INTRODUCTION

Besides dental plaque and external staining, toothbrushing can also remove some sound exposed dentin, the so-called ‘abrasive dentine wear’. Abrasive dentine wear is a multifactorial process and could be affected by factors such as the abrasivity of the toothpaste, the applied brushing force and frequency of toothbrushing and the mechanical properties of the toothbrush, to name a few.¹

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

Abstract

Objective: To investigate the influence of toothbrush bristle stiffness and applied brushing force on the resulting abrasive dentine wear in vitro.

Methods: One hundred sixty bovine dentine samples were randomly allocated in eight groups (n = 20). Groups one to four were brushed with a soft-bristle toothbrush with soft bristles applying 1, 2, 3 and 4 N brushing force, respectively. Groups five to eight were brushed with a medium-bristle toothbrush applying the same aforementioned brushing forces (120 strokes/min, abrasive slurry (RDA = 121), 25 min). Profiles were recorded before and after the brushing sequence, and the median and interquartile range of abrasive dentine wear were calculated and compared using two-way ANOVA and pairwise tests corrected after Tukey (α = 0.05).

Results: At 1, 2 and 3 N brushing force, the tested toothbrushes caused no significantly different abrasive dentine wear. At 4 N brushing force, the medium-bristle toothbrush caused statistically significantly higher abrasive force than the soft-bristle toothbrush. Using the medium-bristle toothbrush, abrasive dentine wear statistically significantly increased with increasing brushing force from 1 to 3 N. However, increasing the brushing force to 4 N did not result in statistically significantly higher wear. Using the soft-bristle toothbrush, abrasive dentine wear statistically significantly increased with increasing brushing force from 1 to 2 N. However, increasing the brushing force to 3 or 4 N did not result in statistically significantly higher wear.

Conclusion: The soft-bristle toothbrush tends to cause less abrasive wear with increasing brushing force than the medium-bristle toothbrush.

KEYWORDS
abrasive dentine wear, non-carious cervical lesions, toothbrush stiffness, toothbrushing force
In two recent studies, toothbrush’s high bristle stiffness was found to be an important factor in the development of non-caries cervical lesions (NNCL, a manifestation of abrasive dentine wear) especially when using toothpastes with medium-to-high abrasivity values. However, contrasting results were reported in the study of Bizhang et al., where a soft-bristle toothbrush caused higher abrasive dentine wear than the hard one. Bizhang et al. speculated that the more flexion of the soft-bristle toothbrush—compared with the medium- or hard-bristle toothbrushes—resulted in a greater contact area and the smooth dispersion of the toothpaste on the dentin surface, and thus in higher abrasive wear. On the other hand, Turassi et al. speculated that the hard-bristle toothbrush dragged more abrasive particles under the tip of the bristle, and thus resulted in higher abrasive wear compared with the soft-bristle toothbrush. It should be mentioned that the tested toothbrushes in both above-mentioned studies had different bristle diameters (hard-bristle > soft-bristle) and different number of bristles per tuft (hard-bristle < soft-bristle), which could affect the resulting abrasive dentine wear.

The force applied during toothbrushing could also be a modifying factor on the resulting abrasive dentine wear. Higher abrasive dentine wear was found to directly correlate with higher applied brushing forces. However, it could be speculated that soft-bristle toothbrushes might respond differently to the applied brushing force than harder ones.

The interaction between toothbrush stiffness and toothbrushing force has not yet been fully evaluated. Furthermore, the effect of the different bristle diameters and the different number of bristles per tuft have also not been fully eliminated in previous studies, which compared toothbrushes with different stiffness. Therefore, this study was carried out to investigate the interaction between toothbrush stiffness (soft vs. medium with the same bristle diameter, number of bristles per tuft and material) and the different toothbrushing forces (1, 2, 3 and 4 N) on the resulting abrasive dentine wear.

The tested toothbrushes were specially fabricated for this study (Paro M43, Eso). The heads of both medium- and soft-bristle toothbrushes showed the same number, material and diameter of tufts and bristles. The only difference between the medium- and soft-bristle toothbrush was the length of the bristles (soft = 12 mm, medium 10.5 mm), which basically gave the bristles its ‘soft’ or ‘medium’ property (Table 1). The abrasive slurry was prepared by mixing 25 g of the silica abrasive Zeodent® 113 (Evonik Industries) and 25 g of the silica abrasive Zeodent® 103 (Evonik Industries) with 225 g of glycerine and 0.25 g of a silicone antifoam agent. Table 2 summarises the study design.

### 2.1 Statistical analysis

Median and interquartile range (IQR) of the abrasive dentine wear for each applied brushing force and for each different toothbrush stiffness were calculated. A two-way ANOVA test was conducted to investigate any significant difference between the groups. Pairwise differences between the groups (based on the type of the toothbrush bristle stiffness and the brushing force) were tested and corrected following the Tukey method for multiple testing. The significance level was set at 0.05. Data were analysed using the R software (The R Foundation for Statistical Computing; Vienna, Austria; www.R-project.org).

### 3 RESULTS

Figure 1 depicts the resulting abrasive dentine wear for each experimental group. The median (and IQR) for the abrasive dentine wear was calculated for each brushing force for both types of toothbrushes as follows: 1 N (soft-bristle toothbrush = 8.5 µm (2.4), medium-bristle toothbrush = 7.3 µm (1.6)), 2 N (soft-bristle toothbrush = 15.3 µm (2.8), medium-bristle toothbrush = 13.3 µm (3.7)), 3 N (soft-bristle toothbrush = 17.5 µm (4.6), medium-bristle toothbrush = 17.1 µm (3.3)) and 4 N (soft-bristle toothbrush = 14.8 µm (3.8), medium-bristle toothbrush = 18.1 µm (3.4)).

| Toothbrush type | Soft | Medium |
|-----------------|------|--------|
| Bristle diameter | 0.2 mm | 0.2 mm |
| Bristle length | 12 mm | 10.5 mm |
| Material | Polyamide | Polyamide |
| Tip configuration | End-rounded | End-rounded |
| Number of tufts | 43 | 43 |
| Number of bristles per tuft | 40 ± 4 | 40 ± 4 |
3.1 | Within the respective toothbrush bristle type

Using the medium-bristle toothbrush, abrasive dentine wear was always statistically significantly higher with increasing brushing force until 3 N. At brushing force of 4 N, abrasive dentine wear tended to be higher compared to 3 N, but it was not statistically significantly different. Using the soft-bristle toothbrush, abrasive dentine wear was statistically significantly higher when the brushing force was 2 N compared to 1 N. However, the wear was statistically significantly lower when the brushing force was set at 4 N compared to 3 N.

3.2 | Within the respective applied brushing force

At 1, 2 and 3 N brushing force, there was no statistically significant difference in the abrasive dentine wear between the soft- and medium-bristle toothbrushes. At 4 N brushing force, the abrasive dentine wear was statistically significantly higher using the medium-bristle toothbrush compared with the abrasive wear caused by the soft-bristle toothbrush with soft bristles.
4 | DISCUSSION

The modifying factors of the abrasive dentine wear have been investigated in several studies. These include—among others—the abrasivity of the toothpaste, the properties of the toothbrush and the force applied on teeth surfaces during brushing. This study was carried out to investigate the resulting abrasive dentine wear when using toothbrushes with soft- and medium-stiff bristles at different brushing forces.

The samples were prepared from bovine dentine in this study. The advantages and the suitability of using bovine dentine in abrasion studies are well established. The abrasive slurry used to brush the samples had an RDA value of 121. This value lies in the middle of the RDA range (69–208) used in similar studies. Regardless, RDA values do not necessarily represent the actual abrasive wear and should only serve as a general guidance. The resulting abrasive dentine wear could have been different if slurries with lower or higher RDA values were used. Nevertheless, it was not tended to investigate this factor in this study. The brushing forces investigated in this study—1 to 4 N—is in accordance with several other abrasion studies. Although higher brushing forces—than 4 N—were applied in some of them, most of the studies used 2 to 3 N brushing force.

In this study, the soft- and medium-bristle toothbrush caused comparable abrasive dentine wear when the brushing force was set at 1, 2 and 3 N. This finding is in contrast to the study of Turssi et al., where a medium— and a hard—bristle toothbrush caused statistically significantly higher abrasive wear than a soft-bristle toothbrush when a medium and a hard abrasive slurry was used at 2 N brushing force. De Boer et al. also found a medium toothbrush to cause more abrasive dentin wear than a soft one at 2 N brushing force independent from the used toothpaste. One possible reason for these contrast findings is the different properties between the tested toothbrushes used in the studies of Turssi et al. and De Boer et al. The soft and harder toothbrushes in both studies had different bristle numbers per tuft—and per toothbrush—as well as different bristle diameters, which could influence the results. The toothbrushes used in this study were custom-made so all the properties of both tested toothbrushes would be the same, which might give a better understanding on the—pure—effect of the bristle stiffness. The findings of this study—and the one of Turssi et al.—are also in contrast to the study of Bizhang et al., where a soft-bristle toothbrush was found to cause statistically significantly higher abrasive wear than a medium—and a hard—one. Different properties of the used toothbrushes could also apply here to explain the different findings.

At 4 N brushing force, the medium-bristle toothbrush caused statistically significantly higher abrasive wear than the soft-bristle toothbrush. This finding is probably attributed to the fact that the soft bristles got far deflected due to the high brushing force, and thus dragged fewer abrasive particles on the dentine surface compared with the medium bristles. It could also be speculated that the deflected bristles trapped more abrasive particles within themselves and acted as a barrier between the particles and the dentine surface. This could also explain why the soft-bristle toothbrush did not cause higher abrasive wear when the brushing force was increased from 2 to 3 N, while the medium-bristle toothbrush did cause statistically significantly higher abrasive wear. As Völk et al. found patients with NCCL to apply significantly higher brushing force in vivo (ca. 3 N) compared with patients without NCCL (ca. 2 N), it might be concluded—based on the findings of this study—that the toothbrush type would not play a role in the development of NCCL when applying these forces. However, it could be argued that patients do not always apply the same force during brushing and might sometimes tend to apply higher brushing force to compensate for shorter brushing time or to obtain a ‘better’ cleaning / whitening effect on a specific group of teeth. Thus, the soft-bristle toothbrush might represent a safer choice here as it tends to cause less abrasive wear with increasing brushing force than the medium-bristle toothbrush. However, the fact that the tested toothbrushes were custom-made in this study should be kept in mind. This does not represent the situation in the market, where soft and harder toothbrushes exhibit—other—different properties beside the bristle stiffness (eg bristle diameter and number of bristles per tuft), and thus, it should not be concluded that every soft-bristle toothbrush would cause less abrasive wear than every medium-bristle toothbrush at higher brushing forces. All other modifying factors should be considered.

Regardless, dentists should keep all other modifying factors in mind when advising patients with NCCL. Zimmer recommended applying 1 N brushing force when patients already show the signs of tooth wear. Patients should be instructed to alter their harmful brushing habits. A calibration of the used brushing force—for example with a kitchen scale—might be a revelation for many patients. It should also be kept in mind that the toothbrush bristle stiffness is also related with soft-tissue injuries. Dentists should comprehend the main complaint of their NCCL patients and advise them accordingly.

Within the limits of this study, it could be concluded that the toothbrushes with soft- or medium-stiff bristles cause comparable abrasive dentine wear at 1, 2, 3 N brushing force. Softer bristles, however, tend to cause less abrasive dentin wear with increasing brushing force than the medium bristles. This interaction could contribute to a more comprehensive understanding of the prevention of NCCL.

5 | CLINICAL RELEVANCE

5.1 | Scientific rationale for study

The interaction between toothbrush bristle stiffness and the applied brushing force still needs to be further comprehended. The results in the literature are not uniform.

5.2 | Principal findings and practical implications

Soft toothbrush might be the safer choice to be advised for patients showing signs of non-curious cervical lesions. Other factors (eg
number of bristles per tuft and bristle diameter) should also be kept in mind.

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

ACKNOWLEDGEMENT
This study is part and in parts identical of the doctoral thesis 'Einfluss der Borstensteifigkeit und des Anpressdrucks auf die Dentinabrasion' by M. Tanner performed at the university of Zurich, Switzerland, under the supervision of T. Attin and F. Wegehaupt. The toothbrushes used in this study were provided by (Esro, Thalwil, Switzerland). The company had no influence on any part of this study.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS
B.H. led the writing. M.T. Performed the experiment in partial fulfilment for master’s degree. T.A. and P.K. Performed critical evaluation of the manuscript. F.J.W. and T.A. conceived and designed the experiment and critical evaluation of the manuscript.

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

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. Lippert F, Arrageg MA, Eckert GJ, Hara AT. Interaction between toothpaste abrasivity and toothbrush filament stiffness on the development of erosive/abrasive lesions in vitro. Int Dent J. 2017;67(6):344-350.
3. Turssi CP, Binsaleh F, Lippert F, et al. Interplay between toothbrush stiffness and dentifrice abrasivity on the development of noncarious cervical lesions. Clin Oral Investig. 2019;23(9):3551-3556.
4. Bizhang M, Riemer K, Arnold WH, Domin J, Zimmer S. Influence of bristle stiffness of manual toothbrushes on eroded and sound human dentin—an in vitro study. PLoS One. 2016;11(4):e0153250.
5. 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.
6. Hamza B, Tanner M, Attin T, Wegehaupt FJ. Dentin abrasivity and cleaning efficacy of novel/alternative toothpastes. Oral Health Prev Dent. 2020;18(1):713-718.
7. 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.
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. González-Cabezás 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.
10. Wiegand A, Attin T. Design of erosion/abrasion studies—insights and rational concepts. Caries Res. 2011;45(Suppl 1):53-59.
11. De Boer P, Duinkerke AS, Arends J. Influence of tooth paste particle size and tooth brush stiffness on dentine abrasion in vitro. Caries Res. 1985;19(3):232-239.
12. Wiegand A, Kuhn M, Sener B, Roos M, Attin T. Abrasion of eroded dentin caused by toothpaste slurries of different abrasivity and toothbrushes of different filament diameter. J Dent. 2009;37(6):480-484.
13. Wiegand A, Schwerzmann M, Sener B, et al. Impact of toothpaste slurry abrasivity and toothbrush filament stiffness on abrasion of eroded enamel - an in vitro study. Acta Odontol Scand. 2008;66(4):231-235.
14. Völk W, Mierau HD, Biehl P, Dornheim G, Riethmayer C. Etiology of wedge-shaped defects. Dtsch Zahnarztl Z. 1987;42(5):499-504.
15. Zimmer S. (Softdrink-associated erosion-abrasion. The description of a treatment case). Schweiz Monatsschr Zahnmed. 1998. 108(6): p. 566-576.
16. Ranzan N, Muniz FWMG, Rösing CK. Are bristle stiffness and bristle end-shape related to adverse effects on soft tissues during toothbrushing? A systematic review. Int Dent J. 2019;69(3):171-182.

How to cite this article: Hamza B, Tanner M, Körner P, Attin T, Wegehaupt FJ. Effect of toothbrush bristle stiffness and toothbrushing force on the abrasive dentine wear. Int J Dent Hygiene. 2021;19:355–359. https://doi.org/10.1111/idh.12536