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Dentinal tubule occlusion by desensitizing dentifrices: SEM study

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Abstract:
Aim - *To evaluate the effects of different desensitizing dentifrices on dentinal tubule occlusion by scanning electron microscopy (SEM).*
Methods and Materials - *Thirty dentine blocks were prepared and divided into three groups of ten specimens each. The groups corresponded to the following treatments: Arginine, Strontium chloride, and Novamin. The toothpaste was applied twice a day for fourteen days. The dentinal tubule occlusion was assessed using scanning electron microscope (SEM), at baseline i.e. before application of the toothpaste, at seven, and fourteen-day application, respectively.*
Results *- Arginine and Strontium chloride almost completely occluded the dentinal tubules at seven and fourteen day treatment as compared to Novamin.*
Conclusions - *As Arginine and Strontium chloride containing toothpaste occluded the dentinal tubules, they may be useful for the treatment of dentine hypersensitivity.*
Keywords: *Arginine, Dentin hypersensitivity, Dentinal tubule occlusion, Desensitizing agents, Novamin, SEM, Strontium chloride.*

I. INTRODUCTION

Dentine hypersensitivity is a short sharp pain in response to thermal, evaporative, tactile, osmotic or chemical stimuli which may not be ascribed to any other form of dental defect or pathology [1]. Dentine hypersensitivity remains an oral health problem in adults on a global scale. It is characterized by a high prevalence of exposed cervical dentine which varies from 3 to 57% [2, 3]. Dentine hypersensitivity can present from early to old age, with the majority of sufferers aged between 20 to 40 years [4]. Many strategies have been evoked for its treatment, resulting in generally effective and immediate reduction of pain.

Brannstrom et al (1968) [5] gave the hydrodynamic theory which assumes that, a stimulus applied on the dentin surface causes movement of tubular fluid, which in turn activates mechanoreceptor nerves, eliciting pain and discomfort. This theory states that if the functional radius of opened dentinal tubules decreases, then the permeability also decreases, reducing dentin sensitivity.

A number of approaches exist to reduce or potentially eliminate hypersensitivity, and these approaches fall into two classes: those that physically occlude the tubules, which comprise the majority of treatment modalities; and those that block neural transmission at the pulpal tissues, chemically depolarizing the nerve synapse with potassium-based therapy [6].

Desensitizing toothpastes contain some active agents, such as fluorides, strontium salts and potassium. Moreover, 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.

Strontium based compounds such as strontium chloride, have been incorporated as the active ingredient in commercial dentifrices since 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 [7]. It occurs naturally within human enamel and dentine as a trace element, is a remineralizing agent, and gets incorporated into the mineral phase of enamel by replacing calcium within the apatitic lattice [8].

The incorporation of Arginine in the dentifrices was reported in the late 1990s. It adsorbs on the surface of the insoluble calcium carbonate particles, forming positively charged agglomerates that readily bind with the negatively charged dentine of the exposed tubule walls to form an occluding adhesive plug [9].

Recently a bioactive glass (Novamin) has been incorporated as a remineralizing ingredient in dentifrice for treating dentin hypersensitivity. It precipitates hydroxycarbonate apatite (HCA) onto the tooth surface and occludes the dentinal tubules [10].

Moreover, 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. But it is unclear whether the active ingredient alone or in combination with abrasive can occlude the dentin tubules.

Many in vivo studies have shown considerable decrease in hypersensitivity when teeth were brushed with desensitizing dentifrices [11, 12, 13]. However, the problem arises when attempts are made to determine the mode of action of active agents incorporated into these dentifrices.

II. MATERIALS AND METHODS

2.1 Specimen preparation

15 freshly extracted sound human premolars stored in 10% formalin were taken. Teeth were cleaned of gross debris and sectioned mesiodistally to obtain 15 buccal and 15 lingual surfaces. The specimens were placed in deionized water till dentin blocks were prepared.

Dentin blocks were prepared in the cervical region measuring 2.5 x 2.5 x 2.5 mm (Fig. 1). The exposed dentin surfaces were polished using pumice and bristle brush (Fig. 2). Specimens were ultrasonicated in distilled water for 12 min and rinsed with deionized water to remove the residual smear layer and to open dentinal tubules (Fig. 3).

Fig.1: Specimen with dentin block in the cervical region

Fig.2: Pumice and bristle brush

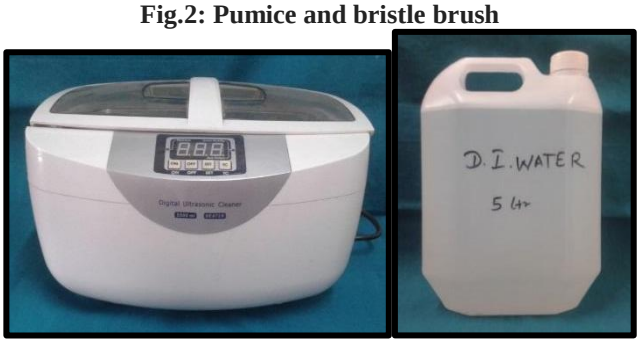

Fig.3: Ultrasonic cleaner and deionized water

2.2 Treatment regimen

The specimens were divided into three groups (n=10), according to the dentin surface treatments followed.

1. Group A – Arginine
2. Group B – strontium chloride
3. Group C – Novamin

A pea-size amount of toothpaste was manually rubbed onto the exposed window of dentin for seven and fourteen days, using tweezer and cotton twice daily for two minutes. After each application the specimens were rinsed with distilled water and kept in saline.

2.3 Assessment of tubule occlusion

The extent of tubule occlusion was assessed after seven and fourteen days using a scanning electron microscope. The specimens were sputter coated to aid conductivity. Photomicrographs of representative dentin surface areas were taken at 2000 and 5000 magnifications respectively.

III. RESULTS

Scanning electron microscopy was done at baseline i.e. before application of the toothpaste. The pre-treatment samples showed open dentinal tubules (Fig. 4).

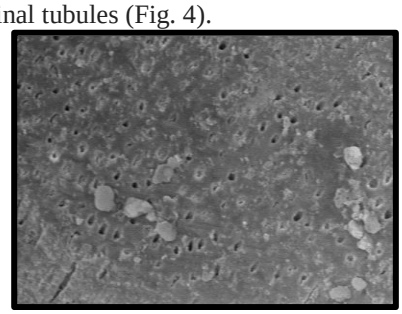

Fig.4: SEM of pre-treated dentine

3.1 Visual assessment at seven and fourteen days

At seven and fourteen days Arginine showed clear tubule occlusion, thought to be caused by deposition of the calcium carbonate + arginine agglomeration within the tubules (Fig. 5). Strontium chloride showed complete tubule occlusion which was indistinguishable from the surrounding specimen surface as a result of the quantity of particulate deposited (Fig. 6). Novamin showed smear layer like occlusion that occluded most of the tubule orifices and very few tubules remained partially open (Fig. 7).

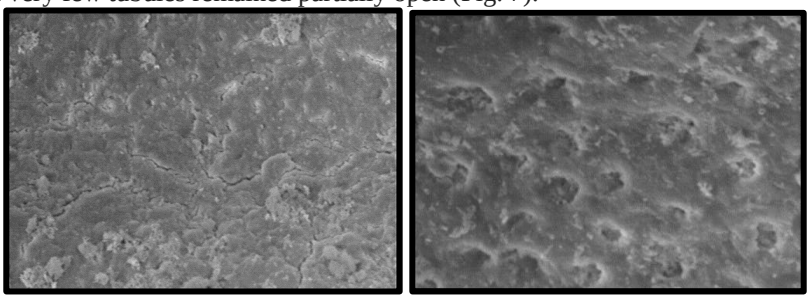

Fig.5: SEM of Arginine treated dentine at 7 days (× 2000) and 14 days (× 5000) respectively

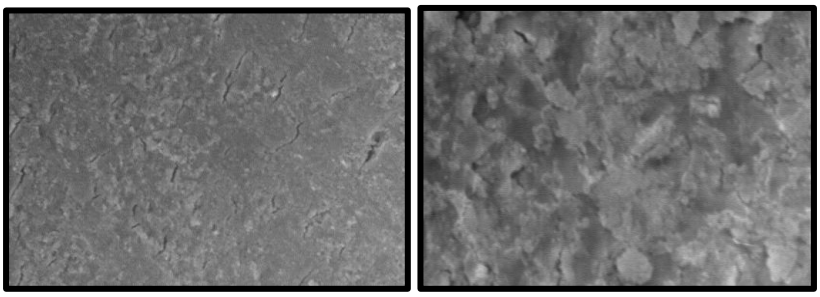

Fig.6: SEM of Strontium chloride treated dentine at 7 days (× 2000) and 14 days (× 5000) respectively

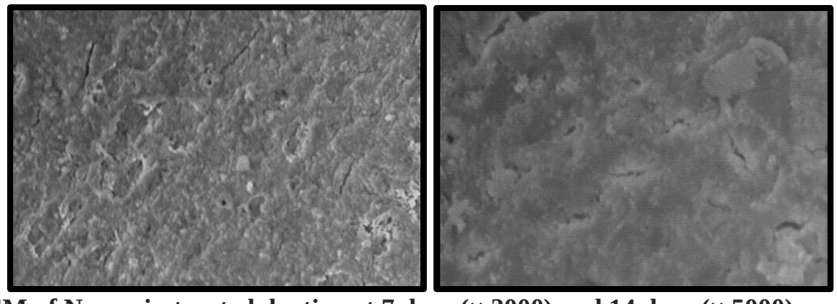

Fig.7: SEM of Novamin treated dentine at 7 days (× 2000) and 14 days (× 5000) respectively

IV. DISCUSSION

Occlusion of dentinal tubules is one approach currently used in the treatment of dentine hypersensitivity. Based on the hydrodynamic theory, dentine hypersensitivity is related to the flow of fluids within the dentinal tubules, and this fluid movement is directly proportional to the fourth power of the radius. As a consequence any reduction in the radius of the tubule opening would be expected to reduce dentine permeability and as such should be effective in treating dentine hypersensitivity. This study evaluated the occlusion of dentinal tubules by three desensitizing agents. The active ingredients used were Arginine, Strontium chloride, and Novamin. Pre-treatment specimen that were polished and ultrasonicated in order to remove smear layer presented open tubules.

At seven and fourteen days Arginine and Strontium chloride treated specimens almost completely occluded the tubules while Novamin could partially do so. Early formulations of strontium-based toothpastes and standard fluoride toothpastes were not always shown to be statistically significantly different in reducing the pain of hypersensitivity [14, 15]. Superior efficacy has been demonstrated for more recently developed strontium based toothpastes [16], and our data is in agreement with these findings. The results of Novamin were similar to those given by Z Wang et al in 2011 [17].

More or less all the desensitizing agents occluded the dentinal tubules. But Strontium chloride and Arginine containing paste were most effective. Hence it can be used effectively to treat the patients with hypersensitivity.

V. LIMITATION

The longevity of the precipitates or resins formed in dentinal tubules after application of desensitizing agents and their ability to resist acid challenge over time was not considered.

VI. CONCLUSION

The results of the present study, demonstrated that Strontium chloride showed the best tubule occlusion, followed by Arginine, and Novamin which was confirmed by SEM analysis. The clinical effectiveness of these materials will depend in part on the dissolution resistance or solubility level of precipitates. Further research is required to provide evidence of the durability of occlusion of these desensitizing agents under simulated clinical conditions and functional studies to assess their ability to reduce fluid flow (hydraulic conductance) through dentin.

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