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Evaluation of dentin abrasion during professional tooth cleaning in an in vitro model

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Abstract

Objectives: Professional tooth cleaning (PTC) may lead to loss of exposed dentin. The aim of the present study was to determine the absolute loss of dentin during PTC using various product combinations with an in vitro model.

Material and Methods: Dentin specimens (72) were randomly assigned to nine groups. In four groups each, prophy brushes and prophy cups were used in combination with four different abrasives (calcium pyrophosphate, pumice, Hawe cleanic, Nupro coarse). In the ninth group, a rubber cup with embedded fluoride and abrasives was used (pasteless prophy cup). The treatment time was 37 s. Surface loss was determined by profilometry.

Results: The surface loss in the nine groups was as following: (1) brush/calcium pyrophosphate: 6.18 μm (a); (2) brush/pumice: 5.51 μm; (3) brush/Nupro coarse: 10.10 μm (b); (4) brush/Hawe cleanic: 1.88 (a, b); (5) prophy cup/calcium pyrophosphate 2.07 (c); (6) prophy cup/pumice: 6.07 μm; (7) prophy cup/Nupro coarse: 5.93 μm (c); (8) prophy cup/Hawe cleanic: 4.93 μm (c); (9) pasteless prophy cup: 11.86 μm (c). Groups with the same letter in parentheses are statistically significant different at $p < 0.05$. In a pooled analysis, no statistically significant difference between brushes and prophy cups was found.

Conclusion: In the present study, the surface loss of about eight PTC procedures was simulated. Hence, the dentin loss ranged between 0.24 and 1.48 μm per PTC. Therefore, PTC does not seem to be a main factor in dentin loss.

Key words: abrasion; dentin; professional tooth cleaning

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Frequent professional tooth cleaning (PTC) is an important element of individualized preventive dentistry programmes. The question of abrasivity arises with patients who have exposed dentin. To assess the abrasivity of prophylaxis pastes in combination with prophy cups or brushes, modifications of established radiotracer methodology (Hefferren 1976) have been used by Stookey & Schemehorn (1979) and Zimmer et al. (2002). With this method, abrasivity can be determined in relation to a calcium pyrophosphate reference abrasive (Hefferren 1976). To determine the risk of repeated PTC, the absolute dentin lost was determined using a profilometry-based abrasion method (Coffman et al. 2000). Therefore, it was the aim of the present study to assess the absolute loss of dentin during PTC using various product combinations with an in vitro model. The second aim was to evaluate the surface roughness of dentin after treatment.

Material and Methods

Preparation of the specimens

Extracted human premolars (72) stored in 20% isopropyl alcohol prior to preparation were used. After being embedded in acrylic resin (Coldpac, Mottloid Company, Chicago, IL, USA) the premolars were ground down from the occlusal surface to remove any enamel using a water cooled, 400 grit silicon carbide abrasive cloth with a Buehler grinder polisher (Buehler Ltd., Evanston, IL, USA) at 250 r.p.m. Thereafter, the specimens were made smooth with Sof-Lex discs superfine (3M, St. Paul, MN, USA) attached to a dental hand piece (DNTL Portable II, DNTL, Englewood, CO, USA) at 1500 r.p.m. The surfaces of the specimens were examined with a stereomicroscope for remaining enamel remnants and cracks (× 20, Olympus SZ-PT, Olympus Optical Co. Ltd. Tokyo, Japan) using a fibre

optic illumination (Cole-Parmer Instrument Company, Vernon Hills, IL, USA, Model 41500-50). Thereafter, the 72 specimens were randomly assigned to nine groups with eight specimens each.

Experimental setting

In four groups each, prophy brushes (nylon brush art# 835, KerrHawe, Bioggio, Switzerland) or prophy cups (art# 991, KerrHawe) were used in combination with four different prophylaxis abrasives. In the ninth group, a fluoride releasing rubber cup with embedded abrasives was used (pasteless prophy cup, KerrHawe). The abrasives used in groups 1–8 were calcium pyrophosphate reference abrasive ISO Toothpaste Specification 11,609 (hefferren@ku.edu) (Hefferren 1976), pumice flour with glycerin (10 g pumice/6 ml glycerin), Hawe cleanic monodose (KerrHawe), or Nupro coarse (Dentsply, Des Plaines, IL, USA). The product combinations in the nine experimental groups can be seen in Table 2.

For the testing procedure, the hand piece of a portable dental unit (DNTL Portable II, DNTL) was mounted on a tooth brushing machine (Dual Action Mark II, Sabri Enterprises, Downers Grove, IL, USA). By combining the linear movement of the brushing machine (stroke distance of 13 mm) and the rotating movements of the dental hand piece, the typical movement performed during PTC on a tooth surface was simulated. Each specimen was treated for 80 s at 2600 r.p.m. and a load of 1.5 N corresponding to approximately 150 g. Dental hand piece speed and load were determined using a strobe light (Monarch Nova-Strobe, Amherst, NH, USA) and a laboratory scale (EK 1200G, A&D, Bradford, MA, USA). Both measurements were repeated after each group and if necessary, parameters were adjusted.

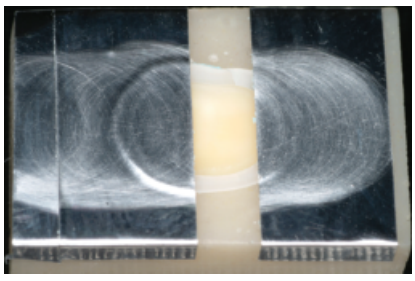

Fig. 1. Specimen after running time of the experiment before removal of the aluminum tape. The tarnished surface of the metal tape indicates the whole treatment area. The ''effective'' treatment area was between the metal tapes only.

Testing procedure

A 3 mm test area was marked on each dentin surface. Thereafter, a baseline profilometric measurement was performed on this area (Surfanalyzer System 5000/400, Federal Products Co., Providence, RI, USA). This was done to determine the initial surface roughness and to ensure that the surface of the specimens initially was planoparallel. After the baseline measurement, aluminum tape (Bogen Tape MPS 3818, Vitec, Kingston upon Thames, UK) was placed at the limits of the test area to protect from abrasion during the test procedure. The specimens were then mounted into the tooth brushing machine. To simulate oral conditions, all dentin specimens were coated with freshly collected, stimulated human saliva (SZ) at the start of the experiment. In groups #1–8, 30 μl saliva was used per cycle (80 s) period. With the pasteless prophy cup 30 μl of saliva was added every 20 s to a total of 120 μl. In groups #1–8, 250 μl of each paste was used per cycle. The pasteless prophy cup was used without any paste. Treatment time per specimen was 80 s. As the stroke distance of the brushing machine was 13 mm and the diameter of the nylon brush and the rubber cups 6 mm, this resulted in an effective treatment time on the test area of the specimen between the two strips of aluminum tape of about 37 s ($6/13 \times 80 = 37$). After the test procedure was completed, the aluminum tape was removed and the post-treatment profilometric scan was performed. Figure 1 shows a typical specimen after the experiment prior to removal of the tape. All profilometric measurements were performed in duplicate.

Statistical analysis

The surface loss was defined as the average loss in micrometres. The roughness was calculated as R_a-value. R_a is defined as the average deflection from the median line of the surface profile in micrometres. For statistical analysis, the mean value of both profilometric measurements was used. The analysis was performed with the SPSS 9.0 program. As the Kolmogorov–Smirnov test did not show normal distribution, median values were calculated for surface roughness and substance loss. Kruskal–Wallis and Mann–Whitney's *U*-test with α adjustment were used for statistical testing ($p < 0.05$). The testing was performed in two steps. First, the three ''main groups'' were compared (brushes, prophy cups, and pasteless prophy cup). Thereafter, differences in the ''brush'' and the ''prophy cup group'' were analysed separately. In this analysis, the pasteless prophy cup was assigned to the prophy cup group.

Results

The median surface roughness (R_a) of the dentin samples before treatment ranged from 0.03–0.05 μm. No statistical significant difference was found between the groups (Tables 1 and 2). Tables 1 and 2 show the roughness values before and after treatment. When compared with the baseline values, an obvious increase in surface roughness was observed. The values ranged from 0.06 to 0.22 μm. No statistical significant difference was found between the three ''main'' groups (brushes, prophy cups, and pasteless prophy cup) (Table 1). However, in the ''brush group'', the roughness was statis-

Table 1. Pooled data for the combinations with prophy brush (#1–4) and prophy cup (#5–8) and compared with the pasteless prophy cup (#9): median roughness values (R_a) before and after treatment and median depth of surface in micrometres

	Nylon brush (#1–4) ($n = 32$)	Prophy cup (#5–8) ($n = 32$)	Pasteless prophy cup (#9) ($n = 8$)
R_a before treatment (μm): median (min; max)	0.04 (0.02; 0.05)	0.04 (0.03; 0.06)	0.04 (0.03; 0.07)
R_a after treatment (μm): median (min; max)	0.14 (0.06; 0.22)	0.15 (0.05; 0.26)	0.13 (0.08; 0.20)
Surface loss (μm): median (min; max)	5.21 (0.56; 20.47) a	4.43 (0.97; 10.08) b	11.86 (2.38; 30.56) a,b

Groups with the same letter are statistically significant different at $p < 0.05$ (Kruskal–Wallis and Mann–Whitney's *U*-test with α-adjustment).

Table 2. Data for each group: median roughness values (R_a) before and after treatment and median depth of surface in micrometres

	Nylon brush				Prophy cup				Pasteless
	#1 ($n = 8$) calcium pyrophosphate/ glycerine	#2 ($n = 8$) pumice/ glycerine	#3 ($n = 8$) Nupro coarse	#4 ($n = 8$) Hawe cleanic	#5 ($n = 8$) calcium pyrophosphate/ glycerine	#6 ($n = 8$) pumice/ glycerine	#7 ($n = 8$) Nupro coarse	#8 ($n = 8$) Hawe cleanic	prophy cup #9 ($n = 8$) –
R_a before treatment (μm): median (min; max)	0.03 (0.02;0.05)	0.03 (0.03;0.05)	0.05 (0.04;0.05)	0.04 (0.03;0.05)	0.04 (0.03;0.06)	0.04 (0.03;0.05)	0.04 (0.03;0.04)	0.04 (0.03;0.06)	0.04 (0.03;0.07)
R_a after treatment (μm): median (min; max)	0,06 (0.06;0.11) a,b,c	0.14 (0.10;0.22)a	0.16 (0.12;0.20) b	0.16 (0.12;0.17) c	0.07 (0.05;0.10) d,e,f,g	0.18 (0.12;0.25) d	0.22 (0.20;0.26) e,g	0.12 (0.08;0.18) d,e	0.13 (0.08;0.20) g
Surface loss (μm): median (min; max)	6.18 (2.39;16.51) a	5.51 (1.29;8.23)	10.10 (2.18;20.47) b	1.88 (0.56;5.62) a,b	2.07 (0.97;3.03) c	6.07 (1.01;10.08)	5.93 (3.45;7.92) c	4.93 (1.54;8.63) c	11.86 (2.38;30.56) c

Groups with the same letter are statistically significant different at $p < 0.05$ (Kruskal–Wallis and Mann–Whitney's u-test with α-adjustment)

tically significant lower for calcium pyrophosphate (group 1) when compared with the three other abrasives (Table 2, groups 2–4, $p < 0.05$). This was also true in the ''prophy cup group'', including the pasteless cup (Table 2). In this group, some additional statistical significant differences were found ($p < 0.05$).

Tables 1 and 2 show the surface loss after the treatment. The median surface loss ranged from 1.88–11.86 μm. After use of the pasteless prophy cup, statistically significant more surface loss was found when compared with the pooled data of the brushes (groups 1–4) and the prophy cups (groups 5–8), both combined with an abrasive ($p < 0.05$, Table 1). A comparison of the four brush groups (1–4) revealed a significant difference for Hawe cleanic (#4) only. The use of this prophy paste resulted in less surface loss when compared with calcium pyrophosphate (group 1) and Nupro coarse (group 3) ($p < 0.05$, Table 2). The surface loss data related to the use of prophy cups showed a different pattern (Table 2). The combination of prophy cup and calcium pyrophosphate (group 5) resulted in significantly less surface loss than the combination with Nupro coarse and Hawe cleanic (groups 7 and 8), and the pasteless prophy cup, respectively (group 9).

Discussion

In the present study, PTC was simulated in vitro using human dentin to determine surface loss and roughness resulting from this procedure. An effective treatment time of 37 s was chosen. According to Christensen & Bangerter(1984), the average time applied to clean one tooth surface is 4.5 s in vivo. Based on this data, the surface loss of about eight PTC procedures was simulated in the present study. The lowest substance loss (1.88 μm) was found for the combination brush/Hawe cleanic (group 4), whereas the highest (11.86 μm) resulted from the use of the pasteless prophy cup (group 9).

The substance loss of the various abrasives was different when nylon brushes or prophy cups were used. This indicates that the abrasivity of a prophy paste is depending on the manner it is applied. However, from the present study, no explanation can be given for this fact.

Based on the assumption, that eight PTC were simulated, the average loss per tooth cleaning ranged between 0.24 and 1.48 μm. According to Axelsson et al. (1991) the frequency of PTC ranges between one and six per year, depending on the patient's individual oral disease risk. This means, that in a worst case scenario the dentin loss may be between 1.44 and 8.88 μm per year, and that it takes between 11 and 69 years before 0.1 mm dentin is abraded during PTC. Coronal dentin usually is not exposed to PTC as it is covered by enamel. In anterior teeth, the mean thickness of radicular dentin in the region of the cemento-enamel junction varies between 1.38 mm (distal surface of mandibular incisors) and 3.06 mm (lingual surface of maxillary central incisors) (Bellucci & Perrini 2002). For upper and lower premolars, these values were scattered between 1.54 and 2.21 mm (Bellucci & Perrini 2002), and for lower molars, the respective mean values were between 1.42 and 3.01 mm (Berutti & Fedon 1992, Sterrett et al. 1996). The specimens in the studies of Bellucci & Perrini (2002) and Sterrett et al. (1996) were gathered from subjects aged between 35 and 55 years. No age was given in the study of Berutti & Fedon (1992). With increasing age of the subjects, dentinal thickness increases (Sterrett et al. 1996, Murray et al. 2002). Considering the thickness of radicular dentin, the abrasion found in the present study does not seem to be threatening. However, the average substance loss presented in the ''Results'' neglects the fact, that the abrasion occurring during PTC in one specimen was not always uniform. This was mainly observed in group 9 (pasteless prophy cup). This product was abraded during its use. The consequence was, that the dental hand piece was rotating along its suspension axis to compensate the material loss. Therefore at the end of the testing procedure the prophy cup was not always in full contact with the specimen but only with an edge, resulting in an unequal abrasion of the dentin sample. This may also occur in vivo if the prophy cup is not in uniform contact with the tooth surface.

Furthermore, it has to be taken into account, that PTC is not the only event leading to noncariogenic dentin loss. Erosions and abrasions occurring during tooth brushing have to be considered. In an in situ study Noordmans et al. (1991) found wear rates of dentin between 4 and 35 μm/week with 100 strokes of brushing with toothpaste. The substance loss was depending on toothpaste and

toothbrush type. The dentin surface loss found in this study was far less than that reported by Noordmans et al. (1991). Dental erosion usually is the combined effect of deminalization of tooth surface by an erosive agent and abrasion of the demineralized surface by surrounding oral soft tissues and through food mastication (Amaechi et al. 2003). Dietary erosion can occur with no mechanical action. Tooth brushing with toothpaste may act as an important co-factor (Mierau 1992, Osborne-Smith et al. 1999). For upper permanent incisors of 11–13-year-old children, erosions were found in 37% and 41% of the cases in UK and USA (Deery et al. 2000). However, no data are available about the average loss of tooth substance.

The surface roughness of the dentin samples after treatment ranged between 0.06 and 0.22 μm in the present study. This is in good agreement with the data found by other authors (Lutz et al. 1993). It can be assumed that all tested systems resulted in a surface smoothness which promotes plaque adherence less than a rough surface (Quirynen et al. 1990). It can be concluded from the data of the present study that the amount of dentin loss occurring during PTC depends on which product combination is used. In general, PTC does not seem to represent a major risk factor for dentin loss.

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References

Amaechi, B. T., Higham, S. M. & Edgar, W. M. (2003) Influence of abrasion in clinical manifestation of human dental erosion. *Journal of Oral Rehabilitation* **30**, 407–413.

Axelsson, P., Lindhe, J. & Nystrom, B. (1991) On the prevention of caries and periodontal disease. Results of a 15-year longitudinal study in adults. *Journal of Clinical Periodontology* **18**, 182–189.

Bellucci, C. & Perrini, N. (2002) A study on the thickness of radicular dentine and cementum in anterior and premolar teeth. *International Endodontics Journal* **35**, 594–606.

Berutti, E. & Fedon, G. (1992) Thickness of cementum/dentin in mesial roots of mandibular first molars. *Journal of Endodontics* **18**, 545–548.

Christensen, R. P. & Bangerter, V. W. (1984) Determination of rpm, time, and load used in oral prophylaxis polishing in vivo. *Journal of Dental Research* **63**, 1376–1382.

Coffman, L., Berg, M. L. & Hefferren, J. J. (2000) Profilometric measurement of dentifrice abrasivity in the laboratory. *Journal of Dental Research* **79**, 469 (Abstr.#2606).

Deery, C., Wagner, M. L., Longbottom, C., Simon, R. & Nugent, Z. J. (2000) The prevalence of dental erosion in a United States and a United Kingdom sample of adolescents. *Pediatric Dentistry* **22**, 505–510.

Hefferren, J. J. (1976) A laboratory method for assessment of dentifrice abrasivity. *Journal of Dental Research* **55**, 563–573.

Lutz, F., Sener, B., Imfeld, T., Barbakow, F. & Schupbach, P. (1993) Comparison of the efficacy of prophylaxis pastes with conventional abrasives or a new self-adjusting abrasive. *Quintessence International* **24**, 193–201.

Mierau, H.-D. (1992) Der freiliegende Zahnhals. *Deutsche Zahnahnarztliche Zeitschrift* **47**, 643–653.

Murray, P. E., Stanley, H. R., Matthews, J. B., Sloan, A. J. & Smith, A. J. (2002) Age-related odontometric changes of human teeth. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **93**, 474–482.

Noordmans, J., Pluim, L. J., Hummel, J., Arends, J. & Busscher, H. J. (1991) A new profilometric method for determination of enamel and dentinal abrasion in vivo using computer comparisons: a pilot study. *Quintessence International* **22**, 653–657.

Osborne-Smith, K. L., Burke, F. J. & Wilson, N. H. (1999) The aetiology of the non-carious cervical lesion. *International Dental Journal* **49**, 139–143.

Quirynen, M., Marechal, M., Busscher, H. J., Weerkamp, A. H., Darius, P. L. & Steenberghe, D. (1990) The influence of surface free energy and surface roughness on early plaque formation. An in vivo study in man. *Journal of Clinical Periodontology* **17**, 138–144.

Sterrett, J. D., Pelletier, H. & Russell, C. M. (1996) Tooth thickness at the furcation entrance of lower molars. *Journal of Clinical Periodontology* **23**, 621–627.

Stookey, G. K. & Schemehorn, B. R. (1979) A method for assessing the relative abrasion of prophylaxis materials. *Journal of Dental Research* **58**, 588–592.

Zimmer, S., Barthel, C. R., Schemehorn, B. R. & Imfeld, T. (2002) A new fluoride-releasing rubber cup for professional oral hygiene. *Journal of Clinical Dentistry* **13**, 253–257.

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