ORIGINAL ARTICLE

The Efficacy and Durability of Three Desensitising Agents for Management of Hypersensitive Teeth: An *In Vitro* Study

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ABSTRACT

Introduction: Dentine hypersensitivity (DH) is a brief and acute pain produced when dentine is subjected to various stimuli. The treatment for DH has been classified by mode of delivery as at- home and in-office therapy. It was proven that desensitising agents have the capacity for occluding dentinal tubules. The purpose of this study was to evaluate the efficacy and durability of desensitising agents for management of DH. **Methods:** Twelve non-carious extracted human permanent premolars were sectioned into dentine layer. The dentine disc specimens were divided into four groups. Each group were applied with 8% arginine-calcium toothpaste, 0.24% sodium fluoride toothpaste, 5% potassium nitrate toothpaste and distilled water respectively. Scanning Electron Microscope (SEM) is used to evaluate the magnitude changes of dentinal tubules post treatment with the desensitising toothpastes in terms of the efficacy and durability at day one, week one and week three after application. The data will be analyzed by analysis of variance (ANOVA) using the Statistical Package for the Social Sciences (SPSS) software (version 19.0). **Results:** All toothpastes demonstrated significant dentinal tubule occlusions. However, 8% arginine-calcium toothpaste showed the greatest percentage of occlusion at day one followed by potassium nitrate toothpaste and sodium fluoride toothpaste. After three weeks, 8% arginine-calcium toothpaste remained the greatest percentage of dentinal tubules occlusion **Conclusion:** The result revealed that 8% arginine-calcium toothpaste is the most efficient and has longer durability among the other toothpaste. Therefore, with this finding it could help the patient for selection of desensitising toothpaste in managing the DH.
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Keywords: Dentine hypersensitivity, Desensitising agent, 8% arginine-calcium, 0.24% sodium fluoride, 5% Potassium nitrate toothpaste

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INTRODUCTION

Dentinal hypersensitivity (DH) affects one's quality of life and becomes major problem nowadays. It is presented as short, sharp pain resulting from exposed dentine and occurs typically in response to chemical, thermal, evaporative, or even osmotic stimuli and cannot be categorised to any other type of dental pathology or disease (1).

Among previous studies, DH is considered as the most frequent complaint by many patients in dental office (2). Patients who have periodontal problems reported to be at high risk (70%) of experiencing DH (3). Dental literature suggests that both men and women may suffer DH with prevalence of occurrence is age group of thirty to forty year (4). Moreover, premolars are the most frequent tooth affected by this phenomenon compared to other teeth in the oral cavity (3).

The mechanisms of DH are explained by several theories, but the widely accepted explanation is the hydrodynamic theory which had been designed by Brannstrom (5). This theory describes that the main factors in the pathophysiology of DH are the patent dentinal tubules and the exposed dentine to oral cavity (6). Rapid flow of dentinal fluid in response to the stimuli then stimulates the pulpal nerve endings and subsequently causes irritation to the pulp (7).

Generally, there are two methods available in managing DH which are at-home and in-office treatment (8). In-office treatment includes application of the dentine bonding agents HEMA, lasers, restorative material and periodontal surgery done by clinician. While at-home treatment is done by the patients themselves at home. The most widely agents used for this approach is home-use desensitising toothpastes which are available in the market. These toothpastes work in either by blocking the pulp nerve response or occluding the dentine tubules (9).

Majority of home-use desensitising toothpastes are those which occlude the dentinal tubule. These toothpastes contain a wide variety of active components which is responsible to block the dentinal tubule, preventing the exposure of the dentine to the stimuli (6). Arginine, calcium carbonate, fluoride, oxalate and calcium sodium phosphosilicate are some of the active components used in the desensitising toothpastes. Several studies proved that the primary action of the potassium-containing toothpastes is blocking the pulp nerve response. Nonetheless, there are hypothesis claim that potassium may be absorbed into dentine and finally resides at the junction between the dentine and the pulp (10). This process eventually causes the exposed dentinal tubules to be occluded, similar to the concept suggested above.

Up to these days, there are only few in vitro studies conducted on desensitising agents to find out their efficacy and durability for occluding dentinal tubules. Efficacy according to Cambridge English Dictionary is defined as the ability, especially of a medicine or a method of achieving something, to produce the intended result while durability is defined as the ability to last and be used for a long time without becoming damaged. In this context, efficacy is said to be the capability of the desensitising toothpaste to occlude the dentinal tubule after its application and durability in simple words is how long does the applied toothpaste work. As for this study, it is expected that the desensitising agent containing 8% arginine calcium carbonate to be occluded more and at the longest duration of time in the dentinal tubules compared to others. This will suggest that it is an effective and durable desensitising agent for management of DH.

MATERIALS AND METHODS

Samples

Twelve extracted sound human premolar teeth were obtained from the dental outpatient clinic and were preserved in the normal saline. Decayed teeth, fractured teeth and teeth with malformations were excluded in this study. The teeth were stored in normal saline inside the incubator until further use.

Each tooth was cut horizontally at the mid coronal area into a flat dentine disc using saw machine. Then, the dentine discs were smoothen using a sandpaper. To remove the smear layers and debris on the dentine disc surfaces, the dentine discs were etched with 37% phosphoric acid for fifteen seconds and rinsed thoroughly followed by light air drying.

All twelve dentine disc specimens were divided equally into four groups: group A, B, C and D respectively. Group A was applied with 8% arginine-calcium carbonate-containing toothpaste, group B was applied with 0.24% sodium fluoride-containing toothpaste, group C was applied with 5% potassium nitrate-containing toothpaste while group D which acted as the negative control group, was applied with distilled water. All the materials were applied using dental micro brush for one minute without rinsing and stored at the body temperature (36.7°C) inside the incubator.

SEM evaluation of the number dentinal tubules occlusion
After twenty-four hours, the first specimens from each group were mounted on stubs and gold coated then viewed under scanning electron microscope (SEM). Micrographs were taken at 100k magnification. The same procedures were repeated on the second and third specimens at week one and week three. For data collection, each specimen was observed three times to get the mean of the dentinal tubule occlusion. The number of the occluded dentinal tubules was quantified using the image analysis software programme, Image J (http:// imagej.nih.gov/ij/docs/guide).

Statistical analysis

All data were analysed using SPSS VERSION 19. The statistical significance was defined by a $p \leq 0.05$. Values for calculation were presented as mean ± SD.

RESULT

The collected data were statistically analyzed by one-way analysis of variance (ANOVA). Then, multiple comparisons were performed using Tukey's post hoc tests between groups (significance level $p<0.05$) using SPSS Statistics Version 19. The magnitude changes on the occlusion of the dentinal tubules (to evaluate the

efficacy and durability) of each desensitising toothpaste were observed under SEM. The number of dentinal tubules occlusion on day one, week one and week three was then calculated and evaluated as shown in Fig. 1. In this variation time of the percentage dentinal tubules occlusion for each studied toothpastes, it can be observed that the highest percentage after one day was the Group A, followed by Group C and Group B. However, it showed the decreases in the percentage of dentinal tubule occlusion throughout the investigation period for all these three groups. Meanwhile, Group A revealed the greatest dentinal tubule occlusion percentage after three weeks duration.

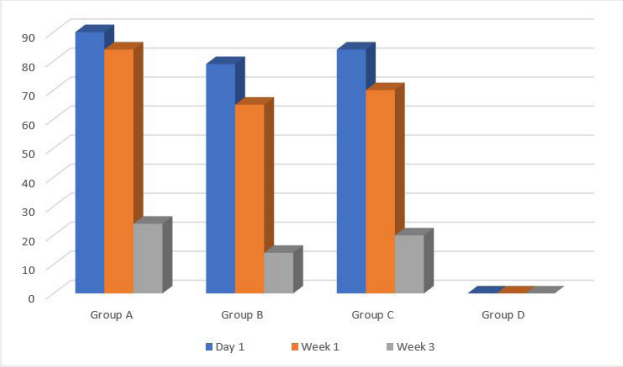

Figure 1: The variation in time of the percentage of dentinal tubule occlusion for each studied toothpastes. For percentage dentinal tubule occlusion at day one, there was statistically significant differences present among all four groups in ANOVA test ($p< 0.05$). Since [$F (3, 8) = 418.335$, $p< 0.05$] there was a significant difference in the mean percentage of dentinal tubule occlusion at day one across four groups.

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The independent-samples Kruskal-Wallis test p-value was 0.000 and for percentage of dentinal tubule occlusion across all four different groups from day one until week three. By pairwise comparison, all test groups showed significantly more dentinal tubule occlusion as compared to control group. Statistical analysis did not reveal any significant difference in the percentage of dentinal tubule occlusion among the three different groups of toothpastes shown in Table I.

As from the statistical analysis presented in Table I, the median percentage of dentinal tubule occlusion for Group A (80.98, 71.00) was significantly higher than Group C (66.87, 54.50). While the median percentage of dentinal tubule occlusion for Group B (57.02, 50.84) was lower than Group C (66.87, 54.50).

DISCUSSION

Several studies have shown that the precipitates of arginine, calcium carbonate and phosphate within dentine tubules efficiently lower the fluid flow thus minimized hypersensitivity (11). In earlier clinical study, toothpaste consisting of 8% arginine, calcium carbonate and 1450ppm fluoride is proven to offers remarkably greater hypersensitivity relief after eight weeks of product use compared to commercial sensitive toothpaste containing 2% potassium (12).

Arginine-calcium carbonate is highly effective in occluding dentine tubules quickly and completely. As the name implies, this toothpaste contains arginine, a positively charged amino acid in physiological pH, bicarbonate as a pH buffer and calcium carbonate. Its action is based on the normal function of saliva, which also contains arginine and calcium carbonate. Arginine-calcium carbonate provides calcium and phosphorus ions to travel to the exposed dentinal tubules and create a precipitate to occludes the tubules.

Besides that, fluorides are believed to develop the mineralization of hydroxyapatite and its formation within the dentine tubules, consequently, hinders fluid flow thus reduces the sensitivity (8). Furthermore, fluorides also increase resistance against acid towards dental hard tissue. A lot of clinical studies showed that toothpaste containing sodium fluoride or high fluoride content is efficient in managing DH (9).

Several studies proved that the primary action of the potassium-containing toothpastes is blocking the pulp nerve response. Nonetheless, there are hypothesis claim that potassium may be absorbed into dentine and finally resides at the junction between the dentine and the pulp (6). This process eventually causes the exposed dentinal tubules to be occluded, similar to the concept suggested above.

A rapid, long-lasting effects, painless, non-irritant to pulp, easy to apply, and not causing staining of the tooth are the requirements for an ideal desensitising agent (13). The mechanism of the desensitising agents is by purporting the active Ions to occlude and to block the exposed dentinal tubules. As a result, the occluded dentinal tubules prevent the stimulation of pulpal nerve endings which consequently leads to reduce the problem of DH. The efficacy and durability of these variety desensitising

agents might be differed between one with another. In the present study, the twelve dentine disc specimens were used and soaked in normal saline to simulate the in vivo environment following brushing the teeth. The magnitude of dentinal tubules occlusion was evaluated at day one which reflects the efficacy of the toothpastes twenty-four hours after the application. The occlusion of the toothpaste however will become reduce over some period as it might be brushed away through mechanical factors such as during tooth brushing. This phenomenon is inevitable. Therefore, to assess the durability of these desensitising toothpastes, the percentage of dentinal tubules occlusion was evaluated again at week one and week three. This means that, the toothpaste that persist the greatest percentage of dentinal tubules occlusion at week three is believed to be the most durable as it portrays the smallest magnitude of changes over time.

This study showed that the highest percentage of dentinal tubules occlusion at day one was attained by 8% arginine-calcium carbonate toothpaste. This was followed by 5% potassium nitrate toothpaste, whereas 0.24% sodium fluoride toothpaste presented with the lowest percentage of dentinal tubules occlusion under SEM. It reflected that the most effective desensitising agent for dentinal tubules occlusion was revealed by using 8% arginine-calcium carbonate toothpaste followed by 5% potassium nitrate toothpaste and 0.24% sodium fluoride toothpaste.

The null hypothesis was rejected as there were significantly differences in the percentage of dentinal tubule occlusion at day 1 among three groups of toothpaste ($p < 0.05$). Table I presented that the Group A (8% arginine-calcium carbonate) was the highest mean percentage of dentinal tubule occlusion followed by Group C (5% potassium nitrate). The lowest mean percentage of dentinal tubule occlusion was Group B (0.24% sodium fluoride). Thus, it reflected that the most effective desensitising agent with 82.3116 of mean percentage of dentinal tubules occlusion was revealed by using 8% arginine-calcium carbonate toothpaste followed by 5% potassium nitrate toothpaste and 0.24% sodium fluoride toothpaste.

After one week and three weeks of application the desensitising agents, again Group A (8% arginine-calcium carbonate) presented with the greatest percentage of dentinal tubules occlusion (80.98) under SEM. This was followed by Group C (5% potassium nitrate); (66.87). Then, the smallest percentage of dentinal tubules occlusion was shown by using 0.24% sodium fluoride toothpaste (57.02). These data indicate that the 8% arginine-calcium carbonate toothpaste is the most durable desensitising agent among the other two desensitising agents.

It was an evidence based on previous in vitro studies that was conducted by Kumar S. (14) that assessed the effectiveness of dental products containing 8% arginine and calcium carbonate. The result of this study revealed that the arginine-calcium carbonate technology is greatly effective in blocking dentine tubules under the Confocal Laser Scanning Microscopy (CLSM), Scanning Electron Microscopy (SEM), and Atomic Force Microscopy (AFM) studies. This study also showed that there was significant reduction in dentine fluid flow in dentinal tubules occlusion by using arginine and calcium carbonate.

Table I: Percentage of dentinal tubule occlusion across all four different groups from day one until week three.

Groups	Median% (IQR)	*p*-value
A	80.98 (71.00)	
B	57.02 (50.84)	
C	66.87 (54.50)	0.00
D	0.00 (0.0)	

From the statistical analysis as presented in Table I, the median percentage of dentinal tubule occlusion for Group A (80.98, 71.00) was significantly higher than Group C (66.87, 54.50). While the median percentage of dentinal tubule occlusion for Group B (57.02, 50.84) was lower than Group C (66.87, 54.50).

Although there are extensive *in vitro* studies exploring occlusion of dentine with toothpastes, but there is none similar study that evaluated the effectiveness and durability comparing the three desensitising agents which are 8% arginine-calcium carbonate toothpaste, 0.24% sodium fluoride toothpaste and 5% potassium nitrate toothpaste evaluating for the magnitude changes of dentinal tubules occlusion post treatment under SEM. It was found that a lot of previous studies were conducted for the particular desensitising agent respectively (15).

From the results shown in this study, it could give an option to the patient for selection of desensitising toothpaste as at-home treatment in managing DH. Furthermore, this desensitising toothpaste is widely available in the supermarkets around Malaysia. Therefore, it can be said that this toothpaste is somehow well known and easily accessible by the Malaysians population. It is hoped that more research especially in the in vivo study would be conducted to further prove the validity of this study. In the future, perhaps this study also could be developed into a clinical study for further assessment of the efficacy of desensitising agents for DH management.

CONCLUSION

From this study, it can be concluded that 8% arginine-calcium carbonate-containing toothpaste is the most effective and durable among the three-desensitizing agent for management of DH. By this finding, it can enhance the treatment efficacy of home remedies using this toothpaste for patients' satisfaction. Moreover, this study has a potential in capturing as one of the humanizing technologies in line with the Principles of Maqasid al-Shari'ah in sustainable healthcare and wellbeing.

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