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Filament end-rounding quality in electric toothbrushes

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Abstract

Objectives: A good quality of filament tips is desirable to protect both gingiva and dental hard tissues. The aim of the present study was to compare the end-rounding quality of the filaments in 15 electric toothbrushes (Rowenta dentaclip® ZH-07, dentaclip® ZH 010, rotaclip® ZH-11; Blend-a-dent Wellenprofil 2000 hart, Wellenprofil 2000 mittel-weich, Medic for kids; Broxo®; UltraSonex™; Krups 548, Waterpik® BH-4U; Butler Gum®; Dr. Best e-Flex3; Oral-B® (EB3, EB 17-8, Plak Control Kids)).

Material and Methods: From each brand five brushes were chosen randomly. Five tufts were selected from each brush and studied with a scanning electron microscope ($\times 45$) at a viewing angle of 45°. The filament tips were numbered from top left to bottom right and selected filaments were judged by a well-trained, blinded second examiner according to the Silverstone & Featherstone method.

Results: Nine of the 15 brands examined showed a high (''acceptable'': $>89\%$), four products a medium (76–84%) and two a bad (34–38%) end-rounding quality.

Conclusion: A good quality of filament tips is claimed by the dental profession to protect both gingiva and dental hard tissues from abrasion. This could be observed for 13 of the 15 brands examined.

Key words: caries prevention; filament end-rounding; scanning electron microscopy; toothbrush

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In the maintenance of good oral hygiene, toothbrushing plays a key role. For protection of mucosa, gingiva and dental hard tissues brushes with end-polished filaments are desirable (Anneroth & Poppelman 1975, Breitenmoser et al. 1979, Bergstrom & Eliasson 1988). As early as 1948 it was reported that gingival trauma is related to sharp filament tips and the need for hemispherical or rounded filament ends without any sharp points or rough edges was reinforced (Bass 1948). A double-blind crossover study revealed that non-rounded filaments caused a 30% increase in gingival abrasion when compared with rounded filament (Breitenmoser et al. 1979). Three weeks of actual toothbrush filament wear was not found to adequately alter sharp and pointed filament tips to a more favorable pattern (Klima & Rossiwall 1976). The wear of filament tips by brushing with an abrasive dentifrice also has not been found to alter sharp and pointed soft nylon filament tips (Massassati & Frank 1982).

The degree of filament end-rounding found in commercially available manual toothbrushes has been studied in several investigations. Currently, studies have assessed the end-roundness of filament tips using either a scanning electron microscope (SEM) or a stereomicroscope for visualisation (Mulry et al. 1992, Dellerman et al. 1994, McLey et al. 1997). When SEM is used, three different methods classify the degree of roundness: direct comparison of the tips to a grading scale (Althaus et al. 1990, Muller et al. 1992, Bienengraber et al. 1995, Jung et al. 2003, Meyer-Lueckel et al. 2004a, b), comparison with a grading scale by computerized image analysis (Silverstone & Featherstone 1988), or by shape factor (SF) analysis (Rawls et al. 1993a, b, Meyer-Lueckel et al. 2004a). It was revealed that the time-consuming SF analysis was as reliable as the visual comparison with a grading scale when examiner blinding was assured (Meyer-Lueckel et al. 2004b).

Since no data about the end-roundness of the filaments of electric toothbrushes are available in the dental literature, the aim of the present study was to evaluate the quality of filament tips of 15 different brands by a single well-trained blinded examiner.

Material and Methods

From each of 15 different European brands of electric toothbrushes, five brushes were purchased from various drug stores in Germany (Table 1). In order to perform a blind comparative analysis, the filaments were prepared by one examiner and the different brands were each assigned a code number.

The tufts of each toothbrush were numbered in rows from left to the right, starting at the top of each brush moving down to the neck of each brush. The number of tufts varied from 14 to 40.

Table 1. Number of tufts and percentage of acceptably end-rounded filaments of the toothbrush brands examined ($n = 5$)

Product	Manufacturer	No. of tufts	Acceptable (%)	Significance
Rowenta dentaclip® ZH-07	SEB group	22	98	A
Waterpik® BH-4U	Waterpik	21	98	A
Rowenta rotaclip® ZH-11	SEB group	14	96	A
Dr. Best e-FLEX3	Glaxo SmithKline, Bühl, Germany	40	93	AB
Rowenta dentaclip® ZH 010	SEB group	14	91	ABC
Krups 548	Krups, Solingen, Germany	26	91	ABC
Oral-B® EB3	Braun Oral-B	28	91	ABC
Oral-B® Plak Control Kids	Braun Oral-B	24	90	ABCD
Broxo® hard	Broxo	28	89	ABCD
Blend-a-dent Wellenprofil 2000 hart		28	84	BCD
Blend-a-dent Wellenprofil 2000 mittel-weich	Procter & Gamble	28	78	CD
Blend-a-dent Medic for kids		23	78	CD
Braun Oral-B® Flexisoft EB 17-8	Braun Oral-B	26	76	D
Butler Gum® for E1	Butler	23	38	E
UltraSonex™	Dent-O-Care	35	34	E

Significant differences in end-roundnesss quality beween the various brands are indicated with different letters ($p < 0.05$; adjusted χ^2 test).

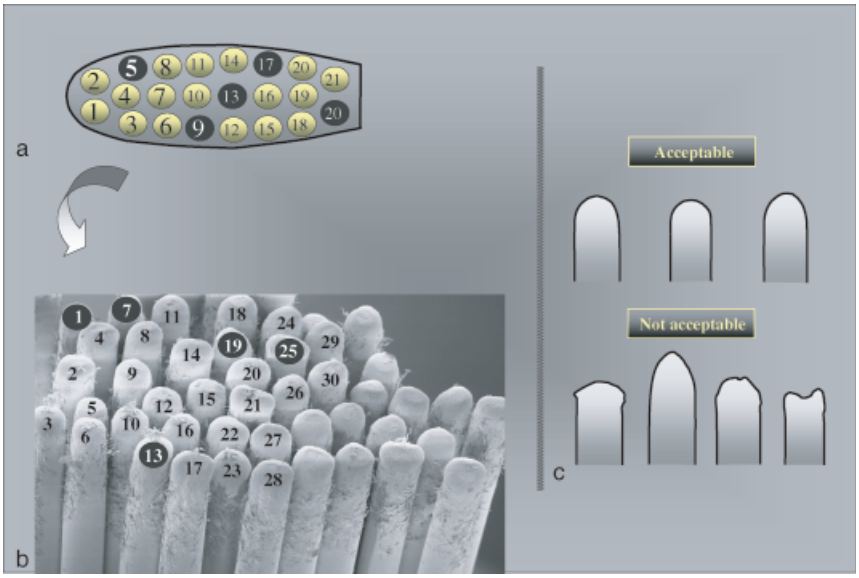

Fig. 1. From each brush five tufts were chosen randomly (a) and five filaments within each tuft (b) were classified as ''acceptable'' or ''not acceptable'' end-rounded based on the Silverstone and Featherstone grading scale (c) (Meyer-Lueckel *et al.* 2004b).

From each brush five tufts were chosen randomly ensuring that any possible location of a tuft was at least examined once (Fig. 1a, b). The remaining tufts were cut off using a surgical scissor. The grips were removed (Exakt Trennschleifsystem, Norderstedt, Germany), the brushes cleaned under running tap water and dried in an incubator. Subsequently, the samples were mounted on special SEM holders (Plano, Wetzlar, Germany) and SEM's (CamScan MaXim 2040, Camscan, Cambridge, UK) were taken by the first examiner at a viewing angle of 45° relative to the long axis of the filaments. The filament tips were numbered from 1 to 30 in vertical rows starting up left to bottom right. Then, from each tuft every sixth filament was chosen, ensuring that counting started with different numbers for each tuft of the same brush (Fig. 1c). The filament ends were graded according to the Silverstone and Featherstone scale (Fig. 1d) by a well-trained blinded second examiner (Silverstone & Featherstone 1988). The numbers of ''acceptable'' and ''not acceptable'' rounded filaments were analyzed using adjusted χ^2 test at a 5% level of significance.

Results

Representative scanning electron micrographs of the brushes of six brands examined revealed differing end-rounding qualities (Fig. 2). A tuft with a multilevel (rippled) filament design showed sufficient filament end-rounding of the longer filaments, whereas the shorter ones were partly not acceptably rounded ((a) Blend-a-dent Wellenprofil 2000 hart; Proctor and Gamble, Schwalback, Germany). This was not the case in another brush with a multilevel filament design, where most of the filaments were badly rounded ((b) UltraSonex™ (Dent-O-Care, Hoehenkirchen, Germany)). For flat filament designs various qualitative observations could also be made. The tufts of some brands showed smooth filaments with perfect end-rounding ((c) Rowenta rotaclip® ZH-11 (SEB group, Offenbach, Germany), (d) Oral-B® Plak Control Kids (Braun Oral-B, Gillette Group, Kronburg, Germany)), while others had some unfavorable end-rounded tips ((e) Blend-a-dent® Medic for Kids; Proctor and Gamble) The filament tips of one brand were mainly not acceptably end-rounded ((f) Butler Gum® (John O. Butler Europe, Kriftel, Germany)).

The quantitative evaluation (Table 1) revealed a very good quality (percentage of ''acceptable'' filaments $> 89\%$) for nine of the 15 brands examined. The percentages of acceptably rounded tips were significantly higher for Rowenta dentaclip® ZH-07 (SEB group), Waterpik® BH-4U (Waterpik, Lenzhahn, Germany) and Rowenta rotaclip® ZH-11 compared with the six worst brands examined ($p < 0.05$; adjusted χ^2 test). Two of these products (Butler Gum®, UltraSonex™) showed a significantly lower percentage (38% and 34%) of well end-rounded tips than all others ($p < 0.05$).

Discussion

Several studies have shown the injury potential of sharp non-rounded filament tips on gingival abrasion (Alexander et al. 1977, Breitenmoser et al. 1979). Considerable efforts have been made by manufacturers to end-round filaments, particularly for those brush heads with multilevel filament designs. The degree of end-roundness has been promoted to the

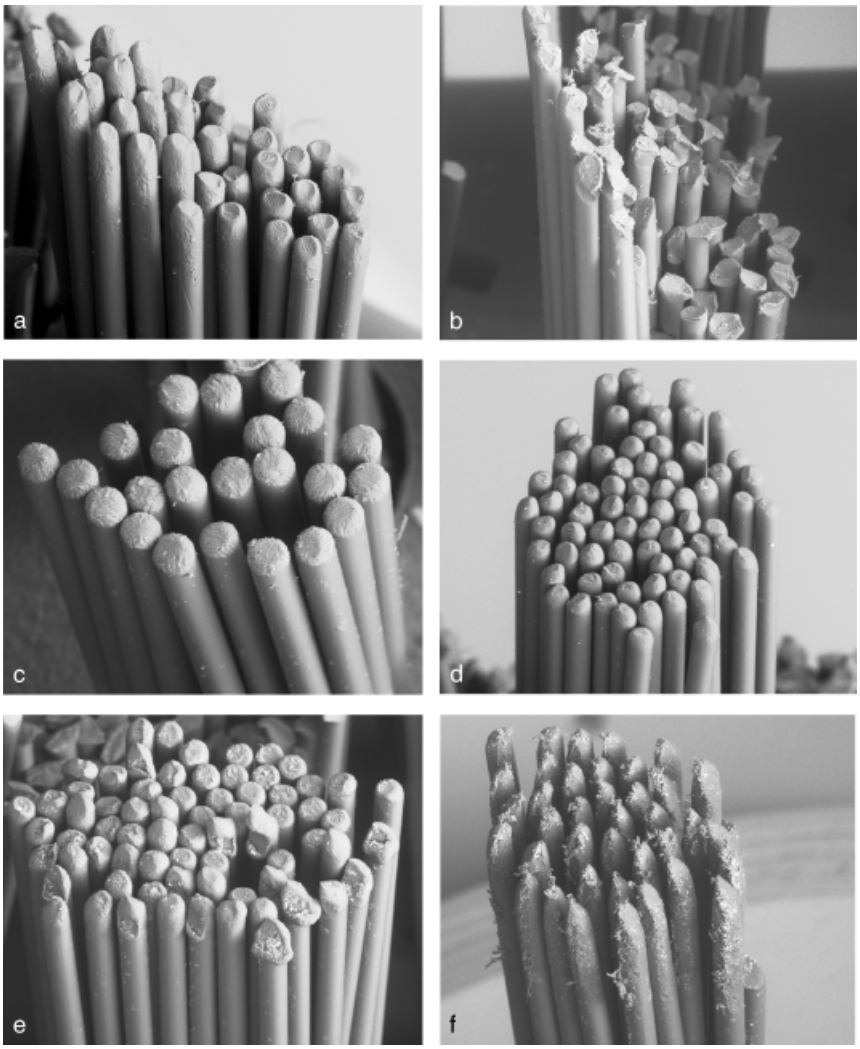

Fig. 2. Representative scanning electron microscope (SEM)'s of various tufts: (a) Blend-a-dent Wellenprofil 2000 hart, (b) UltraSonex™, (c) Rowenta rotaclip® ZH-11, (d) Oral-B® Plak Control Kids, (e) Blend-a-dent® Medic for Kids, (f) Butler Gum®.

dental profession as a sign of quality and is supposed to be taken into consideration when recommending a toothbrush.

In a recent study, it was shown that end-rounded nylon filaments wear flat during normal use within several minutes (McLey et al. 1997). Here, used filaments were compared with new ones, that might lead to false negative results, because the filaments examined might not have shown an ''acceptable'' degree of end-roundness before the brushing procedure started. Therefore, it is not assured that end-roundness may be only a transient feature, although this has been reported for hard filaments (Massassati & Frank 1982).

The viewing equipment used in end-rounding studies includes either the use of a stereomicroscope or a SEM. The three-dimensional-impression (although being only two dimensional) of SEM images enables the examiner to determine differences in surface texture and the superior depth of focus of these images allows for judging various filaments within a tuft at the same time (Drisko et al. 1995). Therefore, in the present study, SEM images have been used to obtain accurate projections of the filaments. For both methods it has to be taken into account that a three-dimensional filament tip is converted into a two-dimensional image that does not allow for analysis of the hidden side of the filament tip when images are taken either with a video or conventional camera. Therefore, some false positive judgements or measurements are expected with either the SF analysis or the comparison with a grading scale (Drisko et al. 1995).

It has been demonstrated that the original form of a filament tip may be altered by traditional sputter coating prior to an examination by SEM (Franchi & Checchi 1995). Therefore, a low-vacuum SEM method where no gold-palladium coating is needed was used in the present study.

A review about end-roundness studies commented that blinding has not been reported in earlier end-roundness studies (Drisko et al. 1995). Two recent studies contained no information about the blinding procedure (Checchi et al. 2001, Jung et al. 2003). Since the shape of the brush heads might be known by the person who judges the filament ends, in the present study one examiner prepared the brush samples and took the SEM images, whereas a trained second examiner judged the filament tips. Therefore, a complete blinding of the examiner could be ascertained.

A former study revealed that a viewing angle of 45° allows more filaments from various locations within a tuft to be judged and showed comparable end-rounding results as from 90°. Moreover, this study revealed that the SF analysis (Rawls et al. 1993a, b), which is a time consuming but semi-quantitative method, results in similar values for end-rounding measurement as the subjective comparison with a grading scale when intra- or inter-examiner reliability is given and blinding is ascertained (Meyer-Lueckel et al. 2004b).

Moreover, the number of brushes of each brand examined is crucial to obtain reliable data. In a former study it has been shown that the average number of ''acceptable'' rounded filamentends differed significantly between two and four, but not between four and six brushes studied per brand (Meyer-Lueckel et al. 2004b). Therefore, five brushes of each brand were chosen for end-rounding evaluation in the present study.

Numerous studies (Kockapan & Wetzel 1987, Althaus et al. 1990, Mulry et al. 1992, Rawls et al. 1993a) on the end-rounding quality of filament tips in various brands have been published. In Fig. 3 investigations focusing on at least three of four brands of manual toothbrushes are depicted. In the present study evaluating the tips of electric brushes for the first time, a good quality could be found for most of the products. In former studies for Oral-B® (Silverstone & Featherstone 1988, Muller et al. 1992, Rawls et al. 1993b, Dellerman et al. 1994, Bienengraber et al. 1995, Checchi et al. 2001, Jung et al. 2003, Meyer-Lueckel et al. 2004a) some ''not

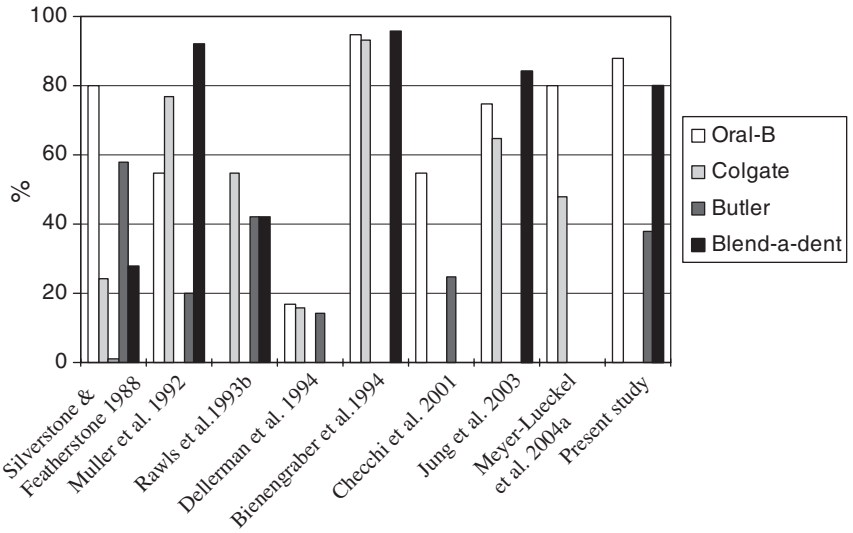

Fig. 3. Percentage of ''acceptable'' rounded filaments of four manufacturers (Oral-B®, Colgate®, Butler® and Blend-a-dent® reported in various studies (details see text).

acceptable'' filaments could be shown within the tufts, whereas brushes from Colgate® (Silverstone & Featherstone 1988, Muller et al. 1992, Rawls et al. 1993b, Dellerman et al. 1994, Bienengraber et al. 1995, Jung et al. 2003, Meyer-Lueckel et al. 2004b) and Blend-a-dent® (Silverstone & Featherstone 1988, Muller et al. 1992, Rawls et al. 1993b, Bienengraber et al. 1995, Jung et al. 2003) were judged quite inconsistently, suggesting a great variance in end-rounding quality depending on the brush type. On the other hand brushes from Butler® showed a high number of ''not acceptable'' filaments in former studies (Muller et al. 1992, Rawls et al. 1993b, Dellerman et al. 1994, Checchi et al. 2001), which could be confirmed in the present investigation for electric toothbrushes.

The end-rounding quality of filaments of electric toothbrushes were studied for the first time. It can be concluded that most of the brands examined showed an acceptable quality (13 of the 15 brands). Nevertheless, in numerous studies a wide range of qualities has been reported, confirming the need for effective quality control in the future.

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References

Alexander, J. F., Saffir, A. J. & Gold, W. (1977) The measurement of the effect of toothbrushes on soft tissue abrasion. *Journal of Dental Research* **56**, 722–727.

Althaus, D., Kockapan, C. & Wetzel, W. E. (1990) Bristle end rounding and anchoring in children's toothbrushes. *Schweizer Monatsschrift für Zahnmedizin* **100**, 159–164.

Anneroth, G. & Poppelman, A. (1975) Histological evaluation of gingival damage by toothbrushing. An experimental study in dog. *Acta Odontologica Scandinavica* **33**, 119–127.

Bass, C. C. (1948) The optimum characteristics of toothbrushes for personal oral hygiene. *Dental Items of Interest* **70**, 697–718.

Bergstrom, J. & Eliasson, S. (1988) Cervical abrasion in relation to toothbrushing and periodontal health. *Scandinavian Journal of Dental Research* **96**, 405–411.

Bienengraber, V., Sponholz, H. & Hagin, J. (1995) Bristle End-rounding and Anchoring Quality in brand-new and used Adult's Toothbrushes. *Deutsche Zahnärztliche Zeitung* **50**, 517–524.

Breitenmoser, J., Mormann, W. & Muhlemann, H. R. (1979) Damaging effects of toothbrush bristle end form on gingiva. *Journal of Periodontology* **50**, 212–216.

Checchi, L., Minguzzi, S., Franchi, M. & Forteleoni, G. (2001) Toothbrush filaments end-rounding: stereomicroscope analysis. *Journal of Clinical Periodontolology* **28**, 360–364.

Dellerman, P. A., Burkett, T. A. & Kreyling, K. M. (1994) A comparative evaluation of the percent acceptable end-rounded bristles: Butler G.U.M., Colgate Plus, Crest Complete, and Reach. *Journal of Clinical Dentistry* **5**, 38–45.

Drisko, C., Henderson, R. & Yancy, J. (1995) A review of current toothbrush bristle end-rounding studies. *Compendium of Continuing Education in Dentistry* **16**, 694–698.

Franchi, M. & Checchi, L. (1995) Temperature dependence of toothbrush bristle morphology. An ultrastructural study. *Journal of Clinical Periodontolology* **22**, 655–658.

Jung, M., Kockapan, C. & Wetzel, W. E. (2003) Bristle end rounding of manual toothbrushes and reproducibility of end rounding classification. *American Journal of Dentistry* **16**, 299–304.

Klima, J. & Rossiwall, B. (1976) Shape of toothbrush bristles, scanning electronmicroscopic studies. *Quintessenz* **27**, 113–119.

Kockapan, C. & Wetzel, W. E. (1987) Rasterelektronenmikroskopische Untersuchung der Borstenenden verschiedener Kinderzahnbürsten. *Oralprophylaxe* **9**, 77–84.

Massassati, A. & Frank, R. M. (1982) Scanning electron microscopy of unused and used manual toothbrushes. *Journal of Clinical Periodontolology* **9**, 148–161.

McLey, L., Boyd, R. L. & Sarker, S. (1997) Clinical and laboratory evaluation of powered electric toothbrushes: relative degree of bristle end-rounding. *Journal of Clinical Dentistry* **8**, 86–90.

Meyer-Lueckel, H., Borchert, N., Roggensack, M., Munz, I. & Kielbassa, A. M. (2004a) Quality of bristle end-rounding in ten brands of children's toothbrushes. *Schweizer Monatsschrift für Zahnmedizin* **114**, 564–572.

Meyer-Lueckel, H., Renz, H., Hopfenmuller, W. & Kielbassa, A. M. (2004b) Bristle end-rounding in toothbrushes: a comparison of different evaluation techniques. *Journal of Clinical Dentistry* **15**, 22–27.

Muller, P. J., Kockapan, C. & Wetzel, W. E. (1992) Bristle anchoring and bristle end-rounding in adults' toothbrushes. *Schweizer Monatsschrift für Zahnmedizin* **102**, 38–46.

Mulry, C. A., Dellerman, P. A., Ludwa, R. J., White, D. J. & Wild, J. E. (1992) A comparison of the end-rounding of nylon bristles in commercial toothbrushes: crest Complete and Oral-B. *Journal of Clinical Dentistry* **3**, 47–50.

Rawls, H. R., Smith, N. K., Lentz, D. L., Cobb, G. W., Jr. & Bailey, M. S. (1993a) An electron microscopic comparison of bristle end-rounding of three commercial toothbrushes. *Journal of Clinical Dentistry* **4**, 96–100.

Rawls, H. R., van Gelder, R., Smith, N. K., Jeppesen, M. & Yuan, C. (1993b) Bristle end-rounding in children's toothbrushes: a comparative study. *Journal of Clinical Dentistry* **4**, 61–66.

Silverstone, L. M. & Featherstone, M. J. (1988) Examination of the end rounding pattern of toothbrush bristles using scanning electron microscopy: a comparison of eight toothbrush types. *Gerodontics* **4**, 45–62.

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