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DOI: https://doi.org/10.1080/00016357.2022.2035816

Originally published at:
Hamza, Blend; Svellenti, Leonardo; Körner, Philipp; Attin, Thomas; Wegehaupt, Florian J (2022). Effect of tapered-end and round-end bristles on the abrasive dentine wear applying increasing brushing forces. Acta Odontologica Scandinavica, 80(6):465-469.
DOI: https://doi.org/10.1080/00016357.2022.2035816

ACTA ODONTOLOGICA SCANDINAVICA
https://doi.org/10.1080/00016357.2022.2035816

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ORIGINAL ARTICLE

Effect of tapered-end and round-end bristles on the abrasive dentine wear applying increasing brushing forces

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ABSTRACT

Objective: To investigate the effect of toothbrush bristles end configuration on the abrasive dentine wear at different brushing forces.

Material and methods: One hundred and sixty bovine dentine samples were randomized into eight groups ($n = 20$). Groups (1 to 4) were brushed with tapered-end bristles at 1-, 2-, 3-, and 4-N brushing forces, respectively. Groups (5 to 8) were brushed with round-end bristles with the same brushing forces. The brushing sequence was carried out using an abrasive slurry (RDA = 121) for 25 min. Profiles were recorded using a contact profilometer. Mean and standard deviation were calculated for the abrasive dentine wear in each group. Two-way ANOVA was used to locate any significance. The significance values were corrected after Tukey ($\alpha = 0.05$).

Results: Brushing with tapered-end bristles resulted in statistically significantly less abrasive dentine wear than round-end bristles regardless of the applied brushing force (1 N: 4.4 ± 1.5 vs. 7.7 ± 2.0 µm; 2 N: 7.7 ± 2.1 vs. 12.2 ± 2.7 µm; 3 N: 11.3 ± 2.6 vs. 19.4 ± 3.7 µm; 4 N: 11.2 ± 2.1 vs. 25.3 ± 4.8 µm). The interaction between bristle configuration and brushing force was statistically significantly ($p < 0.001$).

Conclusion: Tapered-end toothbrushes might be a safer choice for patients, especially when showing signs of non-carious cervical lesion. However, other toothbrush properties should also be considered.

ARTICLE HISTORY
Received 21 September 2021
Revised 28 December 2021
Accepted 2 January 2022

KEYWORDS
Abrasive dentine wear; non-carious cervical lesions; round-end bristles; tapered-end bristles; toothbrush

Introduction

Non-carious cervical lesions (NCCL) are characterized by the loss of dental hard tissue at the cementoenamel junction with no involvement of dental caries [1]. Due to its increasing prevalence, the aetiology of NCCL has been the focus of numerous investigations [2]. Several factors were held responsible for the development of NCCL including abrasive/erosive dentine wear and occlusal stress [2–4]. Abrasive dentine wear has also been connected to several modifying factors, such as toothpaste abrasivity, toothbrush design, and toothbrushing force and frequency, amongst others [4,5].

Applying higher toothbrushing forces was found to cause higher abrasive dentine wear [6]. However, this fact depends on how the toothbrush bristles react to the applied force, i.e. depends on the toothbrush bristle properties [7,8]. Different toothbrush bristle properties include stiffness (e.g. soft, hard), arrangement inside the toothbrush head (e.g. crisscross, flat-trimmed, bilevel) and bristle end configuration (e.g. tapered-end, round-end) [9].

The majority of the studies that compared tapered-end bristles to round-end ones investigated the effect of each bristle end configuration on the cleaning efficacy and/or gingival abrasion [10–16]. A recent systematic review found tapered-end bristles to be more effective in cleaning proximal areas than round-end bristles [15]. Regardless, it is safe to assume that bristles' end configuration would modify the way abrasives are rubbed against the tooth surface and thus modify the resulting abrasive dentine wear.

To the authors' best knowledge, no study has yet investigated the effect of different bristle end configuration on the resulting abrasive dentine wear, and hence on NCCL. This study was therefore carried out to investigate the effect of tapered-end and round-end bristles on the resulting abrasive dentine wear applying 1, 2, 3 and 4 N brushing forces.

Materials and methods

One hundred and sixty standard bovine dentine samples (diameter = 3 mm) were prepared for this study. The samples were obtained from the roots of extracted permanent bovine incisors. After embedding in acrylic resin (Paladur, Heraeus Kulzer, Hanau, Germany), the samples were ground (5 N, 80 rpm) in a grinding machine (Tegramin-30, Stuers, Birmensdorf, Switzerland) with 2000-grit (20 sec) and 4000-grit (30 sec) carborundum paper. Further details concerning samples' preparation can be obtained from an earlier study [17]. The samples were then randomly divided into eight groups ($n = 20$) and baseline profiles were recorded using a

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contact profilometer (MFW-250, Perthometer S2; Mahr, Göttingen, Germany) under wet conditions. The samples underwent a brushing sequence for 25 min (this corresponds to approximately seven months clinically brushing time, assuming the 2-min recommended brushing time twice daily [18]) at 120 strokes/min brushing speed using an abrasive slurry with a relative dentine abrasivity (RDA) value of 121. The RDA value was measured using a standard and well-established method reported previously by Imfeld [19]. Each group was brushed with a different combination as follows: group 1 (tapered-end bristles, 1 N brushing force), group 2 (tapered-end bristles, 2 N brushing force), group 3 (tapered-end bristles, 3 N brushing force), group 4 (tapered-end bristles, 4 N brushing force), group 5 (round-end bristles, 1 N brushing force), group 6 (round-end bristles, 2 N brushing force), group 7 (round-end bristles, 3 N brushing force), group 8 (round-end bristles, 4 N brushing force). Final profiles were then recorded under wet conditions following a standard detailed protocol described in an earlier study [20].

The tested toothbrushes (Paro M39, Esro; Thalwil, Switzerland) and bristles (7 mils, PBT Monofilament, BBC Co., Daejeon, South Korea) were custom-made to meet the conditions of this study. Other than the bristle end configuration and a very slight change of length, all other bristle properties of both tested toothbrushes were identical. The tapered part of the tapered-end bristles started within the last 5 mm of the bristle tip. Table 1 shows the bristle properties of each toothbrush. Figure 1 shows a magnified photo of the tested bristles' tips.

The abrasive slurry was prepared by mixing 25 g of two silica abrasives (Zeodent® 113 and Zeodent® 103, Evonik industries, Hanau-Wolfgang, Germany) with 225 g of glycerine and 0.25 g of a silicone antifoam agent. Table 2 summarizes the study design.

Table 1. Bristle properties of the tested toothbrushes.

Bristle end configuration	Tapered-end	Round-end
Bristle length	12.0 ± 0.2 mm	11.7 ± 0.2 mm
Bristle end diameter	0.02 mm	0.2 mm
Bristle stiffness	Soft	
Bristle diameter	0.2 mm	
Bristle material	PET	
Number of tufts	39	
Number of Bristles per tuft	48 ± 4	

Statistical analysis

Mean values and standard deviations (SD) of the abrasive dentine wear (μm) for each bristle end configuration at each applied brushing force were calculated. Two-way ANOVA test was applied to investigate any significant difference between the groups. Pairwise differences based on the bristle end configuration and the brushing force were tested on marginal means and the significance values were corrected following the Tukey method for multiple testing. The confidence level was set at 0.95. Data were analysed using the R software (The R Foundation for Statistical Computing; Vienna, Austria; www.R-project.org).

Table 2. Study design.

Preparation of 160 bovine dentine samples							
Randomising the samples into eight groups ($n = 20$)							
Recording of baseline profiles							
Brushing sequence (25 min, 120 strokes/min, abrasive slurry (RDA = 121))							
Groups 1 to 4 Tapered-end bristles				Groups 5 to 8 Round-end bristles			
Group 1 1 N	Group 2 2 N	Group 3 3 N	Group 4 4 N	Group 5 1 N	Group 6 2 N	Group 7 3 N	Group 8 4 N
Recording of final profiles							

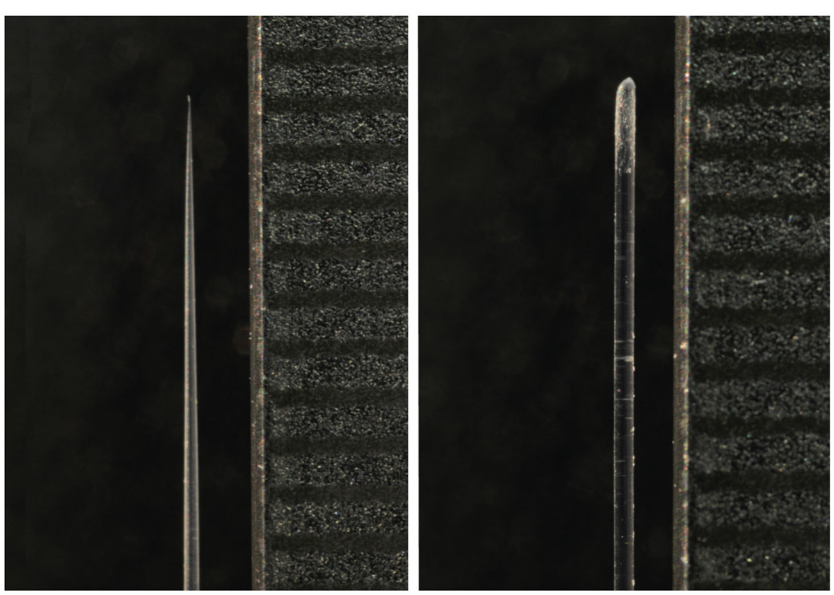

Figure 1. Magnified photographs (x 3.25) showing the tested bristles with a millimetre scale (left: tapered-end bristle, right: round-end bristle).

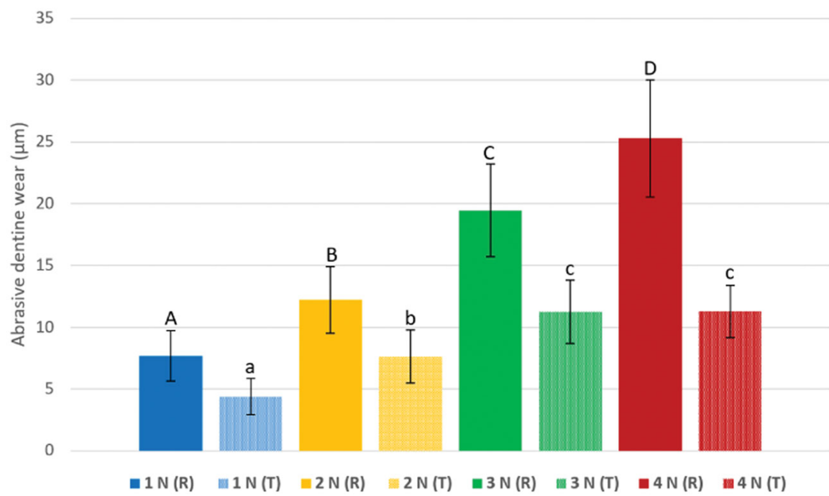

Figure 2. Abrasive dentine wear (mean ± SD) for the different combinations of bristle end configuration (round-end bristles = (R), tapered-end bristles = (T)) and brushing forces (1 – 4 N). Same letters indicate no statistically significant difference within the respective bristle end configuration (lower case letters for the tapered-end bristles, capital letters for the round-end bristles). Within the groups brushed with the same force (same colour), all pairs are statistically significantly different.

Results

A statistically significant interaction between bristle end configuration and the applied brushing force was found in this study ($p < .001$). Tapered-end bristles caused statistically significantly less abrasive wear than round-end bristles at each applied brushing force. The mean (±SD) of the abrasive dentine wear was calculated for each combination as follows: 1 N: round-end bristles = 7.7 ± 2.0 µm, tapered-end bristles = 4.4 ± 1.5 µm; 2 N: round-end bristles = 12.2 ± 2.7 µm, tapered-end bristles = 7.7 ± 2.1 µm; 3 N: round-end bristles = 19.4 ± 3.7 µm, tapered-end bristles = 11.3 ± 2.6 µm; 4 N: round-end bristles = 25.3 ± 4.8 µm, tapered-end bristles = 11.2 ± 2.1 µm. Figure 2 depicts the resulting abrasive dentine wear for each tested combination (applied brushing force/ bristle end configuration).

Based on the bristle end configuration

When brushing with the round-tip bristles, abrasive dentine wear was always statistically significantly higher with the increasing brushing forces ($p < .001$). When brushing with the tapered-end bristles, abrasive dentine wear was statistically significantly higher with the increasing brushing forces until 3 N ($p < .001$). When 4-N brushing force was applied, tapered-end bristles caused the same amount of abrasive dentine wear as that resulted at 3 N.

Based on the applied brushing force

Regardless of the applied brushing force, round-end bristles always caused statistically significantly higher abrasive dentine wear than tapered-end bristles ($p < .001$).

Discussion

The development of NCCL is influenced by several factors like occlusal stress and abrasive dentine wear. Our knowledge regarding the role of toothbrush bristle end configuration on the abrasive dentine wear – amongst other factors – still needs to be improved. This study was carried out to investigate the effect of the bristle end configuration on the abrasive dentine wear under different brushing forces.

In this study, dentine samples were obtained from bovine teeth, which has already been proved suitable as an alternative to human teeth in abrasion studies [21]. The range of brushing forces used in this study (1 to 4 N) lies within the range used by most of the abrasion studies [22] and also covers the reported mean brushing force (2.3 ± 0.7 N) applied by uninstructed adults using a manual toothbrush in a previous study, with a maximal reported brushing force of 4.1 N [23]. However, it would be interesting to investigate if uninstructed adults would apply different brushing forces when using tapered-end vs. round-end toothbrushes (or generally soft vs. medium or hard bristles). It can be assumed that some patients might apply higher brushing forces with tapered-end bristles to reach a 'satisfying' pressure feedback against the teeth surface, which might wrongfully be interpreted by patients as 'better for cleaning'.

Regarding the abrasive slurry used in this study, it could be assumed that different results might have been recorded if a different abrasive slurry (with higher or lower RDA value) had been used. However, this possible effect was not the focus of the present study and the used RDA value of 121 lies in the middle range of RDA values used in other abrasive studies [24,25]. As shown in Table 1, the round-end bristles were 0.3 mm shorter than the tapered-end ones. This was due to the manufacturer's observation that the tip of the tapered-end bristles will anyhow get bound – that is, shorter – when touching the tooth surface. Regardless, the bristles' length of both toothbrushes was anyhow 0.2 mm shorter or longer and it is safe to assumed that this very slight change of length would not affect the results.

The tapered-end bristles caused statistically significantly less abrasive dentine wear than the round-end ones regardless of the applied brushing force. This might be attributed

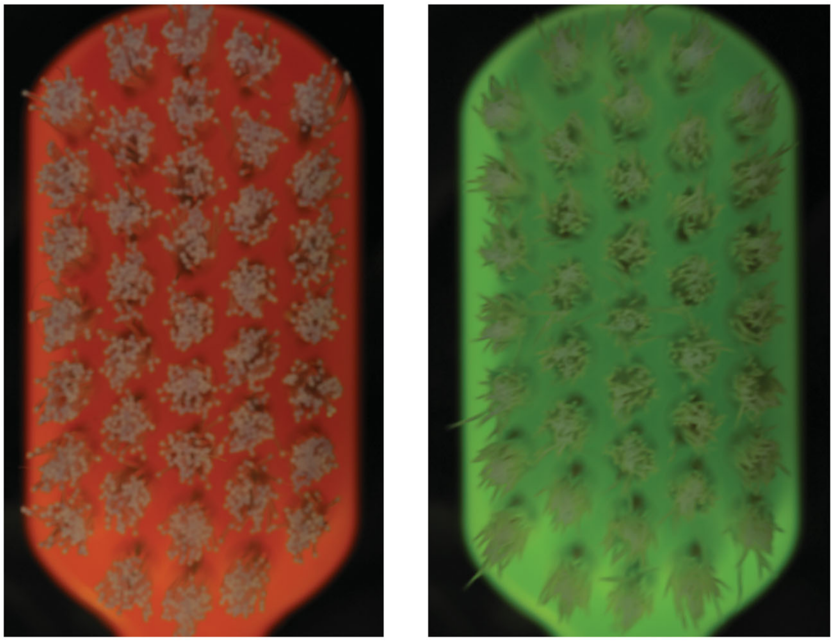

Figure 3. A superior view of the tapered-end (right) and round-end bristles toothbrushes head. Although both heads have the same number of bristles per tuft and per toothbrush, the tapered-end bristle toothbrush has more spaces between the tufts, which might have allowed more deflection of the bristles in comparison to the round-end bristle toothbrush.

to the fact that the tapered tips were so soft that they bound and started swiping the abrasive particles sideways over the tooth surface instead of trapping them under and rubbing them against the tooth surface. Increasing the brushing force from 3 to 4 N did not result in higher abrasive dentine wear when brushing with tapered-end bristles. This could be explained by assuming that under such high brushing force, not only the bristle tip got bound but the entire bristle also got deflected which led to even less abrasive particles being rubbed against the sample surface. Another factor that could have contributed to this finding is the density of the bristles at the brushing surface. The fact that the tapered-end bristles had the same number of bristles per tuft as the round-end bristles makes their brushing surface less dense (i.e. has more space between the tufts compared to the round-end brush, see Figure 3). This 'extra-space' between the tufts could have allowed the tapered-end bristles to deflect more than the round-end bristles and further contribute to the less abrasive wear.

The fact that the round-end bristles caused statistically significantly higher abrasive wear with increasing brushing forces – especially from 3 to 4 N – is rather unexpected. After all, the round-end bristles were also categorised as 'soft', and thus, one might assume that the entire bristle would also get deflected at high brushing forces and not cause higher abrasive wear. In a recent study with the same laboratory settings, a soft round-end bristle toothbrush caused less abrasive dentine wear at 4-N brushing force in comparison to 3 N [26]. This discrepancy of the results between this study and the later one could be explained by the fact that the soft end-round bristles used in each of them were made from different materials (Polyamide vs. PET) which reacted differently under the applied brushing forces. It might also be argued that the tapered-end bristles in this study acted as 'extra soft' in comparison to the 'soft' round-end bristles.

The previous point emphasises the fact that the selection or recommendation of a certain toothbrush should not only be based on its stiffness (soft or medium). Other variables should also be taken into account (e.g. bristle design, bristle material, bristle end configuration, bristle diameter, number of bristles, etc.). As a matter of fact, the presence of these – and other – variables represent the limitations of the present study, which only focussed on the interaction between two of these variables. At the same time, it might be unfeasible to pack all the possible variables in one study. Further variables/interactions and their effect on the abrasive process should be investigated in future studies.

Based on the results of this study and within its limitations, tapered-end bristles tend to result in less abrasive dentine wear especially when applying high brushing forces. Taking the studies, which also reported better cleaning efficacy of tapered-end bristles in comparison to round-end bristles into consideration, tapered-end bristles might be considered a safer or even a better choice for patients, especially those showing signs of NCCL. Other properties of toothbrushes should always be considered when advising the patient.

Acknowledgments

This study is part and in part identical to the doctoral thesis 'Einfluss der Borstengestalltung und des Anpressdrucks auf die Dentinabrasion' by L.S. performed at the University of Zurich, under the supervision of T.A. and F.J.W.

The toothbrushes used in this study were provided by (Esro; Thalwil, Switzerland). The company had no influence on any part of this study.

Disclosure statement

The authors report no conflict of interest

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [B.H.], upon reasonable request.

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