American Journal of Dentistry, Vol. 28, No. 6, December, 2015

AMERICAN JOURNAL OF DENTISTRY

Volume 28, No. 6, December, 2015 - p. 309-376

AMERICAN JOURNAL OF DENTISTRY

Published By Mosher & Linder, Inc.

Volume 28, Number 6, December, 2015 - p. 309 - 376

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Dentin wear after simulated toothbrushing with water, a liquid dentifrice or a standard toothpaste

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ABSTRACT: Purpose: To investigate the influence of dentifrices with and without abrasives on the wear and surface topography of human dentin following simulated toothbrushing in vitro. **Methods:** 24 dentin specimens were prepared and randomly allocated to a liquid dentifrice (Garglin Gum-Guard), conventional dentifrice (333 Clinic Total Care), and control (distilled water) groups. Specimens were subjected to simulated toothbrushing of 50,000 repeated strokes under a 150 g-load. The dentin surface was profiled in each specimen using a profilometer before and after toothbrushing. The mean surface roughness (Ra) of the specimens was calculated and compared by one-way ANOVA and Tukey's post-hoc test ($\alpha= 0.05$). The dentin surfaces were further examined by scanning electron microscopy (SEM). **Results:** The Ra values were similar between the liquid dentifrice and control groups ($P> 0.05$), and was significantly higher in the conventional dentifrice group ($P< 0.001$). On SEM examination, patent dentin tubules were observed in the conventional dentifrice and liquid dentifrice groups, but were not observed in the control group. (*Am J Dent* 2015;28:333-336).

CLINICAL SIGNIFICANCE: Liquid dentifrice reduced dentin wear caused by toothbrushing compared to conventional dentifrice. However, for dentin hypersensitivity, liquid dentifrice requires further validation because both conventional and liquid dentifrices caused patent dentin tubules on the worn dentin surface.

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Introduction

Dentin hypersensitivity is one of the most common dental issues, comprising more than one-quarter of all cases of oral and maxillofacial pain in adults.[1,2] Although the mechanism of dentin hypersensitivity is not fully understood, the non-caries cervical lesion (NCCL), including cervical abrasion, is a major contributing factor.[3,4] Daily toothbrushing is important in the development of dentin hypersensitivity because toothbrushing is reportedly closely associated with NCCL.[5,6] Toothbrushing alone rarely causes excessive wear to the dental hard tissue,[6-9] but when it is combined with the abrasives in dentifrice, cervical dentin wear may be accelerated.[10]

Conventional dentifrices contain a variety of abrasives such as silica, alumina, dicalcium phosphate dihydrate, and calcium carbonate to improve their cleaning power, which may increase dentin wear.[11] In this context, a recently introduced liquid dentifrice, which does not contain dental abrasives, may have clinical potential to reduce dentin wear caused by daily toothbrushing. Turssi et al[9] reported that the magnitude of dentin wear from toothbrushing was associated with the concentration of abrasives in the dentifrice; thus, liquid dentifrice appears to be advantageous compared with conventional dentifrices in reducing NCCL development. However, evidence concerning the wear characteristics of liquid dentifrice is still lacking.

The present study investigated the effect of liquid dentifrice on the wear and surface topography of human dentin under simulated toothbrushing in vitro. The null hypothesis in this study was the following: liquid dentifrice and conventional dentifrice did not differ in the magnitude of wear and surface morphology alteration in human dentin when used in conjunction with toothbrushing.

Materials and Methods

Dentin specimen preparation - This study was approved by the Research Ethics Committee of Seoul National University, Graduate School of Dentistry (IRB number: S-D20140001). The specimen preparation, dentin wear test, and measurements were performed in accordance with the International Organization for Standardization (ISO) 11609 standards.

A commercial conventional dentifrice (333 Clinic Total Care[a]) and a liquid dentifrice (Garglin Gum-Guard[a]) were used for the two experimental groups, and sterile distilled water[b] served as the negative control. The composition of each product is described in Table 1.

Twelve sound maxillary and mandibular premolars without dental caries or abrasion were extracted and stored in 0.1% thymol solution until specimen preparation. A total 4 mm of cervical dentin centered at the cemento-enamel junction (CEJ) was isolated from each tooth (2 mm each on the occlusal and apical sides of the CEJ). Cylindrical dentin blocks were generated by removing the occlusal and radicular tooth portions with a diamond disk. The dentin blocks were sectioned sagittally to produce two symmetrical dentin specimens from each tooth (Fig. 1).

Of the 24 dentin specimens, the 16 specimens obtained from the eight premolars were randomly allocated into the two experimental groups (N = 8), and the remaining eight specimens obtained from the four premolars were allocated to the negative control group (N = 8). The specimens were then embedded in a round acrylic mold (outer diameter 20 mm, inner diameter 16 mm, height 8 mm) using self-cure acrylic resin (Ortho-jet Acrylic[c]) with the cervical dentin exposed upward (Fig. 1).

After embedding the specimens, the exposed dentin surfaces were polished with abrasive papers (CC261[d]) sized P100 to P1,200 to generate a reference surface meeting the ISO standard (ISO 6344). Polyvinylchloride (PVC) tape was attached onto each specimen to restrict and standardize the amount of exposed dentin (2 mm × 2 mm) to within the detection range of the surface profilometer (Surftest 402[e]) (Fig. 1). Pre-treatment surface profiling was performed using the surface profilometer.

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Table 1. Composition of the liquid dentifrice and conventional dentifrice.

Material/Brand	Dental abrasives	Composition
Liquid dentifrice/Garglin Gum-Guard	None	Cetylpyridinium chloride (USP) 50 mg, Tocopheryl acetate (USP) 200 mg, sodium monofluorophosphate (USP) 760 mg (equivalent to 1000 ppm of fluoride) per 100 g.
Conventional dentifrice/333 Clinic Total Care	Colloidal silicon dioxide 8 g (equivalent to 7.6 g of silicon dioxide), (equivalent to 8.7 g of silicon dioxide) per 100 g	Colloidal silicon dioxide (NF) 8 g, dental type silica (NF) 10 g, sodium monofluorophosphate (USP) 380 mg (equivalent to 500 ppm of fluoride), ocopheryl acetate (KP) T90 mg per 100 g.

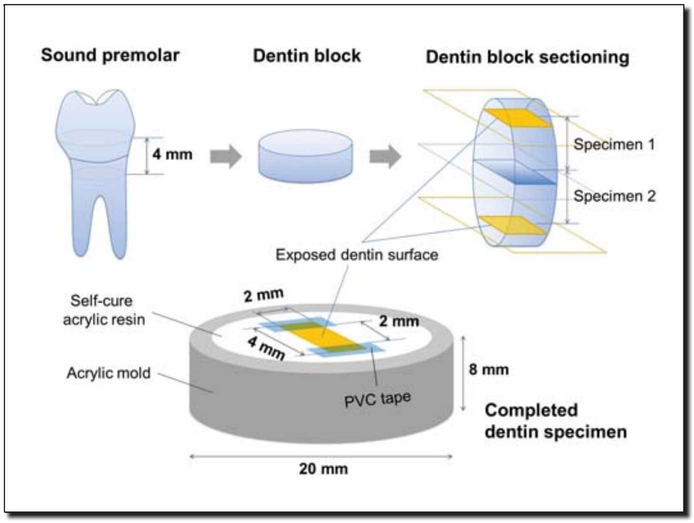

Fig. 1. Dentin specimen preparation and a representative completed specimen.

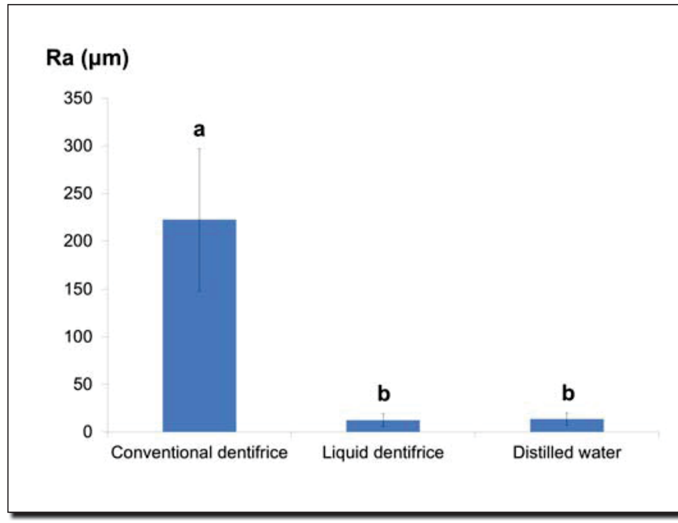

Fig. 2. Dentin wear after simulated toothbrushing with conventional dentifrice, liquid dentifrice, and distilled water. Statistically significant differences between the groups (P< 0.05) are indicated by superscripted letters.

Table 2. Dentin wear after simulated toothbrushing with conventional dentifrice, liquid dentifrice, and distilled water.

Group	Conventional dentifrice	Liquid dentifrice	Distilled water
Ra (µm)	222.50 ± 74.52[a]	12.47 ± 6.74[b]	13.59 ± 6.61[b]

[a, b] Indicates a statistically significant difference between the groups (P< 0.05).

Dentin wear test - To prepare the conventional dentifrice, 25 g of 333 Clinic Total Care was mixed with 20 ml of distilled water on a magnetic stirrer according to the ISO standard. The liquid dentifrice (Garglin Gum-Guard) did not require additional preparation prior to the wear test. The pH values of the prepared conventional dentifrice and the liquid dentifrice were measured by a pH electrode (Orion Glass Body ROSS Combination pH Electrode[f]). A commercially available toothbrush (777 toothbrush[g]) was used in the simulated toothbrushing. The dentin specimens were submerged in the prepared dentifrices and distilled water (control group) to a depth of at least 3 mm. A total of 50,000 repeated strokes (2 strokes/second) were applied using the toothbrush onto each specimen under a 150 g-load.

After the surface wearing, the specimens were washed under running water, and post-treatment surface profiling was performed using the surface profilometer. Surface images of the specimen before and after wearing were superimposed and analyzed using the MTS[h] 3D profiling system. The mean surface roughness (Ra) was calculated for each specimen (Table 2).

Scanning electron microscopy - A SEM was used to quailtatively assess the worn dentin surfaces. After coating the specimen with gold palladium in an ion sputtering coater, the worn dentin surfaces were imaged by SEM (S-4700 FESEM[i]) at a 15.0-kV accelerating voltage and 12-mm working distance. Standard SEM images (×30 and ×300 magnifications) were obtained for each group.

Statistical analysis - The Ra values for the experimental and control groups were compared by one-way ANOVA, followed by Tukey's post-hoc test for multiple comparisons using IBM SPSS Statistics 20[j] with an alpha of 5% (α= 0.05).

Results

pH measurement - The pH values were 6.93 ± 0.06 for the prepared conventional dentifrice and 6.70 ± 0.02 for the liquid dentifrice.

Mean surface roughness - The Ra values and the group comparisons are described in Table 2 and Fig. 2. The Ra values did not differ significantly between the liquid dentifrice and control groups (P> 0.05). However, the conventional dentifrice group showed a significantly higher Ra value compared to the Ra values in both the liquid dentifrice and control groups (P< 0.001). *SEM evaluation* - Figure 3 shows representative SEM images (×30 and ×300 magnifications) of the worn dentin specimens and reveals the differing surface topographies according to the dentifrice type. At ×30 magnification, the dentin specimens in the conventional dentifrice group exhibited crater-shaped defects along the worn surfaces with vertical dentin loss ranging from 50 to 200 µm (Fig. 3A). By contrast, the specimens in the liquid dentifrice and control groups did not exhibit any detectable vertical dentin loss along the worn surfaces (Figs. 3C, 3E). The conventional dentifrice group also showed characteristic furrow-like groove defects at a higher magnification (×300) parallel to the direc-

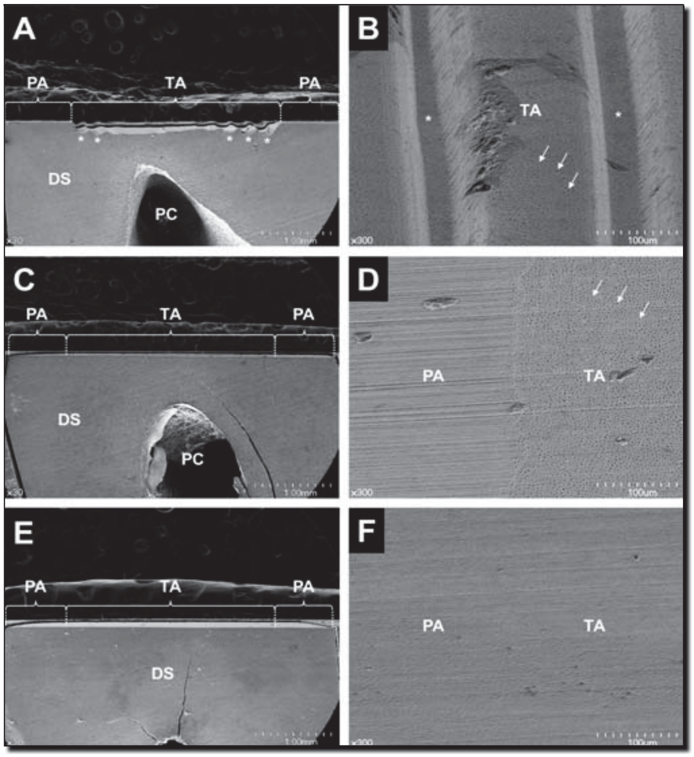

Fig. 3. Representative scanning electron microscope images of the worn dentin specimens treated with conventional dentifrice at **A.** ×30 magnification and **B.** ×300 magnification, liquid dentifrice at **C.** ×30 magnification and **D**. ×300 magnification, and distilled water at **E**. ×30 magnification and **F.** ×300 magnification. Micrographs in 3A, 3C, and 3E were taken in cross-sectional view, and those in 3B, 3D, and 3F were taken in routine two-dimensional view. Asterisks (3A and 3B) indicate the groove defects in the dentin specimen treated with conventional dentifrice. Arrows (3B and 3D) indicate open dentin tubule orifices. The left half of 3D and 3F includes the dentin surface protected using PVC tape during the wear process (PA). DS, dentin specimen; PC, pulp chamber; TA, toothbrushing area; PA, PVC-taped area.

tion of the simulated toothbrushing strokes (Fig. 3B). The liquid dentifrice and control groups showed flat and smooth worn surfaces (Figs. 3D, 3F). Dentin tubule exposure was apparent in both dentifrice groups (Figs. 3B, 3D) but was absent in the control group (Fig. 3F).

Discussion

This study evaluated and compared the effects of liquid dentifrice and conventional dentifrice on dentin wear and surface topography. When simulated toothbrushing (50,000 strokes) was performed in vitro, the liquid dentifrice caused significantly less dentin loss than the conventional dentifrice did, allowing us to reject the null hypothesis. This result is consistent with those of previous studies[11-15] reporting that dental abrasive is one of the main contributors to dentin wear caused by toothbrushing, because the conventional dentifrice in this study contained approximately 18 g of solid contents per 100 g of dentifrice, which are mostly dental abrasives, whereas the liquid dentifrice contained no dental abrasives and approximately 1 g of solid contents per 100 g of dentifrice. In this study, the dentin abrasivity of the dentifrices was compared with distilled water as the negative control, which has been widely used in previous studies,[9,16,17] and notably the liquid dentifrice caused a similar degree of dentin wear compared to distilled water. Therefore, the liquid dentifrice in the present study appeared to be advantageous over a conventional dentifrice in preventing NCCL caused by toothbrushing.

Cervical dentin loss not only reduces the thickness of the dentin surrounding the pulp, but also increases the number and diameter of exposed dentin tubules, which is closely associated with increased hydraulic conductance of dentin.[18] Invasion of bacteria and bacterial by-products into the pulp may be facilitated, favoring development and progression of dentin hypersensitivity.[4] With the SEM, the conventional dentifrice evaluated in this study caused considerable dentin loss and complete dentin tubule exposure along the worn dentin surfaces (Figs. 3A, 3B). Thus, dentifrices containing dental abrasives should be used with care to prevent dentin hypersensitivity, as well as NCCL. Regarding the dentin tubule exposure, liquid dentifrice revealed similar surface morphology compared to the conventional dentifrice. The dentin specimens treated with the liquid dentifrice showed open dentin tubules on the treated surface after toothbrushing, which is markedly different from the surface morphology of the specimens in the control group (Figs. 3D, 3F). Of the theories which explain the dentin tubule opening, the most popular one is the action of intraoral acid, which attacks and removes the smear layer especially when accompanied by mechanical stimulation.[19] However, when considering that the dentifrices used in this study showed pH values which were almost neutral, this explanation appears to be less associated with this study. Meanwhile, previous studies[20,21] suggested that the detergents contained in the dentifrice could be a factor which promotes the smear layer removal by reducing the abrasive resistance of the smear layer, which might be one of the causes of such alteration of surface morphology in the liquid dentifrice group. Although the liquid dentifrice was advantageous in minimizing the magnitude of dentin loss, its ability to remove the smear layer may increase the hydraulic conductance of dentin, tending to promote dentin sensitivity.

The plaque control ability of the dentifrice is another point to consider. Dental abrasives promote plaque removal during toothbrushing by increasing the abrasiveness of dentifrice; dentifrice with low abrasiveness was less efficient at plaque control.[22] However, plaque control is affected by a variety of factors beyond the presence of dental abrasives such as the dentifrice composition and the brushing method. The liquid dentifrice in this study contained cetylpyridinium chloride (CPC), which reportedly functions as an antimicrobial agent,[23-25] inhibits plaque formation,[26] and reduces previously formed plaque.[27] Another point is that both conventional and liquid dentifrice showed similar effectiveness in the smear layer removal when compared to the negative control (Fig. 3B, 3D, 3F), which implies their clinical potential in plaque control. Further studies evaluating the dentifrices regarding the ability to remove the biofilm would be helpful to compare the clinical benefits and limitations between the effects on the plaque control and the cervical dentin preservation.

In this study, the entire dentin wear process was performed in accordance with the ISO standards. However, while the ISO standard recommends 10,000 repeated strokes, the number of repeated strokes was increased to 50,000 because it was considered that 10,000 strokes, which is equivalent to 18.5 days of toothbrushing (assuming 1 stroke/second, 3 minutes/time, 3 times/day), was insufficient for reproducing daily toothbrushing. Therefore, in the present study, 50,000 strokes (equivalent to approximately 3 months of toothbrushing) were performed, which is a more suitable simulation of daily toothbrushing performed over a long period.

The type of dentin substrate is another factor that significantly affects the results in dentin wear testing.[28] Sound teeth that were extracted due to orthodontic treatment were used in this study, and symmetrical dentin specimens from each tooth were randomly allocated to the liquid dentifrice and conventional dentifrice groups in order to minimize variation caused by the dentin substrates.

In this study, dentin wear from toothbrushing was reproduced in vitro, which provides a more controlled environment for quantitative analysis. However, many variables, such as the presence of saliva, oral biofilm and plaque deposition, hydrogen ion concentration (pH) and temperature changes, de- and remineralization of dentin, and individual brushing habits, influence the dentin wear process in vivo.[11,29] Further laboratory studies and clinical trials are needed to address this particular study limitation.

In conclusion, within the limitations of this study, liquid dentifrice, which does not contain dental abrasives, caused less dentin wear than conventional dentifrice. However, both toothbrushing with liquid dentifrice and conventional dentifrice generated open dentin tubules on the dentin surface, which was not observed when toothbrushing was performed using distilled water. Additional laboratory studies and clinical trials are recommended to determine the clinical benefit of liquid dentifrice in mitigating dentin wear and dentin hypersensitivity.

a. Dong-A Pharmaceutical, Seoul, Republic of Korea.
b. JW Pharmaceutical, Seoul, Republic of Korea.
c. Lang Dental Manufacturing Company, Wheeling, IL, USA.
d. DEERFOS, Seoul, Republic of Korea.
e. Mitutoyo, Kawasaki, Japan.
f. Thermo Scientific, Beverly, MA, USA.
g. LG Household & Health Care; Seoul, Republic of Korea.
h. MTS Systems Corporation, Eden Prairie, MN, USA.
i. Hitachi, Tokyo, Japan.
j. SPSS Inc., Chicago, IL, USA.

Disclosure statement: The authors declared no conflict of interest. The first two authors contributed equally to this work and share first authorship. This work was supported by the Dong-A Pharmaceutical Research Fund and the Basic Science Research Program through the National Research Foundation of Korea (NRF), funded by the Ministry of Education, Science, and Technology (2012-009268).

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