0.08

After four, six, eight, and 12 hours of immersion in artificial saliva, the difference in the mean number of the dentinal tubules was considered significant between the study groups ($P < 0.05$) (Table 3). In the present study, paired comparisons were carried out regarding the mean number of the open dentinal tubules at various time intervals following the use of the nanoparticulate mouthwash, and the differences in this regard were considered statistically significant ($P = 0.0001$). Accordingly, increasing the immersion time in artificial saliva from two minutes to 12 hours resulted in the higher mean number of the open dentinal tubules. Moreover, the paired comparisons indicated that the differences in this regard were statistically significant ($P < 0.05$), with the exception of the difference between two

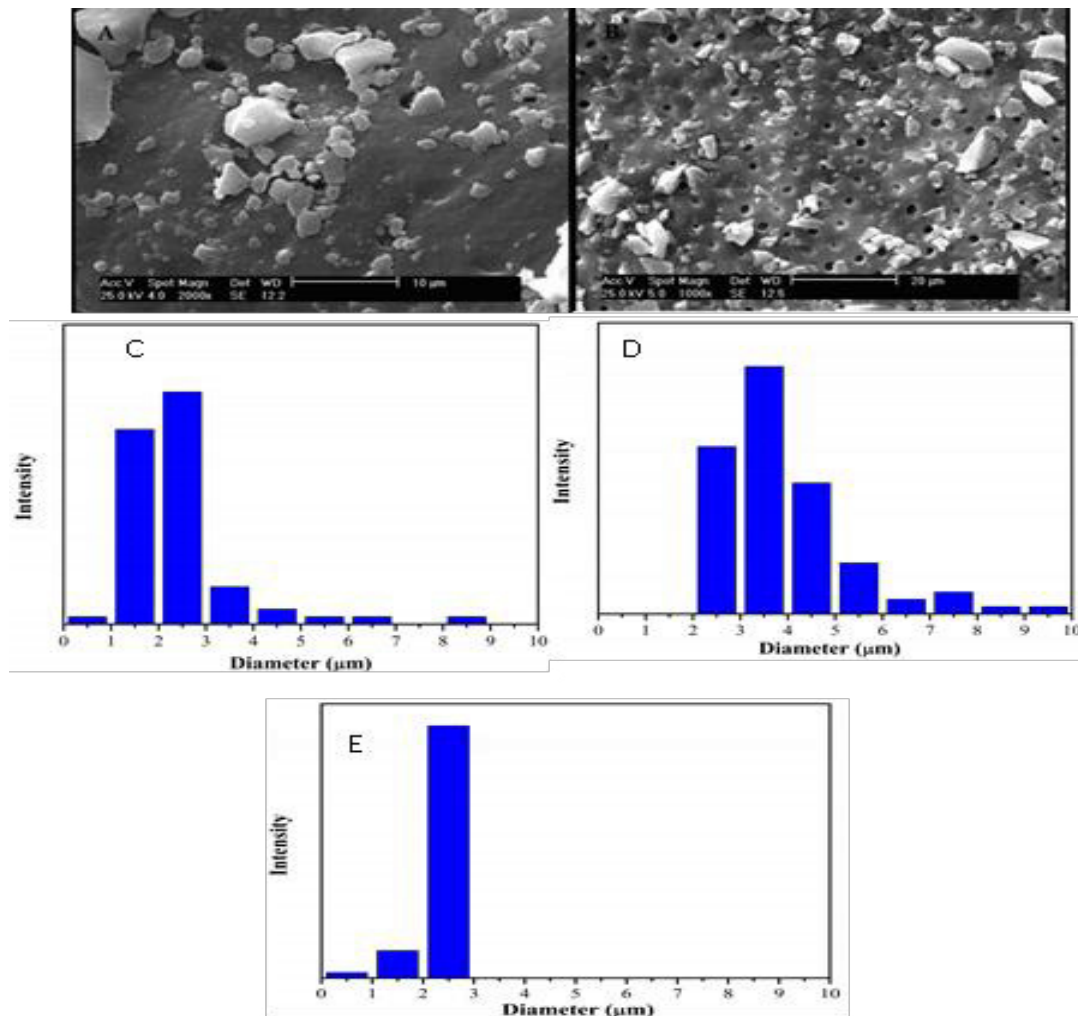


Fig 2. SEM micrograph of tooth following exposure to nanoparticulate (A) and regular (B) mouthwashes for 2 minutes. (C) Particle size distribution of part A, (D and E) Particle size and dentinal tubule holes distribution of part B, respectively

minutes and two hours ($P=0.391$). Therefore, it could be concluded that increasing the time from two minutes to 12 hours resulted in the higher mean number of the open dentinal tubules.

Assessment the diameters of the dentinal Tubules

Table 2 shows the mean diameters of the dentinal tubules. Accordingly, the mean diameter of the open dentinal tubules was 0.17 ± 0.14 micrometers in the nanoparticulate mouthwash group and 1.32 ± 0.1 micrometers in the regular mouthwash group (Table 2; Fig 2).

In addition, the results of t-test indicated a

significant difference between the study groups in terms of the diameters of the dentinal tubules ($P<0.05$) (Table 3).

After two hours of immersion in artificial saliva, the mean diameters of the open dentinal tubules were significantly different between the nanoparticulate and regular mouthwash groups ($P<0.05$) (Table 3; Fig 3). However, after four and six hours of immersion in artificial saliva, the difference in the diameters of the open dentinal tubules was not considered significant ($P>0.05$) (Table 3).

After eight hours of immersion in artificial

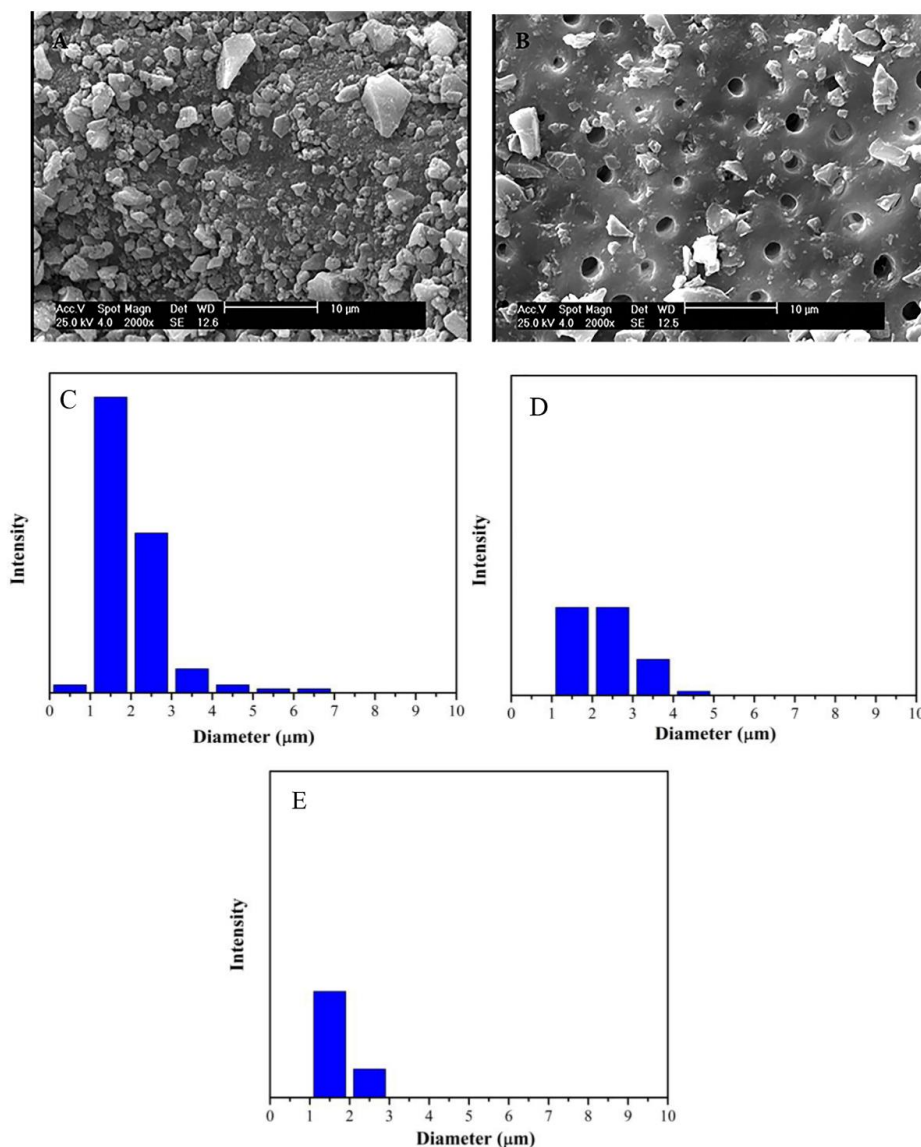


Fig 3. SEM micrograph of tooth following exposure to nanoparticulate (A) and regular (B) mouthwashes and immersion in artificial saliva for 2 hours. (C) Particle size distribution of part A, (D and E) Particle size and dentinal tubule holes distribution of part B, respectively

saliva, the difference in the mean diameters of the dentinal tubules was considered significant between the study groups ($P < 0.05$) (Table 3). After 12 hours of immersion in artificial saliva, the difference in the diameters of the open dentinal tubules was not considered statistically significant ($P > 0.05$) (Table 3). In the present study, the paired comparison of the nanoparticulate mouthwash subgroups in terms of the mean diameters of the open dentinal tubules indicated all the differences in this regard to be significant ($P < 0.05$), with the exception of the difference between four and six hours ($P = 1$). Similarly, the paired comparison of the regular mouthwash subgroups in terms of the mean diameters of the open dentinal tubules indicated all the differences in this regard to be significant ($P < 0.05$), with the exception of the difference between two minutes and two hours ($P = 0.391$) and four and six hours ($P = 1$).

DISCUSSION

The present study aimed to assess the efficacy

of nanoparticulate calcium sodium phosphosilicate mouthwash in the obstruction of dentinal tubules. According to the obtained results, the mean number of the open dentinal tubules was lower in the nanoparticulate mouthwash group in all time intervals compared to the regular mouthwash group.

Therefore, it could be concluded that the nanoparticulate mouthwash had superior efficacy and higher substantivity in the oral cavity. In addition, the mean diameters of the dentinal tubules were lower in the nanoparticulate mouthwash group compared to the regular mouthwash group at all the time intervals, with the exception of four, six, and 12 hours. In a study in this regard, Hill et al. (2015) evaluated the efficacy of nano-hydroxyapatite mouthwash in the obstruction of dentinal tubules [18], reporting the superior efficacy of nanoparticulate mouthwash compared to regular mouthwash.

Despite the use of a different nanoparticulate

Table 3. Comparison of number and diameter of dentinal tubules in the two groups at different time points (t-test)

Time		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F-value	p-value	T-value	Mean Difference
2'	Count of tubule	0.107	0.747	-22.638	-8.8
	Diameter of tubule	0.99	0.333	-21.032	-1.1496
2h	Count of tubule	0.153	0.701	-16.979	-6.2
	Diameter of tubule	0.03	0.864	-15.542	-0.5073
4h	Count of tubule	0.255	0.62	-16.752	-4.9
	Diameter of tubule	0.047	0.831	-0.634	-0.0215
6h	Count of tubule	0.705	0.412	-7.24	-3.1
	Diameter of tubule	0.866	0.364	1.394	0.0444
8h	Count of tubule	0.007	0.936	-3.494	-1.7
	Diameter of tubule	0.424	0.523	-3.976	-0.1729
12h	Count of tubule	1.642	0.216	-3.498	-1.1
	Diameter of tubule	0.007	0.934	1.909	0.0686

mouthwash, this finding is consistent with the results of the present study.

In another research, Chen et al. (2015) investigated the efficacy of three desensitizers in the obstruction of dentinal tubules, including red propolis extract, NovaMin, and arginine-calcium carbonate [21]. According to the obtained results, arginine-calcium carbonate was more efficient than NovaMin in the obstruction of dentinal tubules, which is inconsistent with the results of the present study. It is notable that in the mentioned study, the efficacy of regular calcium sodium phosphosilicate was compared, while we evaluated the nanoparticulate form of this mouthwash.

In another study in this regard, Amaechi et al. (2015) evaluated the efficacy of nano-carboxy apatite, sodium monofluorophosphate, and NovaMin [22]. The SEM results in the mentioned research indicated that nano-carboxy apatite and NovaMin had optimal, equal efficacy in the obstruction of dentinal tubules, and their efficacy was also higher compared to sodium monofluorophosphate, which is incongruence with the findings of the current research. On the other hand, Joshi et al. (2013) compared the efficacy of NovaMin and Gluma (containing glutaraldehyde and hydroxyethyl methacrylate) in the treatment of DH and obstruction of dentinal tubules [19]. According to the SEM results in the mentioned study, NovaMin caused the obstruction of a higher number of dentinal tubules and had superior efficacy compared to Gluma, which is in line with the results of the present study. Similarly, Pradeep et al. (2010) compared the efficacy of toothpastes containing calcium sodium phosphosilicate, potassium nitrate, and placebo in the reduction of DH [23]. According to the obtained results, calcium sodium phosphosilicate was significantly superior compared to the other toothpastes in the reduction of DH, which is consistent with the findings of the current research. Evidence is scarce regarding the clinical efficacy of NovaMin in the macroparticle form in the treatment of DH, and most of the studies in this regard (including the current research) have been conducted *in vitro*. To the best of our knowledge, this is the only study to use the nanoparticulate form of calcium sodium phosphosilicate for the obstruction of dentinal tubules. It is also notable that SEM analysis would suffice to show the advantages of the nanoparticulate form of compounds, which was

performed in the present study. Moreover, we immersed the samples in artificial saliva after their exposure to mouthwash in order to simulate the clinical setting. In this regard, Yilmaz et al. (2017) evaluated five desensitizing agents in terms of efficacy and substantivity [24], concluding that the efficacy of all the desensitizing agents decreased over time. Furthermore, SEM analysis was indicative of physical changes in the dentin structure following the use of the desensitizing agents, which highlights the need for a material that could further penetrate into the tubules for higher substantivity. Therefore, we converted the calcium sodium phosphosilicate macroparticles into nanoparticles so as to enhance their chemical properties, as well as their penetration into the dentinal tubules, to increase the substantivity of the product in the oral environment. In addition, a ball mill was employed for this purpose in order to preserve the chemical properties of the nanoparticles. It is noteworthy that the new formulation proposed in the current research had no toxicity in normal tissues [25]. The findings of the current research indicated the superior efficacy of nanoparticulate mouthwash compared to regular mouthwash in the obstruction of dentinal tubules.

This finding could be attributed to the smaller size of the particles (10^{-9} compared to 10^{-6}), which allowed their easier penetration into narrower tubules with the diameters of 0.9-1.1 micrometers located at the dentinoenamel junction. Through the obstruction of dentinal tubules, the intratubular fluid movement and the subsequent DH could be prevented. On the other hand, the further penetration of the small particles into the dentinal tubules could prevent their easy washout by the saliva.

This study was conducted with an *in-vitro* design. Although it was attempted to simulate the oral environment, the environment in the present may not have been perfectly simulated *in vitro*. Therefore, the generalization of our findings to the clinical setting must be with caution. Further clinical trials are required to assess the efficacy of the nanoparticulate calcium sodium phosphosilicate mouthwash in the clinical setting.

CONCLUSION

According to the results, nanoparticulate mouthwash was more efficient compared to regular mouthwash in the obstruction of dentinal tubules.

ACKNOWLEDGEMENTS

This article was extracted from a thesis conducted by the authors at the Department of Periodontology, School of Dentistry at Islamic Azad University, Tehran Medical Branch, Iran.

REFERENCES

- 1.Porto IC, Andrade AK, Montes MA. Diagnosis and treatment of dentinal hypersensitivity. *J Oral Sci.* 2009; 51(3): 323-332.
- 2.Uchida A, Wakano Y, Fukuyama O, Miki T, Iwayama Y, Okada H. Controlled clinical evaluation of a 10% strontium chloride dentifrice in treatment of dentin hypersensitivity following periodontal surgery. *J Periodontol.* 1980 ; 51(10): 578-581.
- 3.Suge T, Kawasaki A, Ishikawa K, Matsuo T, Ebisu S. Effects of plaque control on the patency of dentinal tubules: an in vivo study in beagle dogs. *J Periodontol.* 2006; 77(3): 454-459.
- 4.Eisenburger M, Addy M. Erosion and attrition of human enamel In Vitro part I: interaction effects. *J Dent.* 2002; 30(7-8): 341-347
- 5.Braennstroem M, Astroem A. A Study on the Mechanism of Pain Elicited from the Dentin. *J Dent Res.* 1964; 43(1): 619-625.
- 6.Gillam D, Orchardson R. Advances in the treatment of root dentine sensitivity: mechanisms and treatment principles. *Endod Topics.* 2006; 13(1): 13-33.
- 7.Pashley DH. Dentin permeability, dentin sensitivity, and treatment through tubule occlusion. *J Endod.* 1986; 12(10): 465-474.
- 8.Prati C, Chersoni S, Lucchese A, Pashley DH, Mongiorgi R. Dentin permeability after toothbrushing with different toothpastes. *Am J Dent.* 1999; 12(4): 190-193
- 9.Prati C, Venturi L, Valdrè G, Mongiorgi R. Dentin morphology and permeability after brushing with different toothpastes in the presence and absence of smear layer. *J Periodontol.* 2002; 73(2): 183-190.
- 10.Greenspan DC. NovaMin and tooth sensitivity-an overview. *J Clin Dent.* 2010; 21(3): 61-65.
- 11.Jennings D, McKenzie K, Greenspan D, Clark A, Clark A. Quantitative analysis of tubule occlusion using NovaMin (sodium calcium phosphosilicate). *J Dent Res.* 2004; 83: 2416.
- 12.Young R. Effect of dose, particle size and exposure time on tooth mineralization from NovaMin-containing dentifrices. South Research Institute, 1998.
- 13.Gillam DG, Orchardson R, Advance in the treatment of root dentin sensitivity : mechanism and treatment, Principles. *J Endod topics.* 2006; 13(1): 13-33.
- 14.Lee BS, Tsai HY, Tsai YL, Lan WH, Lin CP. In vitro study of DP – bioglass Paste for treatment of dentin hypersensitivity. *Dent Mater J.* 2005; 24(4): 562-569.
- 15.Burwell A, Jennings D, Muscle D, Greenspan DC. Novamin and dentin hypersensitivity in vitro evidence of efficacy *J Clin Dent.* 2010; 21(3): 66-71.
- 16.Erdemir U, Yildiz E, Kilic I, Yucel T, Ozel S. The efficacy of three desensitizing agent used to treat dentin hypersensitivity. *J Am Dent Assoc.* 2010; 141(3): 258-296.
- 17.Lee SY, Kwon HK, Kim BI Lee SY, Kwon HK, Kim BI. Effect of dentinal tubule occlusion by dentifrice containing nano-carbonate apatite. *J Oral Rehabil.* 2008; 35(11): 847-853.
- 18.Hill RG, Chen X, Gillam DG. In Vitro Ability of a Novel Nanohydroxyapatite Oral Rinse to Occlude Dentine Tubules. *Int J Dent.* 2015; 2015: 153284.
- 19.Joshi S, Gowda AS, Joshi C. Comparative evaluation of NovaMin desensitizer and Gluma desensitizer on dentinal tubule occlusion: a scanning electron microscopic study. *J Periodontal Implant Sci.* 2013; 43(6): 269-275.
- 20.Kalita MP. Historical Development, Preparation, Characterization, and Pharmacokinetics of Nanoparticles: A Review. *AJP.* 2018; 12(4): 1121-1127.
- 21.Chen CL, Parolia A, Pau A, Celerino de Moraes Porto IC. Comparative evaluation of the effectiveness of desensitizing agents in dentine tubule occlusion using scanning electron microscopy. *Aust Dent J.* 2015; 60(1): 65-72
- 22.Amaechi BT, Mathews SM, Ramalingam K, Mensinkai PK. Evaluation of nanohydroxyapatite-containing toothpaste for occluding dentin tubules. *Am J Dent.* 2015; 28(1) :33-39.
- 23.Pradeep AR, Sharma A.. Comparison of clinical efficacy of a dentifrice containing calcium sodium phosphosilicate to a dentifrice containing potassium nitrate and to a placebo on dentinal hypersensitivity: a randomized clinical trial. *J Periodontol.* 2010; 81(8): 1167-1173
- 24.Yilmaz NA, Ertas E, Orucoglu H. Evaluation of Five Different Desensitizers: A Comparative Dentin Permeability and SEM Investigation In Vitro. *Open Dent J.* 2017; 31(11): 15-33
- 25.Aghayan sh; Assadi R; Bayandori Moghaddam A; Seyedjafari E. Comparison of the cytotoxic effects of nanoparticulate and microparticulate calcium sodium phosphosilicate mouthwashes on human gingival fibroblasts: an in-vitro Study. *Jdmt.* 2019; 8(3): 135-142.