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Effect of toothbrush bristle stiffness and toothbrushing force on the abrasive dentine wear

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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 ($\alpha = 0.05$).

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

1 | 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]

In two recent studies, toothbrush's high bristle stiffness was found to be an important factor in the development of non-carious cervical lesions (NNCL, a manifestation of abrasive dentine wear) especially when using toothpastes with medium-to-high abrasivity values.[2,3] However, contrasting results were reported in the study of Bizhang et al.,[4] where a soft-bristle toothbrush caused higher abrasive dentine wear than the harder one. Bizhang et al.[4] 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, Turssi et al.[3] 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.[5] 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.

2 | STUDY SAMPLES AND METHODOLOGY

One hundred and sixty bovine dentine samples were prepared for this study. The detailed preparation of the dentin samples is mentioned in an earlier study.[6] The samples were randomized to eight groups (n = 20), and baseline profiles were recorded under wet conditions with a contact profilometer (MFW-250, Perthometer S2; Mahr). Using an abrasive slurry (RDA = 121), samples were subjected to a brushing sequence for 25 min (120 strokes/min) with the following combinations: group 1 (soft-bristle toothbrush, 1 N), group 2 (soft-bristle toothbrush, 2 N), group 3 (soft-bristle toothbrush, 3 N), group 4 (soft-bristle toothbrush, 4 N), group 5 (medium-bristle toothbrush, 1 N), group 6 (medium-bristle toothbrush, 2 N), group 7 (medium-bristle toothbrush, 3 N) and group 8 (medium-bristle toothbrush, 4 N). After the brushing sequence, final profiles were recorded again under wet conditions. The protocol of the profilometric analysis is described in detail in an earlier study.[7]

TABLE 1 Characterisation of the tested toothbrushes

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

The tested toothbrushes were specially fabricated for this study (Paro M43, Esro). 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® 103 (Evonik Industries) and 25 g of the silica abrasive Zeodent® 113 (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 bristle stiffnesses 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)).

TABLE 2 Study design

Preparation of 160 dentine samples							
Allocating the samples to eight groups (n = 20)							
Recording of baseline profiles							
Brushing sequence (120 strokes/min, abrasive slurry (RDA = 121), 25 min)							
Groups 1 to 4 Soft-bristle toothbrush				**Groups 5 to 8 Medium-bristle toothbrush**			
Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
1 N[a]	2 N	3 N	4 N	1 N	2 N	3 N	4 N
Recording of final profiles							

[a]Newton applied brushing force.

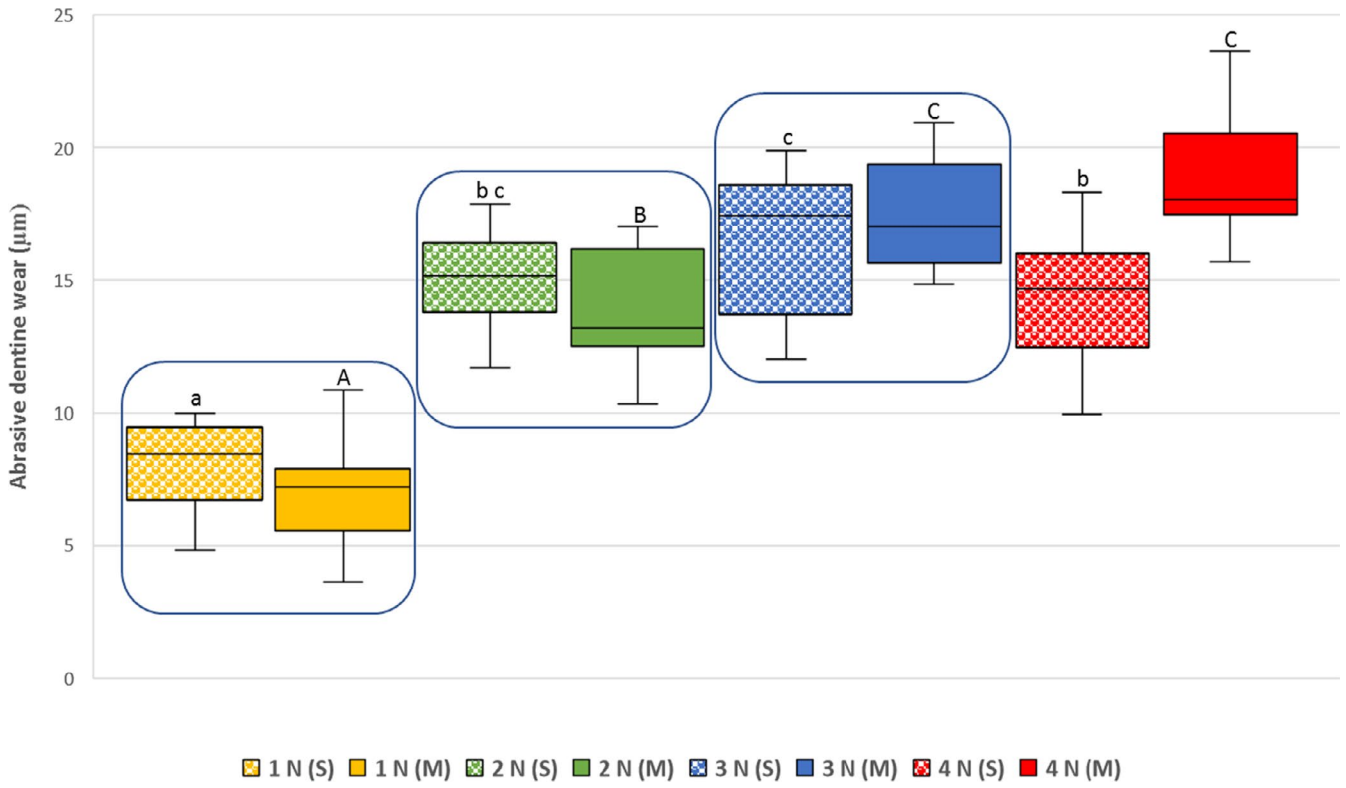

FIGURE 1 Abrasive dentine wear (median + Interquartile range, IQR = whiskers) in the different experimental groups (soft-bristle toothbrush = (S), medium-bristle toothbrush = (M)). Same letters indicate no statistically significant difference within the respective bristle stiffness (lower case letters for the soft-bristle toothbrushes, capital letters for the medium-bristle toothbrush). Within the groups brushed with the same force (same colour), pairs enclosed in a box are not statistically significantly different.

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.[8] 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.[2,3] Regardless, RDA values do not necessarily represent the actual abrasive wear and should only serve as a general guidance.[9] 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.[10]

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.,[3] where a medium—and a hard—bristle toothbrush caused statistically significantly higher abrasive wear than a soft-bristle toothbrush when a medium and a high abrasive slurry was used at 2 N brushing force. De Boer et al.[11] 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.[3] and De Boer et al.[11] 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.[12,13] 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.[3]—are also in contrast to the study of Bizhang et al.,[4] 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.[14] 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[15] 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.[16]

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, tends 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-carious 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.

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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.

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