

Efficacy of commercially available desensitizing dentrifice containing strontium chloride versus mouthwash containing dipotassium oxalate monohydrate on dentinal tubule occlusion-an invitro scanning electron microscopic study

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Abstract

Background: Dentinal hypersensitivity is commonly associated with exposed dentinal tubules. Various desensitizing agents aim to reduce sensitivity by occluding these tubules. Strontium chloride-based dentrifice and dipotassium oxalate-based mouthwash is widely used, yet comparative evidence on their tubule-

occluding efficacy under controlled in-vitro conditions remains limited.

Objectives: To evaluate the occlusion of dentinal tubules in extracted teeth using Strontium chloride based dentrifice and mouthwash containing dipotassium oxalate monohydrate investigating with scanning electron microscopy(SEM).

Materials and methods: Thirty extracted human premolars were sectioned to obtain dentin discs and randomly divided into three groups: Group 1 – Control (distilled water), Group 2 – Strontium chloride containing dentrifice, and Group 3 – Dipotassium oxalate monohydrate-containing mouthwash. The specimens were treated with distilled water, strontium chloride based toothpaste and mouthwash containing dipotassium oxalate monohydrate. Scanning Electron Microscopic(SEM) evaluation was performed to assess the degree of dentinal tubule occlusion. Statistical analysis was performed.

Results: Both desensitizing agents showed significant dentinal tubule occlusion compared to the control group. The dentrifice containing strontium chloride demonstrated greater and more uniform tubule occlusion compared to the dipotassium oxalate mouthwash.

Conclusion: Within the limitations of this in vitro study, the strontium chloride containing dentrifice was more effective in occluding dentinal tubules than the dipotassium oxalate monohydrate mouthwash.

Keywords: Dentinal Hypersensitivity, Dentinal Tubule Occlusion, Dipotassium Oxalate Monohydrate, Scanning Electron Microscopy, Strontium Chloride.

Introduction

Dentin hypersensitivity is characterized by short, sharp pain arising from exposed dentin in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental defect or pathology. It is a prevalent condition affecting a wide range of the population and often interferes with routine oral hygiene practices and quality of life.¹

Causes of dentin hypersensitivity include enamel attrition, erosion, corrosion, abrasion and abfraction. Gingival recession is another major predisposing factor

since this leads to exposure of cervical and root dentin. Other factors, such as aging, soft tissue dehiscence, including aggressive brushing, can also cause apical displacement of the gingival margins thereby leading to exposure of dentin that can ultimately lead to the development of dentin hypersensitivity.²

The most widely accepted explanation for dentinal hypersensitivity is the hydrodynamic theory proposed by Brannstrom, which suggests that pain is caused by fluid movement within exposed dentinal tubules that stimulates mechanoreceptors at the pulp–dentin interface. Therefore, treatment strategies are mainly aimed at either blocking neural transmission or occluding dentinal tubules to reduce fluid movement.¹

Various desensitizing agents are used to treat dentinal hypersensitivity which includes desensitizing toothpastes, mouthwashes, laser, dentin sealing agents, periodontal soft tissue grafting, etc.^[3] Desensitizing toothpastes contain some active agents, such as fluorides, strontium salts and potassium. And also, tooth brushing is generally performed with dentifrices containing abrasives that can increase tubule occlusion. This additional blockage may occur by directly occluding the tubules with abrasive or indirectly by the formation of a smear layer during tooth brushing.⁴

The use of strontium compounds, notably strontium chloride, as active ingredients in commercial toothpaste formulations dates back to the 1960s. It has affinity for dentine owing to the high permeability and possibility for absorption into or onto the organic connective tissues and the odontoblast processes.⁵

In vitro investigations have shown significant reductions in tubule permeability in dentine treated with solutions of 30% (di)potassium oxalate or 3% monopotassium-monohydrogen oxalate. Evidence from scanning electron microscopy utilizing professional in-clinic formulations

of 3% aqueous monopotassium oxalate shows extensive precipitation on the dentine surface and within tubules following a single application⁶

As per authors knowledge, Limited studies have been conducted to examine the effectiveness of desensitizing agents. The aim of the study was to evaluate the occlusion of dentinal tubules in extracted teeth using Strontium chloride based dentrifice and mouthwash containing dipotassium oxalate monohydrate investigating with scanning electron microscopy.

Materials and Methods

A total of 30 human maxillary premolar teeth were extracted for orthodontic purposes and gathered from Department of Oral and Maxillofacial surgery, KVG Dental College and hospital, Sullia.

The inclusion criteria

1. Extracted human permanent premolars for orthodontic purpose.
2. Teeth with intact crown and root surfaces.
3. Teeth unaltered by the extraction procedures.
4. Dentin specimens (discs/slabs) obtained after sectioning must be free of cracks, fractures, or defects.

The exclusion criteria

1. Teeth with carious lesions, restorations or fractures, pulpal or periapical diseases, and fluorosis.
2. Teeth with developmental defects such as enamel hypoplasia or dentinogenesis imperfecta.
3. Teeth showing root resorption or internal pathology.

Sample preparation

Extracted human premolar teeth were cleaned with ultrasonic scaler. Then the coronal portion of teeth were sectioned using double sided carborundum disc and straight micromotor handpiece to obtain dentin discs of 1 to 1.5mm thickness. Discs were etched with 37% phosphoric acid to expose dentinal tubules and stored in

phosphate buffered saline solution to simulate the pH of saliva (pH 7.4).The estimated sample size was 9 per group, by adding 10% attrition rate, it was 9.7 and round off to 10 per group.

Group 1-dentinal discs treated with (distilled water), Group 2-dentinal discs treated with commercially available strontium chloride based dentrifice and group 3-dentinal discs treated with commercially available dipotassium oxalate monohydrate containing mouthwash.

Procedure

For group 1, Dentinal discs were immersed in a bottle filled with distilled water shaken for 60 seconds. For group 2, Strontium chloride based toothpaste was applied with applicator tip to the dentinal discs for 2 minutes and washed with distilled water. For group 3, Dentinal discs were immersed in a bottle filled with dipotassium oxalate monohydrate containing mouthwash shaken vigorously for 60 seconds to simulate the rinsing action. All these processes were repeated twice daily for 7 days and all the samples were stored in phosphate buffered saline solution when not in use. After 7 days, dentinal discs were air dried and prepared for SEM analysis to assess the efficiency of dentinal tubule occlusion. Specimens were mounted on metal stubs and gold sputter coating was done on the samples. The samples were observed under SEM with 5000x magnification. The SEM analysis was carried out in Advanced Facility for Microscopy and Microanalysis, Bengaluru.



Figure 1: Sample preparation: Dental discs were prepared from extracted premolar teeth; discs were etched with 37% phosphoric acid; Discs were stored in phosphate buffered saline when not in use; dental discs were immersed or applied with respective agents; Gold sputter coating was done and examined under SEM.

Statistical Analysis

All Statistical Analysis will be performed using the SPSS version 27 software. Analysis of the data carried out by various tests of significance. Descriptive will be expressed in terms of median and interquartile range. P value <0.05 is considered statistically significant.

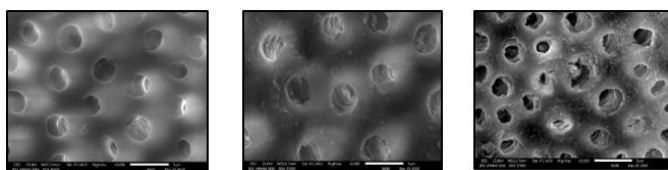


Figure 2: SEM Image Group 1- Control group (Distilled water), SEM Image Group 2- Strontium chloride containing toothpaste, SEM Image Group 3- Dipotassium oxalate monohydrate containing mouthwash.

Results

Using SEM, this study assessed the dental tubule occlusion caused by distilled water, strontium chloride

containing desensitizing toothpaste and dipotassium oxalate monohydrate containing desensitizing mouthwash. Figure 2 reproduces SEM image of each group after treating with respective agents. A statistically significant difference was seen in the dental tubule occlusion among the three groups at the end of the seventh day. $P \leq 0.05$ is statistically significant.

The dental tubule occlusion were analyzed using Zhao et al (2011) classification to quantify the degree of tubule occlusion

Score 0 – No occlusion (open tubules)

Score 1 – $< 25\%$ of tubules occluded

Score 2 – between 25% and 50% tubules occluded

Score 3- between 50% and 75% tubules occluded

Score 4- $>75\%$ of dental tubules occluded

Dental tubule occlusion scores obtained from scanning electron microscopic analysis and graded according to Zhao et al.'s classification are presented in Table 1. The strontium chloride containing dentrifice group demonstrated the highest median dental tubule occlusion score, followed by the dipotassium oxalate monohydrate containing mouthwash group, while the control group showed minimal occlusion.

Intergroup comparison using the Kruskal–Wallis test revealed a statistically significant difference in dental tubule occlusion scores among the three groups ($\chi^2 = 22.400$, $df = 2$, $P < 0.001$) (Table 2). Statistical analysis was performed using SPSS software, version 27.0.

Pairwise comparison using the Mann–Whitney U test showed that the strontium chloride containing dentrifice group had significantly higher dental tubule occlusion scores compared to the control group ($P < 0.001$) and the dipotassium oxalate monohydrate containing mouthwash group ($P = 0.021$). The dipotassium oxalate monohydrate containing mouthwash group also demonstrated significantly greater dental tubule

occlusion compared to the control group ($P = 0.003$) (Table 3).

Table 1: Descriptive statistics of SEM dentinal tubule occlusion scores

Group	n	Median score	Interquartile range(IQR)
Control	10	0	0-1
Strontium chloride containing dentrifice	10	4	3-4
Di potassium oxalate monohydrate containing mouthwash	10	2	2-3

Table 2: Kruskal–Wallis test for intergroup comparison

	Dentinal tubule occlusion score
Chi-square (χ^2)	22.400
Degrees of freedom (df)	2
Asymp. Sig. (P -value)	< 0.001*

*Statistically significant at $P < 0.05$.

Table 3: Pairwise comparison using Mann–Whitney U test

Comparison	Mann–Whitney U	Asymp. Sig. (P -value)	Significance
Control vs Strontium chloride dentrifice	0.000	< 0.001*	Significant
Control vs Dipotassium oxalate mouthwash	5.000	0.003*	Significant
Strontium chloride toothpaste vs Dipotassium oxalate mouthwash	18.000	0.021*	Significant

* $P < 0.05$ was considered statistically significant.

Discussion

Dentin is a permeable tissue that is traversed by fluid-filled dentinal tubules.⁶ which is made up of 30,000–40,000 tubules filled with dentinal fluid. The dentinal tubule’s diameter widens as it approaches the pulpal area. They have a diameter of 2.5 mm close to the pulp, 1.2 mm close to the midpoint of the dentin, and 0.9 mm at the DEJ.⁸

Ling et al. conducted an invitro study on dentinal discs under the SEM, they found out that the surface area of

dentin, its thickness, and its characteristics can be controlled. Dentinal hypersensitivity caused by hydraulic conductance is greater with the coronal dentin compared to radicular dentin. The measured hydraulic conductivity and the density and diameter of tubules appear to be positively correlated.⁹

An ideal treatment for hypersensitivity should mimic the body’s natural desensitizing process, inducing changes in dentin leading to faster and lasting occlusion of dentin tubules.^{10,11} Furthermore, the treatment should have ease

of application with no side effects. According to the Grossman criteria, an ideal desensitizing agent should have long-lasting effects, not irritate pulp, cause pain, be simple to use, and not discolor teeth.¹² Treatment modalities can be available in the form of dentifrices, mouthwashes, gels, sprays, or agents to be topically applied, i.e., glass ionomer cement, varnishes, resin composite, and periodontal membranes.¹² An in vivo study demonstrated that the use of toothpaste containing 5% potassium nitrate on hypersensitive teeth was significantly more effective in immediate pain reduction than using placebo toothpaste.¹³

A study by Hall et al., the effectiveness of an experimental oral rinse containing 3% potassium nitrate in the treatment of Dentinal hypersensitivity was compared to the use of the same fluoride toothpaste alone when used as an adjuvant to brushing. By depolarizing the nerve in the dentinal tubules, potassium nitrate stops the transmission of pain.¹⁴ Calcium oxalate crystals helps in blocking dentinal tubules as well as by inhibiting the activity of sensory nerves, potassium oxalate has been shown to lessen dentin sensitivity³. Swapna Mahale et al conducted a SEM study on dentinal tubule occlusion by desensitizing dentrifices containing arginine, strontium chloride and novamin. Strontium chloride showed the best tubule occlusion, followed by Arginine, and Novamin.¹⁵

In the present study, strontium chloride based dentrifice shown better results followed by dipotassium oxalate monohydrate containing mouthwash and distilled water, which helps in formation of insoluble strontium-containing precipitates within dentinal tubules, These precipitates accumulate at the tubule orifices and gradually form plug-like deposits, narrowing or sealing the tubule openings and also for dipotassium oxalate monohydrate, oxalate ions react with calcium ions

present in dentin leads to calcium oxalate crystals formation which acts as mechanical barrier, narrowing or sealing tubules.

Limitations

The sample size was limited to 30 specimens (10 per group), which may restrict the generalizability of the findings. The evaluation was performed after a limited application period, and long-term durability of dentinal tubule occlusion could not be assessed. Only one commercially available formulation of each desensitizing agent was evaluated; therefore, the effect of different concentrations or formulations could not be compared.

Conclusion

The results of the present study demonstrated that strontium chloride containing dentrifice showed the most dentinal tubule occlusion followed by dipotassium oxalate containing mouthwash and untreated group(distilled water).

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