

Effect of a sonic toothbrush on the abrasive dentine wear using toothpastes with different abrasivity values

Blend Hamza¹  | Entoni Uka² | Philipp Körner² | Thomas Attin² | Florian Just Wegehaupt²

¹Clinic of Orthodontics and Pediatric Dentistry, Center of Dental Medicine, University of Zurich, Zurich, Switzerland

²Clinic of Conservative and Preventive Dentistry, Center of Dental Medicine, University of Zurich, Zurich, Switzerland

Correspondence

Blend Hamza, Clinic of Orthodontics and Pediatric Dentistry, Center of Dental Medicine, University of Zurich, Plattenstrasse 11, 8032 Zürich, Switzerland.
Email: blend.hamza@zzm.uzh.ch

Funding information

No funding was received for this research

Abstract

Objective: This in vitro study aimed to investigate the effect of a sonic toothbrush on the resulting abrasive dentine wear using toothpastes with different abrasivities compared to the use of a manual toothbrush.

Methods: Ninety-six bovine dentine samples were divided into six groups and subjected to a brushing sequence (sonic: 20 min, 0.9 N, 10 strokes/min; manual: 20 min, 1.6 N, 60 strokes/min) as follows: group 1: Elmex Sensitive Plus (RDA = 28) + manual toothbrush; group 2: Elmex Sensitive + sonic toothbrush; group 3: Elmex Kariesschutz (RDA = 65) + manual toothbrush; group 4: Elmex Kariesschutz +sonic toothbrush; group 5: Colgate Total Original (RDA = 121) + manual toothbrush; and group 6: Colgate Total Original +sonic toothbrush. The abrasive dentine wear was measured profilometrically.

Results: The median (IQR) abrasive dentine wear was as follows: Elmex Sensitive Plus (manual toothbrush: 2.7 µm (0.8), sonic toothbrush: 3.1 µm (1.9)); Elmex Kariesschutz (manual toothbrush: 4.9 µm (1.4), sonic toothbrush: 6.4 µm (2.1)); and Colgate Total Original (manual toothbrush: 5.2 µm (1.1), sonic toothbrush: 9.0 µm (3.1)). Differences in dentine wear between sonic and manual toothbrushes were statistically significant only in the groups brushed with Elmex Kariesschutz and Colgate Total Original ($p \leq 0.05$).

Conclusion: Brushing with a sonic toothbrush could result in a higher abrasive dentine wear compared to manual toothbrush when combined with toothpastes with high abrasivity values.

KEYWORDS

abrasive dentine wear, manual toothbrush, sonic toothbrush, toothpaste

1 | INTRODUCTION

Toothpastes are loaded with abrasive particles in order to enhance the ability to remove stains and dental plaque. Abrasives are also

known to be able to remove sound exposed dentine, the so-called 'abrasive dentine wear'. The amount of sound dentine removed during toothbrushing depends on many factors (e.g., type of the toothbrush, force applied while brushing, duration and frequency of toothbrushing, abrasivity of the used toothpaste).¹

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2021 The Authors. *International Journal of Dental Hygiene* published by John Wiley & Sons Ltd.

TABLE 1 Study design, RDA = Relative Dentine Abrasivity

Preparation of 96 dentine samples from 16 bovine incisors - Six samples (A-F) from each incisor					
Allocation of the samples in six groups (n = 16)					
Group 1 Samples A	Group 2 Samples B	Group 3 Samples C	Group 4 Samples D	Group 5 Samples E	Group 6 Samples F
Preconditioning the samples (1000 strokes, 2.5 N, Elmex Kariesschutz slurry)					
Recording of baseline profiles					
Brushing sequence with a manual toothbrush (20 min, 1.6 N, 60 strokes/min, slurry 1:2, fresh slurry every 2 min)					
Elmex Sensitive Plus RDA = 28		Elmex Kariesschutz RDA = 65		Colgate Total Original RDA = 121	
Brushing sequence with a sonic toothbrush (20 min, 0.9 N, 10 strokes/min, slurry 1:2, fresh slurry every 2 min)					
Elmex Sensitive Plus RDA = 28		Elmex Kariesschutz RDA = 65		Colgate Total Original RDA = 121	
Recording of final profiles					

Powered toothbrushes were first introduced to the market in the early 1960s and started to be considered as a legitimate alternative to manual toothbrushes.² The difference between powered and manual toothbrushes regarding the resulting abrasive dentine wear has already been investigated. Bizhang et al.³ and Wiegand et al.⁴ reported that powered toothbrushes led to an increased abrasive dentine wear compared to manual toothbrushes, under the premise that both were used with the same pressure. This was attributed to the more movements performed by the filaments of the sonic toothbrushes. However, in each of these studies, only a single toothpaste was used (RDA = 150 and 77, respectively).

It could be speculated that toothpastes with different abrasivity values would interact differently when dentine is brushed with a manual or powered toothbrush. This study was therefore carried out to investigate the resulting abrasive dentine wear while using a powered (sonic movements) or a manual toothbrush and toothpaste slurries with different abrasivity values (namely RDA = 28, 65 and 121) in vitro. The null hypothesis of this study was that sonic and manual toothbrushes would cause the same amount of abrasive dentine wear when using toothpastes with different abrasivity values.

2 | STUDY POPULATION AND METHODOLOGY

Sixty-nine dentine samples were milled out of 16 bovine permanent incisors (six samples from each incisor). Each dentine sample from each incisor was allocated in a different group, creating six groups of 16 samples from 16 different incisors. The samples were embedded in acrylic resin (Paladur, Heraeus, Kulzer) which was allowed to polymerize in a laboratory pressure pot (12 min, 45°C, 4.8 bar). The samples were then ground with 2000- and 4000-grit silicon carbide paper in an automatic grinding machine (Tegramin-30, Struers) under constant water cooling. All samples were preconditioned by a brushing sequence (1000 brushing strokes, 2.5 N) using a slurry of Elmex Kariesschutz toothpaste (Colgate Palmolive) and a medium-hard manual toothbrush (Paro M43, Esro AG). Baseline profiles were then recorded under wet conditions using a stylus profilometer (MFW-250, Perthometer S2; Mahr).

The samples were then subjected to a brushing sequence as follows: group 1: Elmex Sensitive Plus (RDA = 28, Colgate Palmolive) and a manual toothbrush (Paro M43, Esro AG); group 2: Elmex Sensitive Plus and the sonic toothbrush (Waterpik Sensonic Plus SR-3000, 30'500 strokes/min, Water Pik, Inc.); group 3: Elmex Kariesschutz (RDA = 65, Colgate Palmolive) and the manual toothbrush; group 4: Elmex Kariesschutz and the sonic toothbrush; group 5: Colgate Total Original (RDA = 121, Colgate Palmolive) and the manual toothbrush; and group 6: Colgate Total Original and the sonic toothbrush. The brushing sequence lasted for 20 min, and the used slurry was replaced with 2-minute intervals. Whenever the manual toothbrush was used, the brushing sequence was set at 60 strokes/min and the load applied on the samples at 1.6 N. Whenever the sonic toothbrush was used, the brushing sequence was set at 10 strokes/min

and the load applied on the samples at 0.9 N. The filaments of the sonic toothbrush—originally ripple-shaped—were cut flat to have a similar contact profile with the surface of the dentine samples as the manual toothbrush. The slurries used in this study were prepared by mixing the tested toothpaste with artificial saliva⁵ at 1:2 mass-ratio.

After the brushing sequence, final profiles were recorded under wet conditions. The detailed protocol of the profilometric recording is already reported in an earlier study.⁶ Table 1 summarizes the study design.

2.1 | Statistical analysis

Median and inter-quartile ranges (IQR) of the abrasive dentine wear for each tested toothbrush using each different toothpaste were calculated. Two-factor crossed repeated measures test was conducted. This means that each level (RDA = 28, RDA = 65, RDA = 121, manual, sonic) of one factor (toothpaste, toothbrush) was crossed with each level of the other factor which increases the power. A mixed linear model was first adapted to the data with abrasive wear as the target variable, toothbrush and toothpaste as fixed explanatory variables and the samples as random explanatory variable (a random intercept model). The model diagnosis was carried out by means of residual analysis and the deviations from the asymptotic assumptions were found to be tolerable. Both fixed variables (toothbrush and toothpaste) and their interaction were found to have a significant impact on the target variable (abrasive dentine wear). Pairwise post hoc comparisons between the groups were conducted with the marginal means and corrected for multiple testing after Tukey. The significance level was set at 0.05. All data were analysed using the R software (The R Foundation for Statistical Computing; www.R-project.org).

3 | RESULTS

Figure 1 depicts the resulting abrasive dentine wear for each group (combination of toothpaste and toothbrush type). The median (and IQR) abrasive dentine wear was calculated for each toothpaste when using each toothbrush as follows: Elmex Sensitive Plus, RDA = 28, manual toothbrush: 2.7 μm (0.8), sonic toothbrush: 3.1 μm (1.9); Elmex Kariesschutz, RDA = 65, manual toothbrush: 4.9 μm (1.4), sonic toothbrush: 6.4 μm (2.1); Colgate Total Original, RDA = 121: manual toothbrush: 5.2 μm (1.1), sonic toothbrush: 9.0 μm (3.1).

3.1 | Within the toothbrush type

When the manual and sonic toothbrushes were used, the resulting abrasive dentine wear was statistically significantly lower in the group brushed with Elmex Sensitive Plus (RDA = 28) compared to both other groups. The resulting abrasive dentine wear in the groups brushed with Elmex Kariesschutz (RDA = 65) and Colgate Total Original (RDA = 121) was not statistically significantly different.

3.2 | Within the toothpaste abrasivity

When the samples were brushed with Elmex Sensitive Plus (RDA = 28), no statistically significant difference was observed for the manual and sonic toothbrushes. In the Elmex Kariesschutz group (RDA = 65) and the Colgate total Original group (RDA = 121), samples brushed with the sonic toothbrush showed statistically significantly

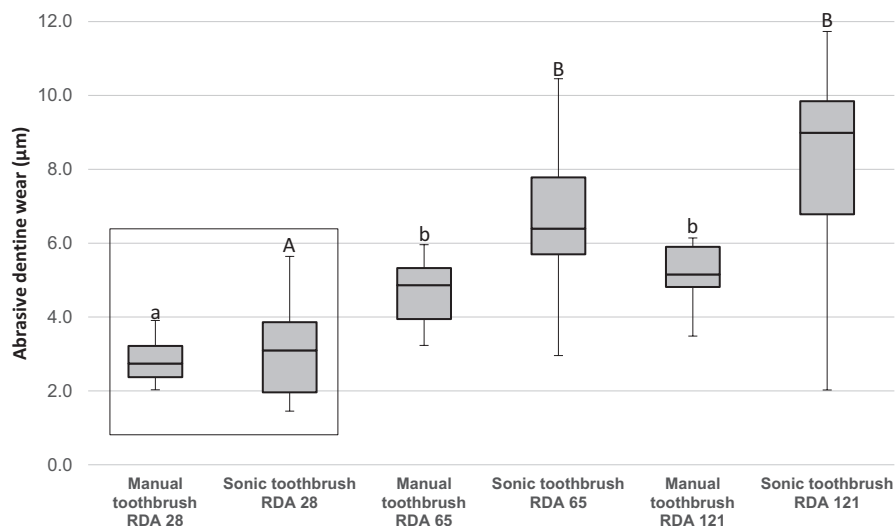


FIGURE 1 Abrasive dentine wear (median + Interquartile range, IQR = whiskers) in the different experimental groups. Tested toothpastes: Elmex Sensitive Plus (RDA = 28), Elmex Kariesschutz (RDA = 65) and Colgate Total Original (RDA = 121). Boxplots marked with identical letters (lower case letters are used for the manual toothbrush, and capital letters are used for the sonic toothbrush) indicate that there is no statistically significant difference between the values when the respective toothbrush is used with different RDA toothpastes. Within the groups brushed with the same toothpaste (same RDA), pairs enclosed in a box are not statistically significantly different

higher abrasive dentine wear compared to the samples brushed with the manual toothbrush (the meaningful difference between groups =1.5 μm for Elmex and 3.8 μm for Colgate⁷).

4 | DISCUSSION

Powered toothbrushes become widely used as an established alternative to manual toothbrushes. Little is known on the influence of powered toothbrushes on the abrasive tooth wear. This study aimed to investigate the influence of a sonic toothbrush on the abrasive dentine wear when using toothpastes with different abrasivity values.

Bovine dentine has already been reported to be a suitable alternative to human dentine in abrasion studies.⁸ Bovine teeth have larger surfaces, which allow many samples to be obtained from one tooth. This advantage was used in this study, where six samples could be extracted from one tooth. This allowed creating six harmonic groups consisting of samples extracted from different, yet altogether the same group of teeth. Logistically, it would have been possible to increase the sample size in each group and consequently obtain more accurate meaningful difference between the groups.⁷ However, this would have required to extract more dentine samples (more than the six samples already extracted) from the same bovine incisor which is not feasible. Obtaining more samples from new incisors could have overcome this issue, but affect the aforementioned harmony between the groups. The different force applied on the dentine samples during the brushing sequence (1.6 N for the manual toothbrush and 0.9 N for the sonic toothbrush) was chosen based on the findings of Wiegand et al.⁹ These values were found to be the mean force applied in vivo by volunteers while brushing their teeth with either sonic or manual toothbrush. RDA values of the tested toothpastes were measured in an earlier study¹⁰ and selected to cover a wide range of abrasivity (from low abrasive (RDA = 28) to very high abrasive (RDA = 121) according to the classification adopted in Zurich, Switzerland¹¹). Samples were brushed for 20 min. If teeth were brushed for 2 min twice daily, each tooth surface would be brushed for 10 sec daily.¹² Thus, the 20-min brushing time used in this study would correspond to 120-day in vivo brushing time. Nevertheless, the number of brushing strokes subjected to each sample should also play a role in this—rough—estimate of the in vivo brushing time. A more accurate approach to interpret in vitro brushing time into in vivo time is advisable.

The filaments of the sonic toothbrush were cut flat in this study. This could alter the resulting abrasive wear. However, only the effect of the sonic movements of the toothbrush was planned to be investigated in this study. Furthermore, Trussi et al.¹³ found flat-trimmed filaments to cause more abrasive wear than ripple-shaped ones. This could have a negative effect on the baseline situation between the groups tested in this study—if the filaments of the sonic toothbrush were not cut flat. Since sonic toothbrushes are usually gently moved from tooth to tooth, the

brushing sequence of the sonic toothbrush was set at lower speed than the manual toothbrush (10 vs. 60 strokes/min).⁹ Regardless, the speed of the brushing sequence was reported not to have an influence on the abrasive dentine wear.¹⁴

4.1 | Abrasive dentine wear based on the toothbrush type

Abrasive dentine wear was statistically significantly higher when the samples were brushed with the sonic toothbrush and toothpastes with higher RDA values (Elmex Kariesschutz, RDA = 65 and Colgate Total Original, RDA = 121) compared to the samples brushed with the manual toothbrush. Therefore, the null hypothesis of this study has to be rejected. This finding is in accordance with earlier studies where the same combination (sonic toothbrush, highly abrasive toothpaste) was investigated.^{3,4,9} On the other hand, brushing with the manual or sonic toothbrush did not have an influence on the resulting abrasive dentine wear when the samples were brushed with a toothpaste with a low abrasivity value (Elmex Sensitive Plus, RDA = 28). Nevertheless, a trend towards higher abrasive dentine wear could be noticed when the sonic toothbrush was used. Brushing for a longer time might have even resulted in a significantly higher wear in this group.

4.2 | Abrasive dentine wear based on the abrasivity value of the toothpaste

Regardless of the toothbrush type, the resulting abrasive dentine wear was not statistically significantly higher when the samples were brushed with Colgate Total Original (RDA = 121) compared to the samples brushed with Elmex Kariesschutz (RDA = 65). This could be considered unexpected as Colgate Total Original is—or should be—almost twice as abrasive as Elmex Kariesschutz. Although considered a robust method to determine the abrasivity of a toothpaste, RDA values do not necessarily represent or predict the actual resulting abrasive dentine wear when brushing with the tested toothpaste. RDA values might also vary up to 20% for the same toothpaste when tested several times.¹⁵ For instance, this variation of the RDA value was noticed in a recent abrasion study where the RDA value of Colgate Total Original was measured to be 100¹⁶ (vs. 121, measured by Tawakoli et al.¹⁰). Both studies measured the RDA values in the same laboratory under the same standards and thus can be compared to each other. RDA values for Elmex Kariesschutz were also a bit higher in 2020 (RDA = 69) in comparison to 2015 (RDA = 65), and therefore, the recent difference between the two toothpastes abrasivity values might not be as high as reported in 2015. When conducting this study, the recently measured RDA values were not yet published, and therefore, the values measured in 2015 were adopted to choose the range of the abrasivity of the toothpastes used in

this study. Differences in the abrasivity for the same toothpaste with different lot numbers have also been noticed in our laboratory. Furthermore, abrasive dentine wear was measured profilometrically in this study. A certain inconsistency between RDA and profilometric values has been reported in earlier studies.^{17,18} All of the above-mentioned factors could contribute to explaining the non-significant difference between the abrasive dentine wear resulting from brushing with toothpastes with different RDA values. Regardless, the primary aim of this study was to compare the effect of sonic and manual movements on the abrasive dentine wear and not to investigate the abrasivity of the tested toothpastes. Also, care should be taken when describing an RDA value as high. Different schools and laboratories have their own classification regarding RDA values.

Within the limits of this study, it could be concluded that the sonic toothbrush causes higher amounts of abrasive dentine wear compared to the manual toothbrush only in combination with toothpastes with high abrasivity values. Further studies are needed to investigate whether this might also be the case for low abrasive toothpastes if the brushing procedure would be prolonged.

5 | CLINICAL RELEVANCE

5.1 | Scientific rationale for study

Little is known about the combination of toothbrush type with toothpastes with different ranges of abrasivity.

5.2 | Principal findings and practical implications

Sonic toothbrush seems to cause more abrasive dentine wear when combined with toothpastes with high abrasivity compared to manual toothbrush.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ACKNOWLEDGEMENTS

This study is part of the master's thesis 'Einfluss der Art der Zahnbürste (Hand vs. elektrisch) auf die Dentinabrasion bei Verwendung unterschiedlich abrasiver Zahnpasten' by E. Uka performed at the University of Zurich, Switzerland, under the supervision of F. Wegehaupt.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

B.H. and P.K. led the writing; E.U. performed the experiment in partial fulfilment for master's degree; T.A. performed critical evaluation of the manuscript; F.J.W. conceived and designed the experiment and critical evaluation of the manuscript.

ETHICAL APPROVAL

This study was not conducted on humans or on human biological material.

ORCID

Blend Hamza  <https://orcid.org/0000-0003-0493-2553>

REFERENCES

1. Wiegand A, Schlueter N. The role of oral hygiene: does toothbrushing harm? *Monogr Oral Sci.* 2014;25:215-219.
2. Yaacob M, Worthington HV, Deacon SA, et al. Powered versus manual toothbrushing for oral health. *Cochrane Database Syst Rev.* 2014;6:CD002281.
3. Bizhang M, Schmidt I, Chun YHP, Arnold WH, Zimmer S. Toothbrush abrasivity in a long-term simulation on human dentin depends on brushing mode and bristle arrangement. *PLoS One.* 2017;12(2):e0172060.
4. Wiegand A, Lemmrich F, Attin T. Influence of rotating-oscillating, sonic and ultrasonic action of power toothbrushes on abrasion of sound and eroded dentine. *J Periodontol Res.* 2006;41(3):221-227.
5. Klimek J, Hellwig E, Ahrens G. Fluoride taken up by plaque, by the underlying enamel and by clean enamel from three fluoride compounds in vitro. *Caries Res.* 1982;16(2):156-161.
6. Attin T, Becker K, Roos M, Attin R, Paqué F. Impact of storage conditions on profilometry of eroded dental hard tissue. *Clin Oral Investig.* 2009;13(4):473-478.
7. Krithikadatta J, Datta M, Gopikrishna V. CRIS Guidelines (Checklist for Reporting In-vitro Studies): a concept note on the need for standardized guidelines for improving quality and transparency in reporting in-vitro studies in experimental dental research. *J Conserv Dent.* 2014;17(4):301-304.
8. Wegehaupt FJ, Widmer R, Attin T. Is bovine dentine an appropriate substitute in abrasion studies? *Clin Oral Investig.* 2010;14(2):201-205.
9. Wiegand A, Burkhard JPM, Eggmann F, Attin T. Brushing force of manual and sonic toothbrushes affects dental hard tissue abrasion. *Clin Oral Investig.* 2013;17(3):815-822.
10. Tawakoli PN, Sener B, Attin T. Mechanical effects of different Swiss market-leading dentifrices on dentin. *Swiss Dent J.* 2015;125(11):1210-1219.
11. Imfeld T. Standard operation procedures for the relative dentin abrasion: (RDA) method used at Zurich University. *J Clin Dent.* 2010;21:S11-S12.
12. Hooper S, West NX, Pickles MJ, Joiner A, Newcombe RG, Addy M. Investigation of erosion and abrasion on enamel and dentine: a model in situ using toothpastes of different abrasivity. *J Clin Periodontol.* 2003;30(9):802-808.
13. Turssi CP, Kelly AB, Hara AT. Toothbrush bristle configuration and brushing load: Effect on the development of simulated non-carious cervical lesions. *J Dent.* 2019;86:75-80.
14. Parry J, Harrington E, Rees GD, McNab R, Smith AJ. Control of brushing variables for the in vitro assessment of toothpaste abrasivity using a novel laboratory model. *J Dent.* 2008;36(2):117-124.
15. González-Cabezas C, Hara AT, Hefferren J, Lippert F. Abrasivity testing of dentifrices - challenges and current state of the art. *Monogr Oral Sci.* 2013;23:100-107.

16. Hamza B, Attin T, Cucuzza C, Gubler A, Wegehaupt FJ. RDA and REA values of commercially available toothpastes utilising diamond powder and traditional abrasives. *Oral Health Prev Dent.* 2020;18(1):807-814.
17. Sabrah AHA, Lippert F, Kelly AB, Hara AT. Comparison between radiotracer and surface profile methods for the determination of dentifrice abrasivity. *Wear.* 2013;306(1-2):73-79.
18. Prencipe M, Vandeven M, Feldman BN, Schemehorn BR. A Comparative study of laboratory dentifrice abrasion measuring methods. *J Clin Dent.* 2016;27(4):105-109.

How to cite this article: Hamza B, Uka E, Körner P, Attin T, Wegehaupt FJ. Effect of a sonic toothbrush on the abrasive dentine wear using toothpastes with different abrasivity values. *Int J Dent Hygiene.* 2021;19:407-412. <https://doi.org/10.1111/idh.12531>