A COMPARATIVE EVALUATION OF DENTINAL TUBULE OCCLUSION USING IONTOPHORESIS WITH 1.23 % SODIUM FLUORIDE GEL AND DIODE LASER: A SCANNING ELECTRON MICROSCOPE STUDY

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Abstract

Introduction: Dentin hypersensitivity (DH) in one of the most common causes of patient discomfort in the general population and its prevalence. There is currently no known specialised therapy that can effectively eradicate dentinal hypersensitivity, according to the literature.

Aim: The purpose of this study was to evaluate and contrast the effectiveness of diode laser alone against iontophoresis with 1.23% sodium fluoride (NaF) gel in occluding dentinal tubules.

Materials and Methods: In this in vitro study, 20 teeth were included with intact root surfaces unaltered by extraction procedure for specimen preparation. Each tooth was cleaned, air dried and cut into three sections. Total 60 sections were prepared, which were acid etched. In control group, no treatment was carried. In iontophoresis treatment group, Samples were placed into a foam tray containing 1.23% NaF Gel and exposed to 1.5 mA output current for three minutes. In laser treatment group, specimens were lased with 940± 10nm diode laser at 0.5 W/PW in a noncontact mode for 30 seconds. Specimens were evaluated under Scanning Electron Microscope (SEM) at 10KV to 20KV under x5000 x1000 magnification for surface characteristics and patency of dentinal tubules. Total number of tubules visible, open, completely, and partially occluded were recorded in each microphotograph and compared.

Results: On comparison, laser group showed maximum number of occluded dentinal tubules, 14.36% followed by iontophoresis group, 7.4% and control group 0.2%

Conclusion: The blockage of dentinal tubules was treated more successfully with diode laser than with iontophoresis. As a result, it can be applied to the treatment of DH patients.

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Introduction

Dentinal hypersensitivity is defined as the short, -exaggerated, painful response elicited when exposed dentin is subjected to certain thermal, mechanical, or chemical stimuli[1]. The loss of tooth surface through occlusal wear and parafunctional habits such as attrition, tooth brushing abrasion, erosion result in the exposure of dentin to the external environment. Various periodontal diseases, periodontal surgeries and faulty tooth brushing habit can lead to gingival recession which in turn can cause dental hypersensitivity. This is because the cementum is thin and less hard than enamel which is easily removed by scaling, abrasive pastes and toothbrushing.[2]

To explain the mechanism of DH, several hypotheses have been put forth [3-5]. Among the theories, Brannstrom hydrodynamic theory, presented in 1966, is currently the most recognised hypothesis for describing pulpal stimulus transmission. According to Brannstrom and Johnson, applying a stimulus result in dynamic fluid movement in dentinal tubules, which deforms odontoblastic processes and nearby nerve fibres, causing DH.[6] In recent years, laser therapy is increasingly used for treating cervical dentin hypersensitivity [7.] Depending on the wavelength, power density, and optical properties of the target tissue, the lasers' interactions with tooth tissue result in a variety of responses. Low-power output lasers (like diode lasers) are thought to mediate analgesic effects by inhibiting neuronal conduction, whereas medium-power lasers (like CO2 and Er: YAG lasers) were demonstrated to diminish sensitivity by occluding the dentinal tubules. Different literature reveals various in-office desensitizing agents but still there is no single agent which is considered ideal for long term relief from DH.

In 1747, Pivati et al. first published the description on iontophoresis [8]. Galvani and his colleagues in the 18th century stated that the electricity causes metal ions to migrate, which in turn produce electric current. Thus, Iontophoresis was first applied to treat dentin hypersensitivity in the early 1960s [9]. It used direct electrical current at low amperage to inject ions or ionised medicines into tissues. According to the assumption that opposite charges attract and like charges repel, this mechanism operates. Following the application of an electrical current that is appropriately charged, ionised drugs can be injected into tissue. Thus, this illustrates the application of concentrated medications in iontophoresis.

The aim of the present in vitro study was to evaluate and compare the effectiveness of iontophoresis with 1.23% NaF gel and diode laser on occlusion of dentinal tubules under SEM. Null hypothesis was proposed that there will be no statistically quantitative difference in occlusion of dentinal tubules on treatment with iontophoresis with 1.23% NaF gel and diode laser irradiation.

Material and Methods

The present in vitro SEM study was undertaken at Department of Periodontology, ITS Dental College Greater Noida, India. The study was conducted during the period from February 2022 to June 2022.Extractedt teeth with intact root surfaces and unaltered by the procedure were included for specimen preparation. Excluded from the study were teeth with damaged restorations, broken teeth, and teeth previously treated with desensitising therapy. These teeth were also excluded if they had received root canal therapy, had any apical lesions, caries, rough root surfaces, or developmental anomalies such concrescence.

Preparation of the specimen: A pilot study was conducted (n=2 for each group) to evaluate the feasibility of acquiring SEM data in transverse sections of dentinal tubules. For each group, a sample size of 20 dentine samples was used. Twenty selected freshly extracted teeth were cleaned of gross debris and stored in 10% formalin solution. Teeth were polished with sand paper after being ground with a carbide bur to remove the outer enamel layer. Teeth were then sectioned with a carborandum disc attached to a straight handpiece to obtain three dentin specimens each. In transverse section, 60 samples of 2 mm thick dentin were collected. The dentin specimens were placed in an ultrasonic cleaner (API Digital Ultrasonic Cleaner) with distilled water for 30 seconds. Later, the specimens were etched with 6% citric acid for a period of two minutes to remove the smear layer and then rinsed in distilled water. The prepared samples were randomly assigned to three groups: Each group included 20 transverse sections.

Control group: Twenty specimens were acid etched with 6 % citric acid for two minutes and no intervention was carried out and they served as control group.

Iontophoresis treatment group: Twenty specimens were inserted into a foam tray containing 1.23% NaF Gel and subjected to iontophoresis (Jonofluor Scientific®, Medical) at 1.5 mA output current for three minutes.

Laser treatment group: Twenty specimens were lased with 940nm ± 10nm nm Diode Laser (Biolase Epic X ^{TM}) at 0.5 W/PW in noncontact mode for 30 seconds.

Scanning electron microscope analysis: The analysis of specimens under micrographs was carried out by an expert to evaluate occlusion of dentinal tubules. SEM test specimens were evaluated at 10KV and x5000 x10000 magnification for surface characteristics and patency or occlusion of dentinal tubules. Samples were examined by low energy SEM (below 1 keV), to ensure that the dentin tubules were in an open un-occluded state. All the specimens were scanned for determining occlusion of tubules using following criteria. The tubules were considered completely occluded when they show either complete penetration of the crystal or complete obliteration of the canals by the reaction products. The tubules were considered partially occluded when there is a central opening in the canal with circumferential closure of the tubule or more than 50% reduction in the diameter of the tubule The percentage of tubules blocked was calculated as: Number of tubules blocked x100/total number of tubules

Statistical Analysis

Intergroup comparison of Mean Percentage of Open tubules was done using one way ANOVA test. Post hoc Tukeys test used to depicted that the mean proportion of open tubules, partially and complete occlusion of dentinal tubules among the groups. Intergroup comparison of Mean Percentage of partially-occluded tubules was done using one way ANOVA test.

RESULTS

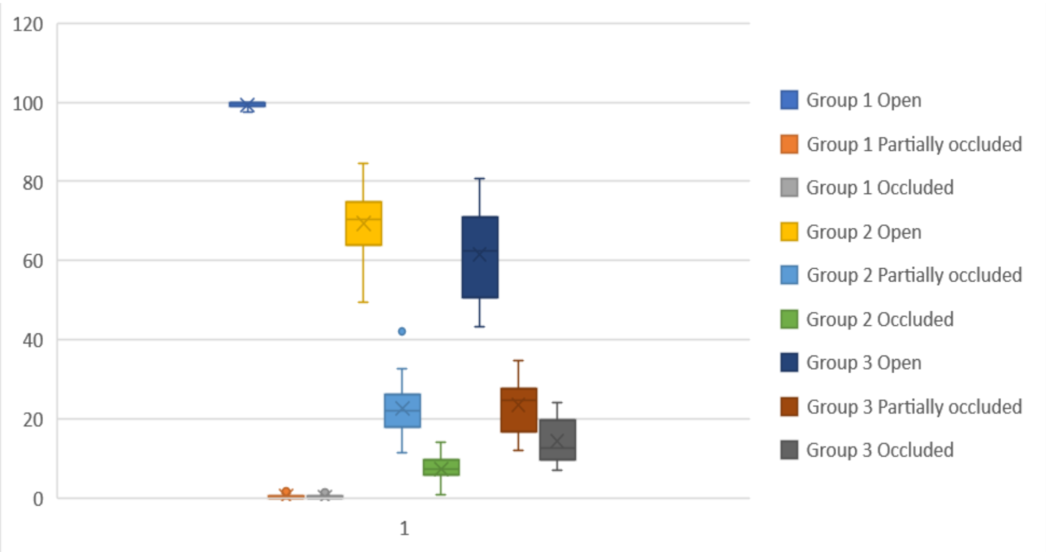


Fig1: Descriptive of proportion of open ,partially occluded and occluded tubules

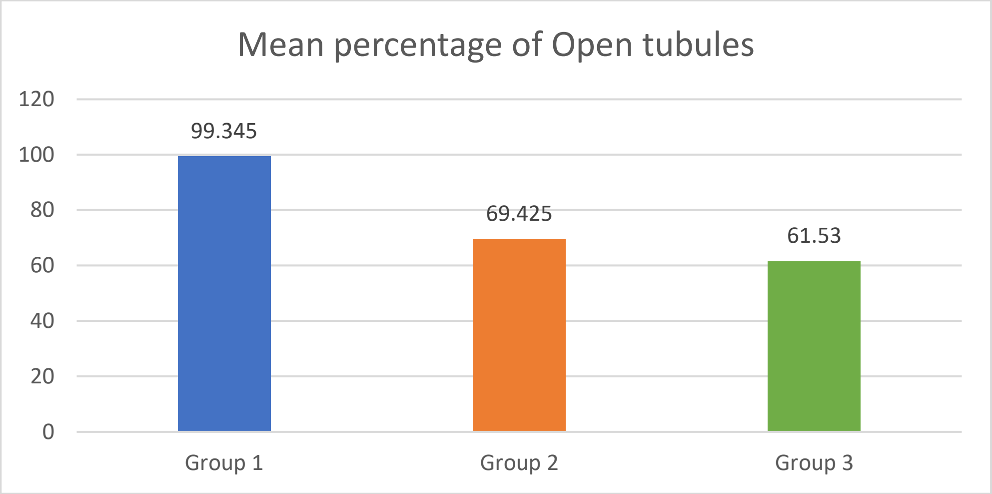


Fig2: Mean Percentage of Open tubules

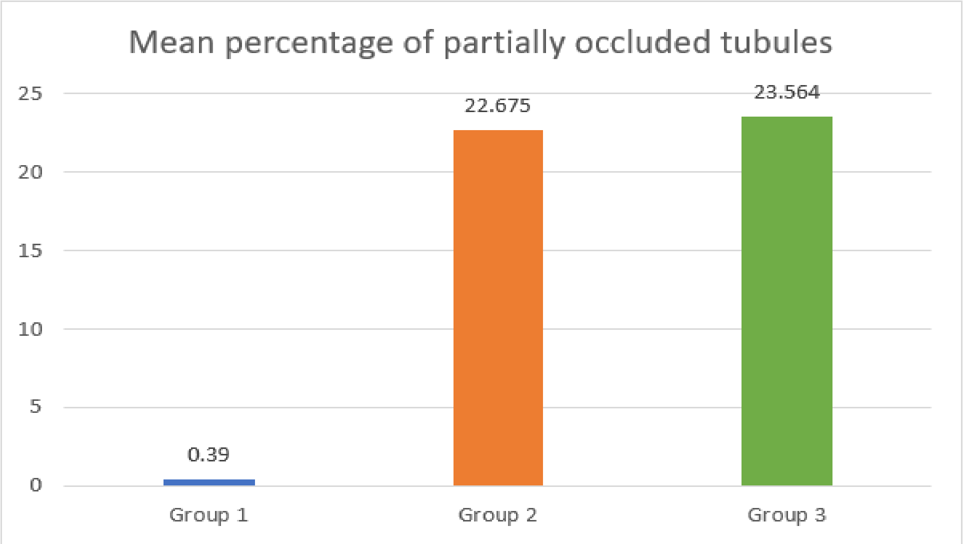


Fig3: Mean Percentage of partially occluded tubules

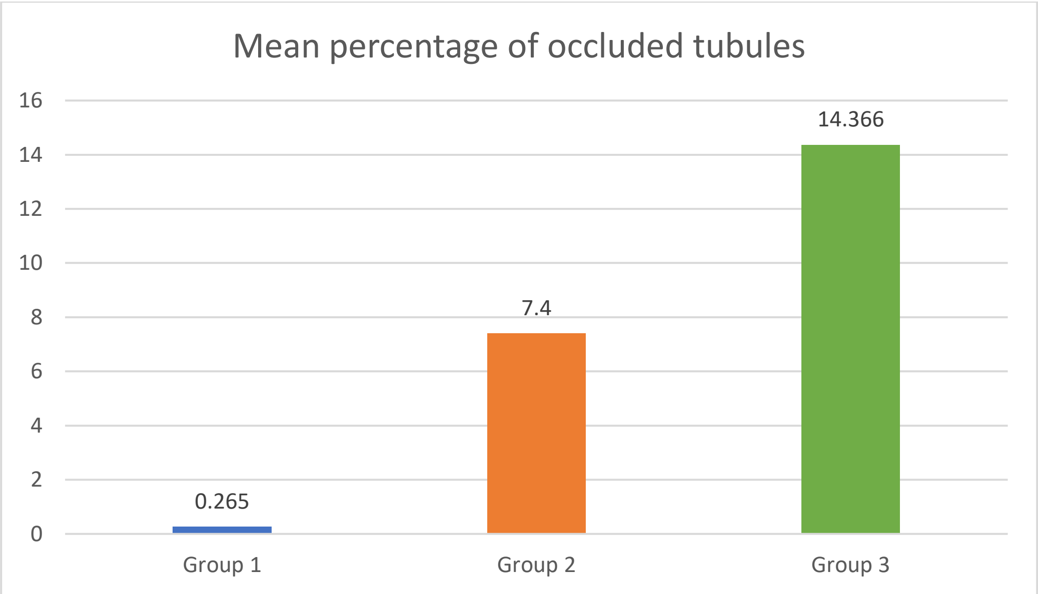


Fig4: Mean Percentage of completely occluded tubules

Tb 1: Intergroup comparison of Mean Percentage of Open tubules

Percentage of Open tubules					
	N	Mean	Std. Deviation	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Group 1	20	99.3450	.95061	98.9001	99.7899
Group 2	20	69.4250	9.14951	65.1429	73.7071
Group 3	20	61.5300	11.07649	56.3460	66.7140
p value[a]	<0.001, S				
Post hoc pairwise comparison[b]	Gr 1 * Gr 2 - <0.001, S Gr 1 * Gr 3 - <0.001, S Gr 2 * Gr 3 - 0.011, S				

[a]One way ANOVA, [b]Post hoc Tukey's test

Tb 2: Intergroup comparison of Mean Percentage of Semi-occluded tubules

Percentage of Semi-occluded tubules					
	N	Mean	Std. Deviation	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Group 1	20	.3900	.72685	.0498	.7302
Group 2	20	22.6750	7.26642	19.2742	26.0758
Group 3	20	23.5640	6.41274	20.5627	26.5653
p value	<0.001, S				
Post hoc pairwise comparison	Gr 1 * Gr 2 - <0.001, S Gr 1 * Gr 3 - <0.001, S Gr 2 * Gr 3 – 0.871, NS				

[a]One way ANOVA, [b]Post hoc Tukey's test

Tb 3: Intergroup comparison of Mean Percentage of Occluded tubules

Percentage of Occluded tubules					
	N	Mean	Std. Deviation	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Group 1	20	.2650	.45105	.0539	.4761
Group 2	20	7.4000	3.05631	5.9696	8.8304
Group 3	20	14.3660	5.43129	11.8241	16.9079
p value	<0.001, S				
Post hoc pairwise comparison	Gr 1 * Gr 2 - <0.001, S Gr 1 * Gr 3 - <0.001, S Gr 2 * Gr 3 – <0.001, S				

[a]One way ANOVA, [b]Post hoc Tukey's test

The descriptives of proportion of open, partially, and completely occluded tubules are shown in fig1,. The whiskers denoted the upper and lower limit. The box denotes the interquartile range while the horizontal line within the box denotes the median value. Intergroup comparison of Mean Percentage of Open tubules was done using one way ANOVA test.(Fig2,3,4).It showed that overall, a statistically significant differences were present in the extent of open tubules. Post hoc Tukeys test depicted that the mean proportion of open tubules among Gr 1 was found to be significantly higher than that among Gr 2, which was further significantly higher than that among Gr 3. (Tb1,2,3). Intergroup comparison of Mean Percentage of partially-occluded tubules was done using one way ANOVA test. It showed that overall, a statistically significant differences were present in the extent of partially-occluded tubules. Post hoc Tukeys test depicted that the mean proportion of partially-occluded tubules among Gr 2 & Gr 3 were found to be significantly higher than that among Gr 1. Intergroup comparison of Mean Percentage of Occluded tubules was done using one way ANOVA test. It showed that overall, a statistically significant differences was present in the extent of Occluded tubules. Post hoc Tukeys test depicted that the mean proportion of occluded tubules among Gr 3 was found to be significantly higher than that among Gr 2, which was further significantly higher than that among Gr 1.

DISCUSSION

The present study was conducted in the Department of Periodontics at I.T.S Dental College, Hospital and Research Centre, Greater Noida for evaluation of the dentinal tubule occlusion using Iontophoresis with 1.23 % Sodium Fluoride Gel and Diode Laser under Scanning Electron Microscope. Based on inclusion criteria, the study was conducted on 20 extracted teeth with 3 sections each and comparing open, partially occluded and completely occluded tubules among the control, iontophoresis and laser group under SEM DH is a common clinical condition that is frequently encountered these days yet very poorly understood [10]. Over the course of more than a century, many hypotheses have been put forth to explain the mechanisms involved in DH. Dentine hypersensitivity is of multi-factorial aetiology and many factors commonly involved in this painful complaint. Therefore consequently, more than one treatment modality should be applied to desensitize the dentine to acceptable levels.

Treatment of DH comprehend use of desensitizing agents applied topically by dentist or patient at home. The characters of ideal desensitizing technique/material should be an easy application, non-irritating to pulp, painless, consistent, and long-term effectiveness and rapid acting with no discoloration.[11,12] Moreover, recently laser irradiation become progressively popular in modern dentistry. Dentin desensitization can be accomplished using a variety of treatment techniques, but laser therapy, initially presented in 1985 by Matsumoto, has shown to be the most successful [13]. Low-power lasers, which modify nerve transmission rather than surface dentin, have recently grown in prominence. The theory that suggests that light permits higher passage of calcium, sodium, and potassium ions into the nerve cells may help to explain the quick reduction of DH recorded with the low power laser treatment. In turn, the buildup of these ions raises the endorphin system and cell action potential, blocking the C fiber afferents and obstructing the transmission of pain signals to the central nervous system. In addition to their alleged efficacy, lower-power diode lasers are currently on the market at affordable prices, providing a successful treatment for DH that requires less time than previous approaches in terms of isolation and application time [14].

NaF gel is chosen in this study as NaF gel is easily absorbed by dental hard tissues and fluoride ions and subsequently adsorbed under the walls of dentinal tubules as well as on the surface of calcium.[15] This compound forms an insoluble compound called calcium fluoride ($CaF2$) with the tooth material. This creates a brand-new physical barrier and reduces the permeability of dentinal tubules by reducing their diameter. Fluoride was found to infiltrate the pulp, interfere with its function, and reduce its vitality. As a result, it loses its sensitivity to pain, and an interaction between fluoride and other electrolytes, such calcium, renders these ions inaccessible to the body's regular system for transmitting pain [16] as it creates calcium fluoride crystals of a size of about 0.05. A single application of NaF is less effective because it produces little calcium fluoride crystals (about 0.05 m), which are easily soluble in saliva.[17]

1.23% APF was chosen in this study, as it has the highest concentration of fluoride ions (12,300 ppm) among all the fluoride gels used in dentistry. It has been postulated that fluorides used in higher concentrations were more effective in treating dentinal hypersensitivity.[18] In this study, concentration of 1.23 % NaF was used in combination with iontophoresis, as it was seen that at this concentration, secondary dentine formation occurs. Iontophoresis is an electric device which produces electric current once the circuit is completed. Application of the appropriately charged electrical current, ionized drugs can be driven into tissue based on the principle that like charges repel and opposite charges attract. Various hypothesis has been proposed to explain the mechanism of action of iontophoresis. One is that electric current results in dead tract due to formation of reparative dentin. Second is that it alters the sensory mechanism and thus produces paraesthesia. Third is that it may block the hydrodynamically mediated stimuli by microprecipitation of calcium fluoride. In our study it showed a positive significance in occlusion of dentinal tubules.

In our present study, the laser group exhibited complete occlusion in 14.36% of the tubules and partial occlusion in 23.56%. Our results agree with the results of Umana M et al., and Nandkumar A and Iyer VH who suggested that diode lasers were able to seal the dentin tubules [19-20]

However, diode lasers are frequently used to treat DH. Researchers primarily focus on destroying dentinal tubules while ignoring the laser's additional bio stimulatory effect. Mitochondrial ATP is increased by diode laser bio stimulation. Also, it has an analgesic effect by raising endorphin levels and free nerve endings' pain thresholds. It prevents the cyclooxygenase enzyme from converting arachidonic acid into prostaglandin, which increases the transmission of pain. Additionally, laser bio stimulation promotes odontoblasts' production of secondary dentin while simultaneously reducing inflammation [(21–25)]

In our present study, the iontophoresis group showed complete occlusion in 7.4% of the tubules and partial occlusion in 22.6% and there was a statistically significant difference. These results are concurrent with Mangalekar SB et al., [26] who reported that NaF iontophoresis provided better desensitising effect than dipotassium oxalate and potassium nitrate. Lefkowitz W et al., proposed formation of reparative dentin in response to current application to dentin resulting in formation of dead tracts in primary dentin [27] Here, the effective agent was direct current. Proposed mechanism involves electric current induced paraesthesia by altering sensory mechanism of pain conduction. Another alternative states that iontophoresis acts by influencing ionic motion by electric currents, thus enhancing ion uptake by the dentinal tubules, and achieving desensitization [28]

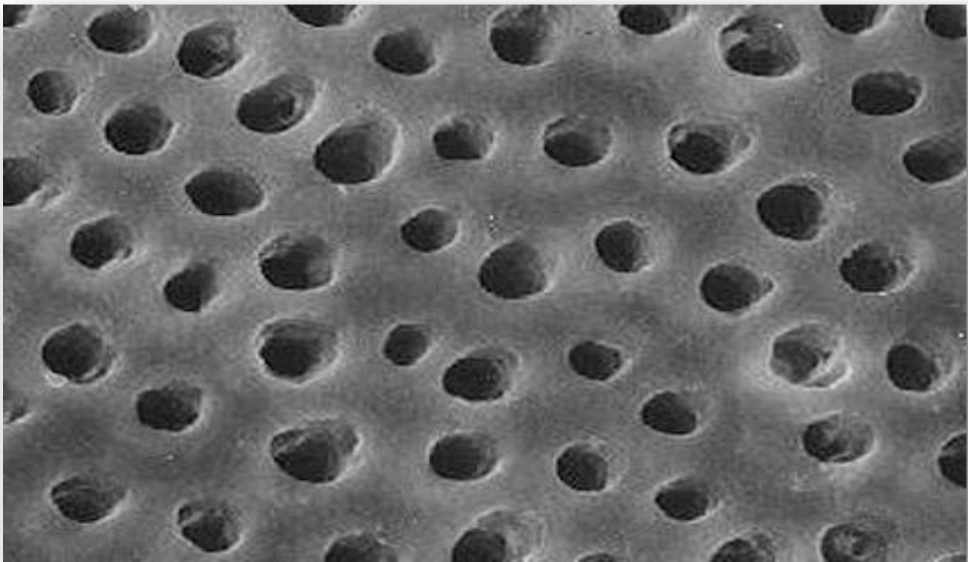
LIMITATION

- Small sample size
- Lack of clinical assessment of DH
- Only particular section of Dentin specimens
- Single power outputs
- Same concentrations of NaF gel

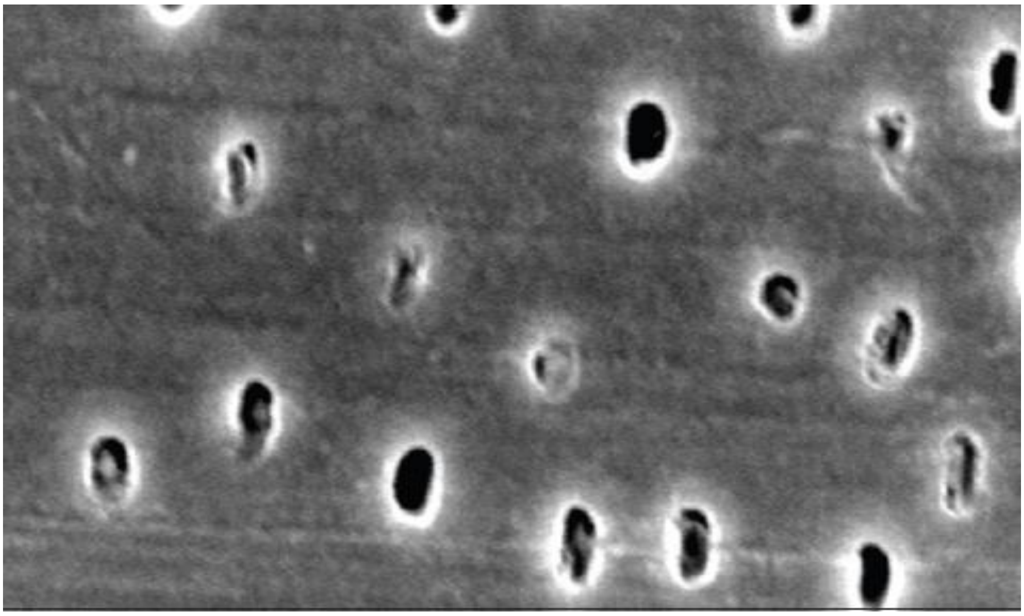
Conclusion

Within the limitation, the study concluded that 1.23% NaF gel with diode Laser was more effective in occluding dentinal tubules than with iontophoresis. Hence Diode laser are therefore more effective in treating DH more successfully and permanently than iontophoresis with NaF gel.

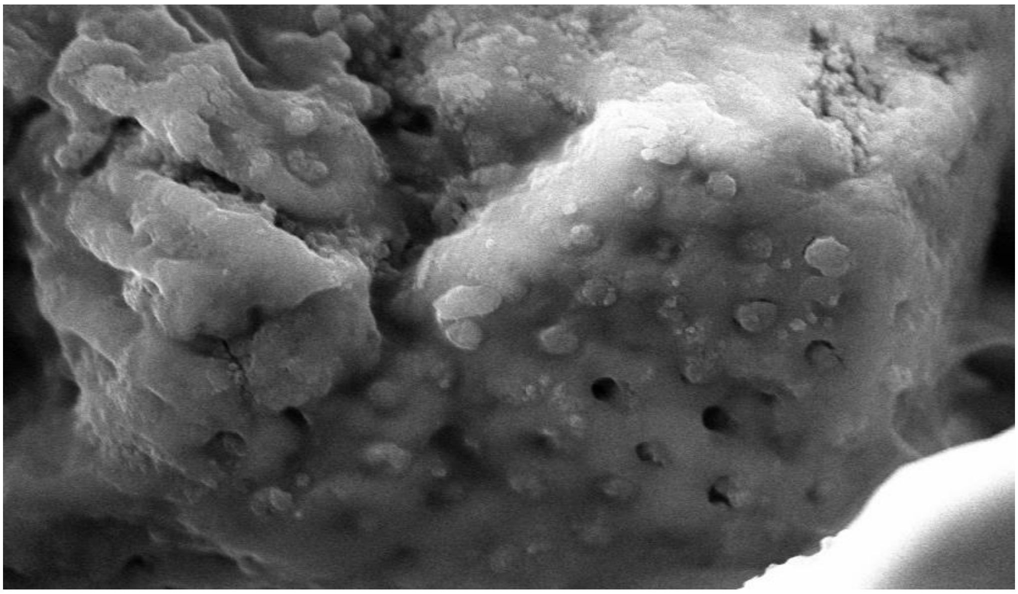
SEM VIEWS OF DIFFERENT GROUPS



Group 1-SEM view of Control Group



Group 2- SEM view of Iontophoresis Group



Group 3 –SEM view of Laser Treatment Group

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