

# IN VITRO EFFICACY OF DIFFERENT DESENSITIZING TOOTHPASTES ON DENTINAL TUBULE OCCLUSION

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**Abstract.** Dentinal hypersensitivity is a common complaint encountered by dentists. In this study, we aimed to assess the efficacy of selected desensitizing toothpastes on the percent of dentinal tubules occluded and the depth of dentinal tubule penetration in order to select the best toothpaste to treat dentinal hypersensitivity. Thirty extracted healthy human premolar teeth were used to prepare 60 dentin blocks with a uniform dimension of 2 mm x 5 mm x 5 mm each. The blocks were divided into 4 (1 control and 3 test) groups, each consisting of 15 samples: 1) saliva control group (CG), 2) Apagard Premio toothpaste (AP), 3) Tooth Builder toothpaste (TB) and 4) Elsenz toothpaste (EZ). The tested toothpastes and control were applied to the respective dentin blocks for two minutes twice daily for 15 days. Post-application, all dentin blocks were examined with scanning electron microscopy (SEM) to detect the percentage of occluded dentinal tubules and the depth of penetration at 2000x and 1500x magnification, respectively. SEM revealed the AP group caused a significantly ( $p < 0.001$ ) greater (mean  $\pm$  standard deviation (SD) percentage of dentinal tubules occluded after treatment ( $71 \pm 4\%$ ) than the EZ ( $63 \pm 3\%$ ), TB ( $54 \pm 3\%$ ) and CG ( $1 \pm 1\%$ ) groups. The AP group samples had a significantly ( $p < 0.001$ ) greater (mean  $\pm$  SD) depth of penetration of tubules ( $200 \pm 15 \mu\text{m}$ ) than the EZ ( $145 \pm 26 \mu\text{m}$ ), TB ( $94 \pm 9 \mu\text{m}$ ) and control ( $0 \pm 0 \mu\text{m}$ ) groups. In summary, all the tested commercial toothpastes were significantly more effective in occluding and penetrating dentinal tubules than the control and AP toothpaste had a significantly greater percentages of tubules occluded and a deeper penetration depth of dentinal tubules than the TB and EZ groups. Our results suggest AP toothpaste is likely to be more effective in treating dentinal hypersensitivity than the other tested toothpastes. Further in vivo studies among human subjects are needed to test this hypothesis.

**Keywords:** dentin hypersensitivity, dentinal tubules, depth of penetration, desensitizing

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## INTRODUCTION

Dentinal hypersensitivity (DH) is a common problem worldwide (Hines *et al*, 2019). DH is a sharp, localized pain lasting for a short duration due to stimulation of exposed dentin by a thermal, chemical, tactile, evaporative or osmotic stimulus (Bakri *et al*, 2017). The exposure may occur due to erosion, abrasion or attrition of the dentin from periodontal disease or gingival recession (Hines *et al*, 2019). A tooth with DH has a substantial number of open dentinal tubules, consequently permitting direct exposure of the pulpal tissues to the oral environment (Splieth and Tachou, 2013). DH is induced by movement of the fluid inside the dentinal tubules resulting in activation of sensory neurons in the pulpal tissues (Bahal *et al*, 2019). DH occurs most frequently among those aged 20-50 years (Li, 2012). Seventy-two to 98 percent of patients with periodontal disease have reported DH (Hines *et al*, 2019; Que *et al*, 2013; Bahal *et al*, 2019).

DH affects the quality of life by interfering with eating, drinking, talking, tooth brushing and obtaining dental care (Garofalo *et al*, 2019). The DH has been reported to affect the quality of life in 10% of subjects with DH (Takamizawa *et al*, 2019; Gillam *et al*, 2002). Scaling and root planning can increase DH in 35% of dental patients and DH can adversely affect oral health care (Bahal *et al*, 2019; Goh *et al*, 2016).

DH can be relieved by modifying the surface of the dentin (Gillam *et al*, 2002). There are two major methods for treating DH; dentinal tubule

occlusion and nerve response obstruction (Hines *et al*, 2019; Addy and West, 2013). Dentinal tubule occlusion is accomplished by brushing with a dentifrice containing an active ingredient that occludes the dentinal tubules through various mechanisms (Hines *et al*, 2019; Kunam *et al*, 2016). Nerve response obstruction is accomplished by using a dentifrice that desensitizes the nerves. Potassium salts, such as potassium chloride, potassium nitrate and potassium citrate, block the nerve response by depolarizing the nerve endings (Hines *et al*, 2019; Markowitz, 2013; Poulsen *et al*, 2006).

Dentinal tubule occlusive agents include: NovaMin (Fluoro-calcium-phosphosilicate) (Shah *et al*, 2017), Pro-Argin (8% arginine and calcium carbonate) (João-Souza *et al*, 2018), strontium compounds (Hines *et al*, 2019; West *et al*, 2013), nano abrasive sealing particles (George *et al*, 2018), fluoride (Mason *et al*, 2010), oxalate salts (Bahal *et al*, 2019) and resin sealers (Hines *et al*, 2019).

Commercially available products for consumers include toothpaste, chewing gum and mouthwash (Hiller *et al*, 2018). Desensitizing toothpaste may contain strontium acetate, hydroxyapatite (HAp), calcium sodium phosphosilicate (bioglass), arginine with calcium carbonate and strontium chloride, as active components (João-Souza *et al*, 2018; West *et al*, 2013).

HAp has bioactive properties similar to dental hard tissue (Kunam *et al*, 2016). Recent studies have reported the use of HAp containing toothpaste is better

than fluoride toothpaste for managing DH, since HAp induces remineralization by forming a biomimetic apatite coating on the surface of the enamel and dentin (Hiller *et al*, 2018; Shah *et al*, 2017). This process occurs rapidly due to the chemical-physical properties of novel nano-structured HAp particles that are similar to the mineral components of enamel (Ansari *et al*, 2014).

Clinical studies have reported dentifrices containing fluoride at a concentration of 1,450 ppm, along with calcium carbonate provides relief from DH (Lavender *et al*, 2010; Ashwini *et al*, 2018). Fluoro-calcium-phosphosilicate, a fluoride-containing bioglass, has been used to treat DH. Fluoroapatite is more stable in acid formed by bacteria than HAp and encourages remineralization due to the phosphate and calcium released from the bioglass (Ashwini *et al*, 2018). The desensitization effect is directly proportional to the depth of penetration: the deeper the penetration of the particles, the longer will be the duration of the effect (Bahal *et al*, 2019).

In this study we aimed to determine the efficacy of various commercially available desensitizing toothpastes for occluding dentinal tubules and the depth of penetration in order to inform dental professionals about the toothpaste that has the greatest chance of reducing DH.

## MATERIALS AND METHODS

The current study was an *in vitro*, single-blinded, experimental study. The study protocol was approved by the Institutional Ethics Committee,

College of Dentistry, King Khalid University, Abha, Kingdom of Saudi Arabia (SRC/ETH/2018-19/037). The principles of the Helsinki Declaration were followed while collecting and using the human teeth samples. Thirty fully erupted, non-carious, premolar teeth from healthy adults aged 20-40 years were extracted for orthodontic reasons at the Department of Oral Surgery, King Khalid University after receiving written informed consent from the patients. Each tooth was sectioned to obtain two similar dentinal blocks. The extracted teeth were then stored in formalin at 4°C until used for the study which was conducted within 3 months of extraction.

Each tooth was sectioned at the cemento-enamel junction and the crown was used for the study. Each sample was cut perpendicular to the long axis of the tooth using a water-cooled diamond saw (Komet type 917, Lemgo, Germany) (Fig 1) to expose the dentin. Sixty dentin blocks, each 2 mm x 5 mm x 5 mm, were prepared. Each dentinal sample was polished using 600-grit silicon carbide paper to form a flat, smooth surface. The samples were then washed with distilled water in an ultrasonic cleaner (BioSonic UC125, Coltene, Switzerland) for 10 minutes to remove debris and remove the smear layer. To obtain patent dentinal tubules, each sample was treated with 17% ethylenediaminetetraacetic acid (EDTA) solution (MD-Cleanser, Meta Biomed, Chungbuk, South Korea) for 5 minutes. An identification mark was placed on the pulpal side of each sample so the dentinal surface could be identified.

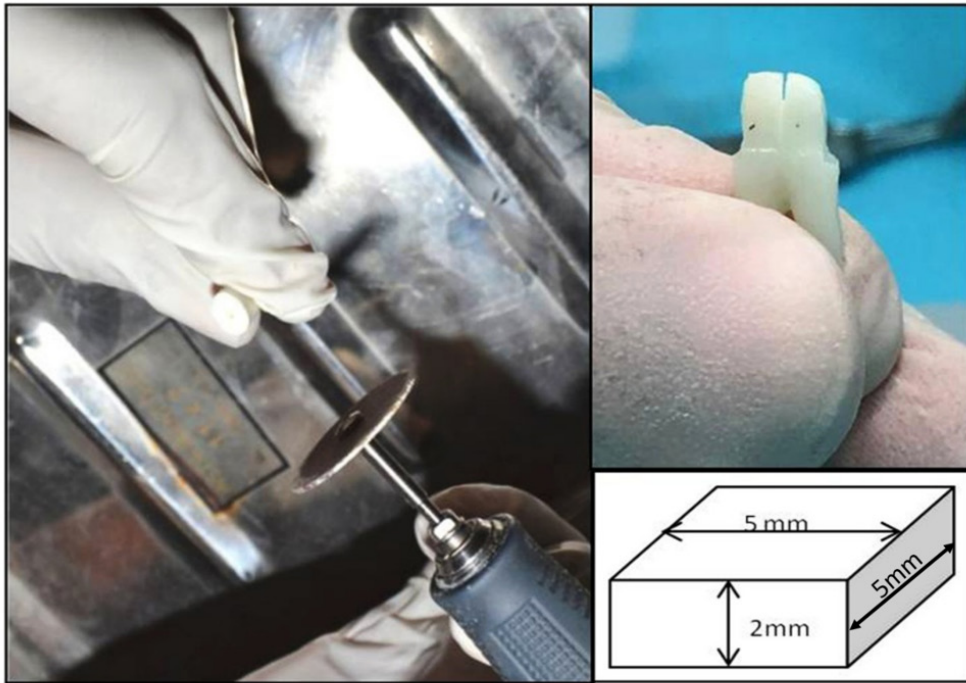


Fig 1 - Preparation of dentinal blocks (5 mm x 5 mm x 2 mm) from extracted premolars

The samples were randomly allocated into one of 4 study groups consisting of 15 samples each: three test and one control group (CG). The commercially available experimental toothpastes used for this study were: 1) Apagard Premio<sup>®</sup>(AP) toothpaste (containing nano-hydroxyapatite crystals (nHAp) and calcium hydrogen phosphate (CHP)) (Sangi Co Ltd, Tokyo, Japan), 2) Tooth Builder<sup>®</sup>(TB) toothpaste (containing non-ionized calcite (NIC)) (Squigle Inc, Philadelphia, PA) and 3) Elsenz<sup>®</sup>(EZ) (containing fluoro-calcium phosphosilicate (FCPS)) (Group Pharma Ltd, Bengaluru, India).

One hundred fifty milliliters of human saliva was obtained from a voluntary saliva donor. The donor was asked not to eat or drink for 30 minutes prior to saliva collection. The saliva donor was asked to wash their oral cavity with distilled water and to chew a paraffin-polyethylene sheet to enhance salivary flow prior to saliva collection. The saliva sample was then stored in a sterile container at -20°C until used.

The studied toothpastes were applied to the dentin samples in their respective groups twice daily for 2 minutes each time for 15 days. The dentin blocks were exposed to

temperature fluctuation (described below) between treatments to replicate the conditions of the oral cavity as described previously (Krifka *et al*, 2017; Spitznagel *et al*, 2014). Two temperature baths, one at 5°C and the other at 55°C, were prepared and the dentin block samples were immersed alternately in each for 30 seconds for a total of 100 cycles/day (Hiller *et al*, 2018). One milliliter human saliva was applied to each sample followed by application of 1 g of the respective undiluted study toothpaste using a medium bristle toothbrush with a small head (Oral-B®, Procter & Gamble, Cincinnati, OH). The sample was then brushed keeping the bristles perpendicular to the sample surface for 2 minutes. After brushing, the sample was washed with normal saline and then stored in saliva at 37°C; the study was continued for 15 days (Bakri *et al*, 2017). In the control group (CG), no surface treatment was applied to the samples. At the end of the 15-day treatment, each sample was dried in a desiccator for 24 hours and then stored until examined with scanning electron microscopy (SEM).

SEM was used to determine the category score for dentinal occlusion, the percentages of tubules completely, partially and not occluded (at 2000x magnification) and the depth of occlusion (at 1500x magnification) (FEI Quanta 250, Thermo Fisher Scientific, Eugene, OR). The category score for dentinal tubule occlusion has been described previously (Al-Saud and Al-Nahedh, 2012): all the dentinal tubules were open and there was no surface debris (1 point); the dentin

tubules were partially occluded with narrowing of the tubular orifices and there was little or no surface debris (2 points); most of the dentinal tubules were occluded and there was little or no surface debris (3 points); most of the dentinal tubules were occluded and the dentinal surface was partially covered by a film or precipitate (4 points); all the dentinal tubules were completely occluded and the dentinal surface was completely covered with a film or precipitate (5 points).

The percentages of completely occluded, partially occluded and not occluded (open) tubules were calculated by taking a photomicrograph and evaluating the photo for each sample and counting the numbers of tubules that were completely occluded, partially occluded and completely open.

After the dentinal tubules were evaluated for occlusion, the samples were longitudinally sectioned using an orthodontic saw (Rocky Mountain Orthodontics, Denver, CO) to obtain a longitudinal slice of each sample. Each sample was then evaluated to determine the depth of penetration of the occlusion caused by the tested toothpaste and if there were any changes in the dentin surface. The average penetration depth in micrometers for each specimen was calculated after examining at least 20 tubules per specimen.

The results for the various groups were compared using the one-way ANOVA test. Multiple comparisons were made using the Bonferroni correction (post hoc) test. Statistical calculations were performed using the

Statistical Package for Social Sciences (SPSS), version 23.0 (IBM Corporation, Armonk, NY) for Microsoft Windows. A  $p$ -value  $<0.05$  was considered statistically significant.

## RESULTS

All the tested toothpastes caused occlusion of the dentinal tubules but the results varied by group (Table 1). The mean ( $\pm$  standard deviation (SD)) dentinal tubule occlusion category score for the AP group ( $4.5 \pm 0.7$ ) was significantly ( $p < 0.001$ ) higher than the TB ( $3.4 \pm 0.8$ ) and CG ( $1.5 \pm 0.5$ ) groups. However, the mean ( $\pm$  standard deviation (SD)) dentinal tubule occlusion category score for the AP group ( $4.5 \pm 0.7$ ) was not significantly ( $p < 0.489$ ) higher than the EZ ( $4.0 \pm 0.8$ ) group.

On SEM, the (mean  $\pm$  SD) percentages of specimens with completely open, partially open and completely closed dentinal tubules in the AP, EZ, TB and CG groups were ( $10 \pm 2\%$ ), ( $19 \pm 3\%$ ), ( $71 \pm 4\%$ ); ( $16 \pm 2\%$ ), ( $21 \pm 2\%$ ), ( $63 \pm 3\%$ );

( $24 \pm 2\%$ ), ( $22 \pm 2\%$ ), ( $54 \pm 3\%$ ); ( $93 \pm 3\%$ ), ( $6 \pm 3\%$ ), ( $1.3 \pm 1\%$ ), respectively (Figs 2a, b, c, d) (Table 2). The AP group had significantly ( $p < 0.001$ ) more specimens with completely occluded tubules than the EZ and TB groups.

On depth of penetration the AP group had a significantly greater mean ( $\pm$  SD) penetration depth ( $200 \pm 15 \mu\text{m}$ ) than the EZ ( $145 \pm 26 \mu\text{m}$ ) ( $p < 0.001$ ), TB ( $94 \pm 9 \mu\text{m}$ ) ( $p < 0.001$ ), and CG ( $0 + 0 \mu\text{m}$ ) ( $p < 0.001$ ) groups (Figs 3a, b, c, d) (Table 3).

When comparing the dentinal occlusion scores, percentages of completely open, partially occluded and closed tubules and the depths of occlusion among all the studied groups we found all comparisons were significantly different from each other except: the percentages of partially occluded tubules were not significantly different among each other for the AP, EZ and TB groups; the dentinal tubule occlusion score was not significantly different between the AP and EZ groups

Table 1

Dentinal tubule occlusion scores for studied toothpastes

Toothpaste	N	Mean	SD	SE	95% CI of mean score range
CG	15	1.5	0.5	0.1	1.2 - 1.8
AP	15	4.5	0.7	0.2	4.05 - 4.88
EZ	15	4.0	0.8	0.2	3.58 - 4.41
TB	15	3.4	0.8	0.2	2.94 - 3.86

CG: Control Group; AP: Apagard Premio<sup>®</sup>; EZ: Elsenz<sup>®</sup>; TB: Tooth Builder<sup>®</sup>  
SD: Standard deviation, SE: Standard error; CI: Confidence interval

Table 2  
Percentages of studied toothpastes by category of dentinal tubule occlusion

Category of tubule occlusion	CG		AP		EZ		TB	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Percent with completely open tubules	93	3	10	2	16	2	24	2
Percent with partially occluded tubules	6	3	19	3	21	2	22	3
Percent with completely occluded tubules	1	1	71	4	63	3	54	3

CG: Control Group; AP: Apagard Premio<sup>®</sup>; EZ: Elsenz<sup>®</sup>; TB: Tooth Builder<sup>®</sup>  
SD: Standard deviation

and between the TB and EZ groups (Table 4).

## DISCUSSION

In our study, all 3 studied toothpastes were significantly more effective in occluding dentinal tubules than the control and the AP toothpaste (containing nHAp and CHP) was significantly more effective than the TB (containing NIC) and EZ (containing FCPS) toothpastes, similar to the results of previous studies (Gopinath *et al*, 2015; Kunam *et al*, 2016).

In our study, all three studied toothpastes had significantly better dentinal tubule penetration depth than the control and AP toothpaste (containing nHAp and CHP) gave significantly better penetration depth than the TB (containing NIC) and EZ (containing FCPS) and toothpastes. This better AP penetration may be due to the small size of the nHAp in an acidic environment (Takamizawa *et al*, 2019).

The results of the current study show AP (containing nHAp and CHP) gave a high percentage of occluded tubules, similar to previous studies that reported CHP was an effective treatment for DH (Gautam and Halwai, 2017; Bahal *et al*, 2019). In our study, AP (containing nHAp and CHP) gave higher percentages of occluded dentinal tubules than the other tested toothpastes, similar to previous studies (Hines *et al*, 2019; Addy and West, 2013). In our study, AP (containing nHAp and CHP) gave similar percentages of dentinal tubule

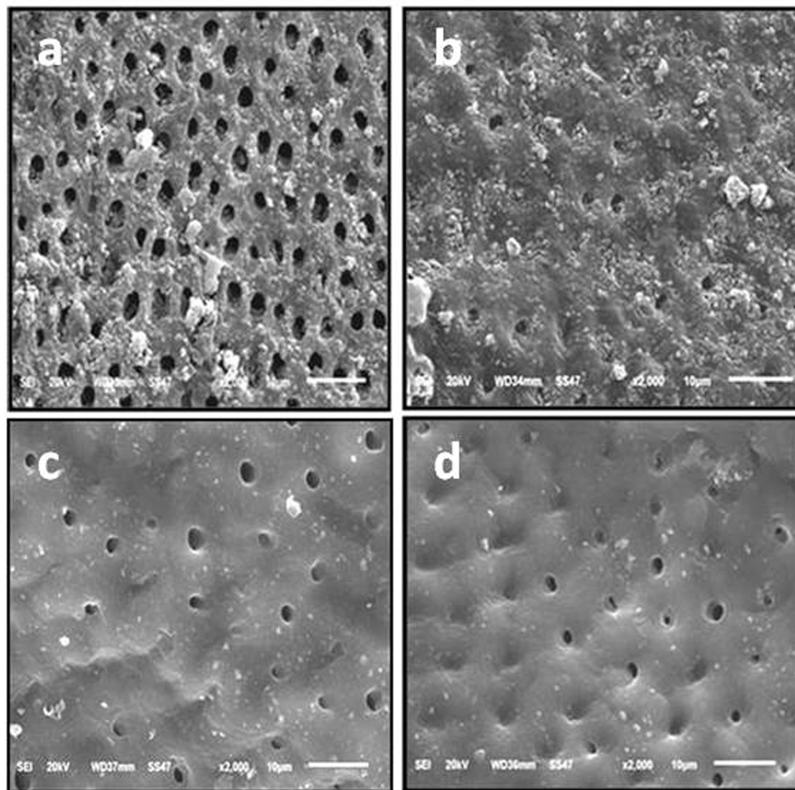


Fig 2 - Micrographs of horizontal sections of tooth samples showing dentinal tubule occlusion in: a) Control Group (CG), b) Apgard-Premio group (AP), c) Elzens group (EZ) and d) Tooth Builder group (TB)

Table 3

Depth of dentinal tubule occlusion in micrometers by type of studied toothpaste

Toothpaste	N	Mean	SD	SE	95% CI for mean depth range
AP	15	200	15	4	19 - 208
EZ	15	145	26	7	131 - 160
TB	15	94	9	2	89 - 98

AP: Apgard Premio®; EZ: Elsenz®; TB: Tooth Builder®

SD: Standard deviation; SE: Standard error; CI: Confidence interval

*p*-value<0.001 is considered to be statistically significant

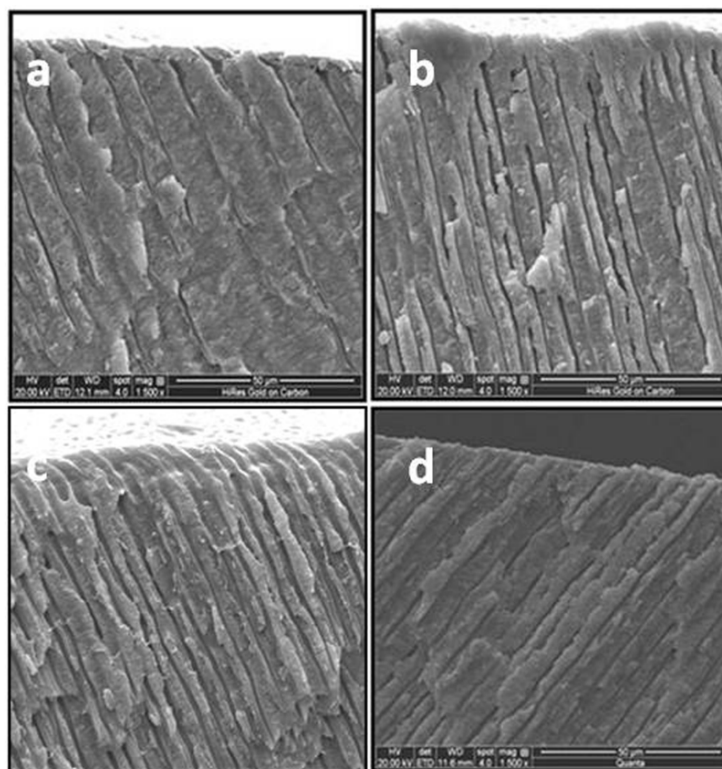


Fig 3 - Micrographs of longitudinal sections of teeth showing tubule occlusion depth in the: a) Control Group (CG), b) Apgaurd-Premio group (AP), c) Elzens group (EZ) and d) Tooth Builder group (TB)

occlusion as previous studies (Wang *et al*, 2016; Burwell *et al*, 2010).

In our study, EZ toothpaste (containing FCPS) resulted in a higher percentage of occluded dental tubules (63%) than that reported by a pervious study (59%) (George *et al*, 2018). Several studies have reported toothpaste containing FCPS give better dentinal tubule occlusion than other studied toothpastes (Gopinath *et al*, 2015; Wang *et al*, 2016; George *et al*, 2018). One

study reported that teeth brushed with toothpaste containing FCPS continued to have occluded tubules even after washing the teeth in 6% citric acid for the 30 seconds (Ashwini *et al*, 2018). In our study, EZ toothpaste (containing FCPS) resulted in a 63% tubule occlusion rate, higher than the 57% reported in a previous study (Markowitz, 2013). However, our 63% tubule occlusion rate is lower than a previous study that reported a 90% tubule occlusion rate (Al-Saud and Al-Nahedh, 2012).

Table 4  
*p*-values comparing studied toothpastes by category of dentinal tubule occlusion, dentinal tubule occlusion depth  
 and dentinal tubule occlusion score

Multiple comparison (BC)	CG vs AP	CG vs EZ	CG vs TB	AP vs TB	AP vs EZ	TB vs EZ
Percent with completely open tubules	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
Percent with partially occluded tubules	<0.001*	<0.001*	<0.001*	0.090	0.498	1.000
Percent with completely occluded tubules	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
Dentinal tubule occlusion depth	N/A	N/A	N/A	<0.001*	<0.001*	<0.001*
Dentinal tubule occlusion score	<0.001**	<0.001*	<0.001*	<0.001*	0.489	0.158

BC: Bonferroni correction; CG: Control Group; AP: Apagard Premio<sup>®</sup>; EZ: Elsenz<sup>®</sup>; TB: Tooth Builder<sup>®</sup>; N/A: Not Applicable  
 \**p*-value <0.001 is considered to be statistically significant

Our results are also in contrast to a study that reported a 87% occlusion rate with a toothpaste containing FCPS (Bahal *et al*, 2019).

An *in vivo* study comparing four different desensitizing agents over a period of 7 days showed Tooth Builder® (TB) (containing NIC) to be least effective in reducing hypersensitivity (Kunam *et al*, 2016) which is in accordance to present study. A previous study (Shaikh *et al*, 2018) supports our study by reporting toothpastes containing NIC had greater resistance to citric acid than toothpastes containing nHAp and CHP. A previous study (Neuhaus *et al* 2013) reported a single application NIC containing toothpaste provided a significant reduction in DH and this reduction in DH lasted for at least 28 days. Comparing the results of Neuhaus *et al* (2013) with this study, our study seems to be more effective. In contrast to present research results, a study conducted by (Wang *et al*, 2016) proposed that NIC represented excellent occlusion effects after brushing treatment and artificial saliva immersion. Similar results were also obtained in an *in vitro* study conducted by Burwell *et al*, 2010 who reported that NIC adhered to an exposed dentin surface and reacted with it to form a mineralized layer but not much effective in tubular occlusion.

Our results should be interpreted with care. The most common location for DH is the cervical part of the tooth but in our study we used the crown for the study samples. Our results may not be applicable to an *in vivo* response. In our study we attempted to apply the studied toothpastes uniformly on the

sample blocks but on the micrograph there was a nonhomogeneous texture on the surface of the tooth indicating uneven distribution of the toothpaste. However, our study design adequately reflects the *in vivo* environment in regards to distribution of the toothpaste.

In summary, all 3 studied toothpastes gave better dentinal tubule occlusion and a greater depth of penetration than the control and AP toothpaste gave the best dentinal tubule occlusion and the greatest depth of penetration leading us to conclude that among the studied toothpastes, AP toothpaste appears to be the most effective toothpaste for DH. Further *in vivo* studies among subjects with DH are needed to confirm these *in vitro* findings.

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#### CONFLICTS OF INTEREST DISCLOSURE

The authors declare no conflicts of interest.

#### REFERENCES

- Addy M, West NX. The role of toothpaste in the etiology and treatment of dentine hypersensitivity. *Monogr Oral Sci* 2013; 23: 75-87.
- Al-Saud LM, Al-Nahedh HN. Occluding effect of Nd:YAG laser and different

- dentin desensitizing agents on human dentinal tubules *in vitro*: a scanning electron microscopy investigation. *Oper Dent* 2012; 37: 340-55.
- Ansari MM, Devkar ND, Lele SV, Nagpal DJ, Navale SR, Jayamangal AS. *In-vitro* assessment of effect of a hydroxyapatite containing desensitizing agent on dentinal tubule occlusion. *J Dent Allied Sci* 2014; 3: 74-9.
- Ashwini S, Swatika K, Kamala DN. Comparative evaluation of desensitizing efficacy of dentifrice containing 5% fluoro calcium phosphosilicate versus 5% calcium sodium phosphosilicate: a randomized controlled clinical trial. *Contemp Clin Dent* 2018; 9: 330-6.
- Bahal P, He T, Zou Y, *et al.* A randomized controlled trial to investigate the efficacy of an oxalate strip for the management of dentine hypersensitivity pain. *J Dent* 2019; 86: 95-101.
- Bakri MM, Hossain MZ, Razak FA, *et al.* Dentinal tubules occluded by bioactive glass-containing toothpaste exhibit high resistance toward acidic soft drink challenge. *Aust Dent J* 2017; 62: 186-91.
- Burwell A, Jennings D, Muscle D, Greenspan DC. NovaMin and dentin hypersensitivity--*in vitro* evidence of efficacy. *J Clin Dent* 2010; 21: 66-71.
- Garofalo SA, Sakae LO, Machado AC, *et al.* *In vitro* effect of innovative desensitizing agents on dentin tubule occlusion and erosive wear. *Oper Dent* 2019; 44: 168-77.
- Gautam V, Halwai HK. Comparison of clinical efficacy of four dentifrices in the management of dentinal hypersensitivity. *Int J Sci Res* 2017; 6: 239-40.
- George G, Ranjini MA, Pai VS, Darsan J, Nadig RR. Evaluation of dentinal tubule occlusion using a desensitizing toothpaste and mouthwash for a period of 60 days: scanning electron microscopy analysis. *J Interdiscip Dent* 2018; 8: 96-101.
- Gillam DG, Bulman JS, Eijkman MA, Newman HN. Dentists' perceptions of dentine hypersensitivity and knowledge of its treatment. *J Oral Rehabil* 2002; 29: 219-25.
- Goh V, Corbet EF, Leung WK. Impact of dentine hypersensitivity on oral health-related quality of life in individuals receiving supportive periodontal care. *J Clin Periodontol* 2016; 43: 595-602.
- Gopinath NM, John J, Nagappan N, Prabhu S, Kumar ES. Evaluation of dentifrice containing nano-hydroxyapatite for dentinal hypersensitivity: a randomized controlled trial. *J Int Oral Health* 2015; 7: 118-22.
- Hiller KA, Buchalla W, Grillmeier I, Neubauer C, Schmalz G. *In vitro* effects of hydroxyapatite containing toothpastes on dentin permeability after multiple applications and ageing. *Sci Rep* 2018; 8: 4888.
- Hines D, Xu S, Stranick M, *et al.* Effect of a stannous fluoride toothpaste on dentinal hypersensitivity: *in vitro* and clinical evaluation. *J Am Dent Assoc* 2019; 150 (4S): S47-59.
- João-Souza SH, Machado AC, Lopes RM, Zezell DM, Scaramucci T, Aranha ACC. Effectiveness and acid/tooth brushing resistance of in-office desensitizing treatments-a hydraulic conductance study. *Arch Oral Biol* 2018; 96: 130-6.
- Krifka S, Preis V, Rosentritt M. Effect of decontamination and cleaning on the shear bond strength of high translucency zirconia. *Dent J (Basel)*

- 2017; 5: 32.
- Kunam D, Manimaran S, Sampath V, Sekar M. Evaluation of dentinal tubule occlusion and depth of penetration of nano-hydroxyapatite derived from chicken eggshell powder with and without addition of sodium fluoride: an *in vitro* study. *J Conserv Dent* 2016; 19: 239-44.
- Lavender SA, Petrou I, Heu R, *et al.* Mode of action studies on a new desensitizing dentifrice containing 8.0% arginine, a high cleaning calcium carbonate system and 1450 ppm fluoride. *Am J Dent* 2010; 23 (Spec A): 14A-19A.
- Li Y. Innovations for combating dentin hypersensitivity: current state of the art. *Compend Contin Educ Dent* 2012; 33: 10-6.
- Markowitz K. A new treatment alternative for sensitive teeth: a desensitizing oral rinse. *J Dent* 2013; 41 (Suppl 1): S1-11.
- Mason S, Hughes N, Sufi F, *et al.* A comparative clinical study investigating the efficacy of a dentifrice containing 8% strontium acetate and 1040 ppm fluoride in a silica base and a control dentifrice containing 1450 ppm fluoride in a silica base to provide immediate relief of dentin hypersensitivity. *J Clin Dent* 2010; 21: 42-8.
- Neuhaus KW, Milleman JL, Milleman KR, *et al.* Effectiveness of a calcium sodium phosphosilicate-containing prophylaxis paste in reducing dentine hypersensitivity immediately and 4 weeks after a single application: a double-blind randomized controlled trial. *J Clin Periodontol* 2013; 40: 349-57.
- Poulsen S, Errboe M, LescayMevil Y, Glenny AM. Potassium containing toothpastes for dentine hypersensitivity. *Cochrane Database Syst Rev* 2006; 2006: CD001476.
- Que K, Guo B, Jia Z, Chen Z, Yang J, Gao P. A cross-sectional study: non-carious cervical lesions, cervical dentine hypersensitivity and related risk factors. *J Oral Rehabil* 2013; 40: 24-32.
- Shah S, Shivakumar AT, Khot O, Patil C, Hosmani N. Efficacy of NovaMin-and Pro-Argin-containing desensitizing dentifrices on occlusion of dentinal tubules. *Dent Hypotheses* 2017; 8: 104-9.
- Shaikh K, Pereira R, Gillam DG, Phad S. Comparative evaluation of desensitizing dentifrices containing BioMin<sup>®</sup>, Novamin<sup>®</sup> and fluoride on dentinal tubule occlusion before and after a citric acid challenge – a scanning electron microscope *in-vitro* study. *J Odontol* 2018; 2: 1000105.
- Spitznagel FA, Horvath SD, Guess PC, Blatz MB. Resin bond to indirect composite and new ceramic/polymer materials: a review of the literature. *J Esthet Restor Dent* 2014; 26: 382-93.
- Splieth CH, Tachou A. Epidemiology of dentin hypersensitivity. *Clin Oral Investig* 2013; 17 (Suppl 1): S3-8.
- Takamizawa T, Tsujimoto A, Ishii R, *et al.* Laboratory evaluation of dentin tubule occlusion after use of dentifrices containing stannous fluoride. *J Oral Sci* 2019; 61: 276-83.
- Wang L, Magalhães AC, Francisconi-Dos-Rios LF, *et al.* Treatment of dentin hypersensitivity using nano-hydroxyapatite pastes: a randomized three-month clinical trial. *Oper Dent* 2016; 41: E93-101.
- West N, Newcombe RG, Hughes N, *et al.* A 3-day randomized clinical study investigating the efficacy of two toothpastes, designed to occlude dentine tubules, for the treatment of dentine hypersensitivity. *J Dent* 2013; 41: 187-94.