Catalogue of Tooth Brush Head Designs

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Abstract

Purpose: Manual toothbrushes (MTBs) and power toothbrushes (PTBs) are effective oral physiotherapy aids for plaque removal. End-rounded bristles are safer and reduce damage to oral tissues. Nylon bristles are more effective in plaque removal because the bristle is stiffer than natural bristles. In the last 10 years the number of options for MTBs and PTBs has expanded significantly and there is very little information providing a reference frame for the design characteristics of the heads. The present in vitro study characterized a variety of MTB and PTB heads to provide a reference library for other research comparisons which might be made.

Methods: Various commercial MTB and PTB heads were used to characterize the following: bristle size, shape, diameter, number of tufts, number of bristles per tuft and surface characteristics. Photographs were collected from the side, at 45 degrees and the top of each toothbrush (TB) head using a scanning electron microscope and digital camera. Images were analyzed (Soft Imaging System) for bristle features and designs. One-way ANOVA ($p \leq 0.05$) was performed to detect differences among TB types within MTB and PTB groups and between pooled values for MTB and PTB groups.

Results: There were significant differences ($p \leq 0.05$) in toothbrush bristle diameter and bristle shape. In contrast, there were no significant differences between PTB vs. MTB in regards to bristle diameter, bristle count and tuft count.

Conclusion: The results suggest that although there are wide variations in toothbrush head designs, significant differences were found only in relation to bristle diameter and shape.

Keywords: manual toothbrush, power toothbrush, toothbrush head, bristles, tufts

This study supports the NDHRA priority area, **Health Promotion/Disease Prevention:** Investigate the effectiveness of oral self-care behaviors that prevent or reduce oral diseases among all age, social and cultural groups.

Introduction

The manual toothbrush (MTB) was invented in China between 618 to 907 A.D., and was composed of hog hair for bristles.[1,2] In 1780, England resident William Addis manufactured the "first modern toothbrush," and this brush had a bone handle and holes for placement of natural hog bristles.[3] In the early 1900s, celluloid began replacing the bone handle - this change came about during World War I, when bone and hog bristles were in short supply.[3] Similarly, as a result of deficit supply, nylon bristles were introduced. Initially, nylon bristles were copies of natural bristles in length and thickness, however, they were stiffer than the natural bristles.[3] They did not have the hollow stem of natural bristle, so they did not allow water absorption. Other advantages of nylon bristles were the ability to form the bristles in various diameters and shapes, and to round the bristle ends to be gentler on gingival tissues.[3]

The first power toothbrush (PTB) was developed in Switzerland in 1939. This brush had a power cord and was introduced in the U.S. in the 1960s.[4] Contemporary PTBs were rediscovered in the 1980s, and today you can find various types of PTBs on the market that utilize varied mechanisms of action (rotational oscillation, sonic, ultrasonic) and power supplies (battery powered or rechargeable).[3,5,6] PTBs also offer an array of brush head designs.

Each brush head, whether it is a MTB or PTB, is divided into 2 parts: the toe, located at the extreme end of the head, and the heel end closest to the handle (Figure 1).[3,5,6] Toothbrush (TB) heads are composed of tufts, which are individual

Figure 1: Digital Photo of Toothbrush Heads (A: Manual Toothbrush Head; B: Power Toothbrush Head)

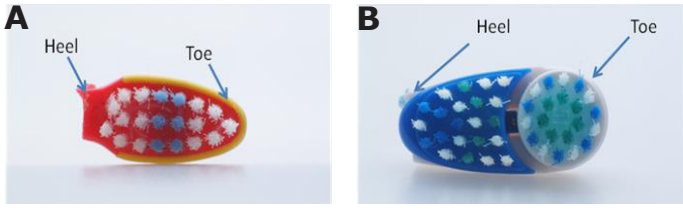
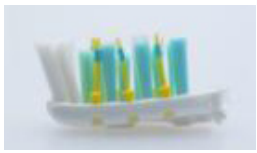
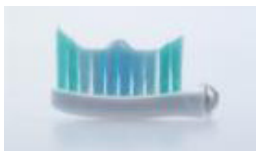
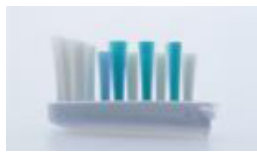


Figure 2: Various Brushing Planes for Power and Manual Toothbrush Heads

PTBs		MTBs	
			
Arm & Hammer Sonic (PTB) Bilevel, separated tufts/ rectangle		Biotene (MTB) Flat	
			
Oral-B Pulsar (PTB) Multilevel		Oral-B Stages mixed dentition (MTB) Angled	
			
Sonicare Elite Standard (PTB) Rippled		Oral-B Advantage Plus (MTB) Multilevel	
			
Oral-B Power Stages 3+ (PTB) Bilevel, round angled		Butler Gum (MTB) Rippled	

bundles of filaments secured in a hole in the TB head. Filaments within the tufts are known as bristles. Number and length of the filaments in a tuft, number of tufts, and arrangement of tufts vary with toothbrush designs.[3,5,6] A brushing plane may be flat with all filaments the same length, bilevel, multilevel, rippled or crisscrossed with tufts angled in at least 2 different directions (Figure 2).[6]

There are several studies that demonstrate that TB head design and proper brushing technique affect plaque removal.[7-15] A study conducted by Stiller et al was evaluating 3 TBs with extended, angled or flat multi-tufted bristles in regards to interproximal access.[11] They concluded the MTB with extended bristles provided an effective cleaning at interproximal areas.[11] Another study looked at orthodontic brushes and determined that the staged and v-shaped brush head designs did perform better than the planar brushes in efficacy of cleaning.[15] Rosema et al concluded from their study that the multi-leveled TB was significantly more efficacious than the flat leveled TB.[16] MTBs with CrissCross bristles that are angled in opposing directions seem to be the most effective in removal of plaque.[7,9,10] Zimmer et al study concluded that MTBs with hard bristles may remove plaque better, but may also cause more soft tissue trauma compared to brushes with softer bristles.[17] PTB head design, along with the mode of action, is to be considered with considering efficacy of plaque removal. PTBs have 5 classification groups: side to side action, counter-oscillation, rotation-oscillation, circular and ultrasonic.[18] The Cochrane review revealed some evidence that rotation- oscillation brushes reduce plaque and gingivitis more than side to side brushes in the short term.[19]

Various studies have examined TB bristles in regards to bristle end-rounding, methods for predicting the quality of nylon 612 filament for use as a bristle material,[20] filament round-ending quality in electric toothbrushes[21] and comparisons of the end-rounding of nylon bristles in commercial toothbrushes.[22-24] Studies involving end-rounding of bristles have established the need for rounding the end of the bristle to protect the tissues of the oral cavity from damage caused by tooth brushing.[24-27] The studies conducted regarding evaluation of TB bristles have either analyzed MTBs compared to other MTBs[22,28] or PTBs compared to other PTBs,[21] and no current studies have ana-

Table I: Manual Toothbrushes Utilized In Study and Features

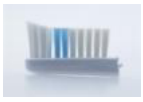
MTB Heads	Manufacturer	Type	Features
	Biotene Supersoft (BIO) (GlaxoSmithKline, USA)	Adult	Extrasoft, medium head size
	Butler Gum Technique (GBTE)	Adult	Soft bristles
	Butler Gum Summit (GS)	Adult	Soft bristles
	Butler Gum (BMTB)	Adult	Soft bristles; compact head, microtip
	Butler Gum Crayola (BCB)	Child	Soft bristles with suction cup handle
	Butler Gum Kids (BCHI)	Child	Soft bristles
	Colgate Wave (COWA) (Colgate-Palmolive Company, New York, NY)	Adult	Soft bristles; compact head
	Crest Dual Action Clean (CRDA)	Adult	Soft bristles
	Crest Complete (CRRM)	Child	Soft bristles; rippled bristles
	Oral-B Advantage Artic (OBAA)	Adult	Soft bristles, compact head
	Oral-B Advantage Glide (OBAG)	Adult	Extrasoft bristles; compact head; sensitouch
	Oral-B Advantage Plus (OBAP)	Adult	Soft bristles

lyzed or compared MTBs and PTBs to each other. The purpose of this preliminary study is to analyze a broad spectrum of commercially available MTB and PTB heads to compare characteristics known to contribute to their safety and efficacy, such as number of tufts, number of bristles per tuft, bristle diameter, bristle shape and surface characteristics of the bristles.

Methods and Materials

A total of 24 MTB and 21 PTB heads commercially available in the U.S. in 2009 were analyzed. The TBs had either soft or extra soft bristles (Tables I, II). Prior to analysis, the TB heads were removed from the handle using a Dremel 3000 series (Dremel, Racine, Ill.) with a 426 Dremel reinforced cut-off wheel. During the removal process, the TB handle was secured in a vice with the brush head face down to reduce handle residue particles getting onto the bristles. The brush heads were individually packaged in small coin sized Ziplock bags (2x3 2 MIL bags) and labeled with the name of brush, date cut and whether the head was a MTB or a PTB. Photographs were taken of each TB head and included in the tables listing the brushes used in this study (Tables I, II).

Table I: Manual Toothbrushes Utilized In Study and Features (continued)

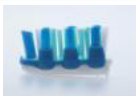
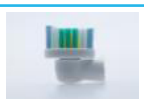
MTB Heads	Manufacturer	Type	Features
	Oral-B Advantage (OBA)	Adult	Soft bristles; compact head
	Oral-B Advantage Sensitive (OBAS)	Adult	Extrasoft bristles
	Oral-B Cross Action (OBCR)	Adult	Soft bristles; compact head
	Oral-B Indicator (OBIC)	Adult	Soft bristles; new comfort grip, fading blue bristles, compact head
	Oral-B Indicator (OBIN)	Adult	Soft bristles; compact head; indicator bristles
	Oral-B Pro-Health CrossAction (OBPH)	Adult	Soft bristles
	Oral-B Ortho (OBOR)	Child/Adult	Soft bristles
	Oral-B Stages One 4-24 months (OBS1)	Child	Cushioned head; baby soft bristles; non-slip handle
	Oral-B Stages 2-4 years (OBS2)	Child	Cushioned head; power tip, narrowhead; easy to hold handle
	Oral-B Stages Mixed Dentition (OBSM)	Child	Cushioned head; unique bristle design; varying bristle texture
	Oral-B Stages 5-7 years (OBSS)	Child	Cushioned head; power tip, cup shaped; handle stabilizer
	Oral-B Indicator Designs (OBID)	Child	Soft bristles

Digital photos were taken of each side and top of the TB head. The number of tufts per TB head was counted using the top view digital photo of each TB head as depicted in Figure 1.

The TB heads were then sputter coated with Au-Pd and inspected and documented in the scanning electron microscope (SEM) at 200x top view for bristle diameter, 15x top view for tuft counts and 40x and 200x horizontal views for surface characteristics. The SEM images were analyzed with the software Soft Imaging System GmbH (Soft Imaging System Corp., Lakewood, Colo.) to measure diameter and count bristles per tufts (Figure 3). The diameter of each bristle was measured by using the circle measurement tool. Three bristles were measured using the 200x SEM top view and averaged for the diameter of the bristles for each TB head. If a TB head had various types of bristles, then each bristle type area had a 200x SEM top view photo taken and analyzed for the various bristles diameters.

The bristles per tuft were counted by using Soft Imaging System touch count tool using the 15x SEM top view photo (Figure 3). Three tufts were counted within each 15x SEM photo, and then averaged for the typical amount of bristles per tuft.

Table II: Power Toothbrushes utilized in study and features

PTB Head	Manufacturer	Type	Features
	Arm & Hammer Spinbrush Sonic (AHSO)	Battery	Soft bristles
	Arm & Hammer Spinbrush (AHSP)	Battery	Soft bristles
	Colgate Motion (COMO) (Colgate-Palmolive Company, New York, NY)	Battery	Soft bristles; two rotational heads
	Oral-B Stages Power Ages 3+ (OB3B)*	Battery	Soft bristles; counter rotational head
	Oral-B Power Polisher (OBPD)	Rechargeable	Soft bristles, special polishing cup in center ; bristle indicators
	Oral-B (OBP)	Rechargeable	Extra Soft bristles
	Oral-B Power Tip (OBPT)	Rechargeable	Soft bristles
	Oral-B Pulsar (OBPU)	Battery	Soft bristles; compact head
	Oral-B Sonic (OBSO)	Rechargeable	Soft bristles; CrissCross Bristles
	Oral-B CrossAction Dual Clean (OBDC)	Rechargeable	Soft bristles; snap on head
	Oral-B Dual Action (OBDU)	Rechargeable	Soft bristles; Indicator bristles; Both heads move for twice the cleaning

*Children PTBs

Figure 3: SEM images (Sonicare Elite Compact PTB) indicating: A. Diameter of 3 Toothbrush Bristles; B. Bristle Count from 3 Sets of Tufts

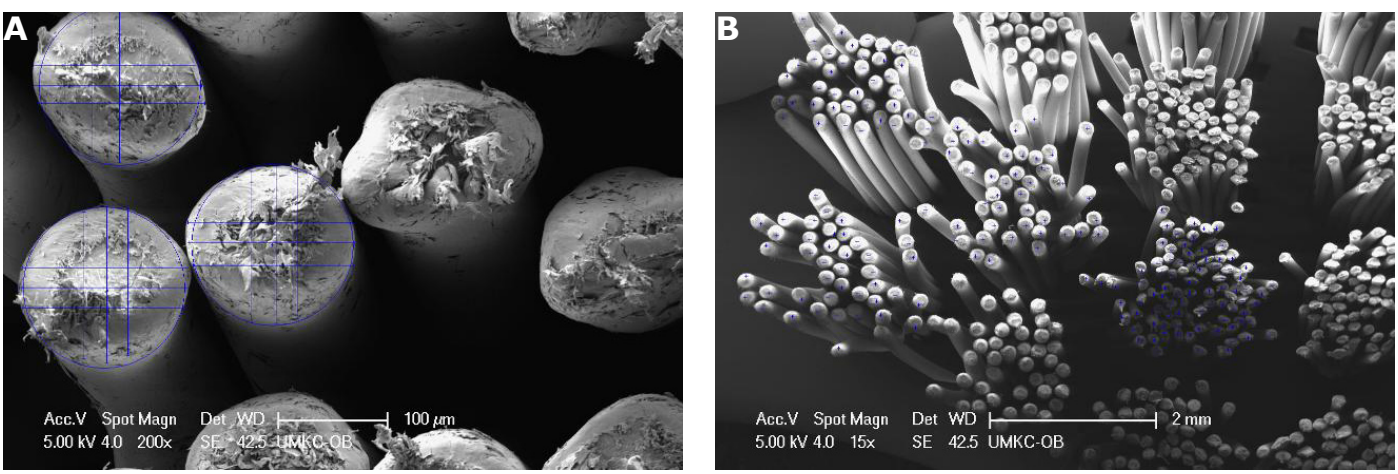
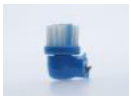


Table II: Power Toothbrushes utilized in study and features (continued)

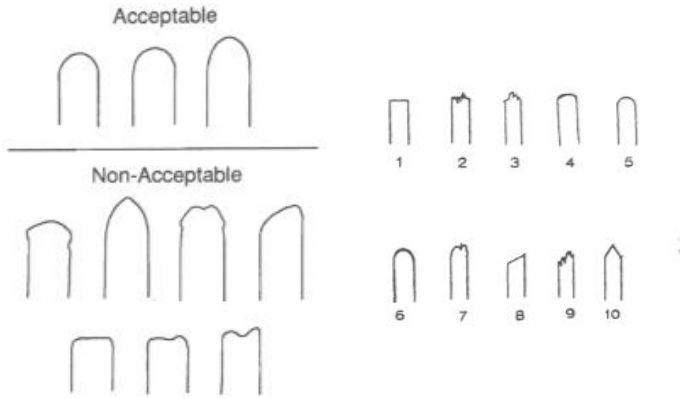
PTB Head	Manufacturer	Type	Features
	Oral-B Pulsonic (PULSE)	Rechargeable	Prosoft bristles; pivots and pulses
	Oral-B Kids 3+ (OBKP)*	Battery	Extras Soft bristles; raised row of bristles, blue indicator bristles, round head; oscillating rotation motion
	Sonicare Elite Compact (SECP)	Rechargeable	Soft Bristles ; Slim, angled neck and contour-fit bristles; rippled bristles; compact head
	Sonciare Eilte Standard (SESP)	Rechargeable	Soft Bristles; Slim,angled neck and contour-fit bristles; rippled bristles
	Sonicare Flexcare Compact (SFCP)	Rechargeable	Soft rippled bristles; indicator bristles; compact head
	Sonicare Flexcare Standard (SSFB)	Rechargeable	Soft rippled bristles; indicator bristles
	Sonicare Kid Age 4+ (SKID1)*	Rechargeable	Extrasoft bristles; compact head; rippled
	Sonicare Kid Age 7+ (SKID2)*	Rechargeable	Extrasoft bristles; rippled
	Waterpik Large (WATP1) (Fort Collins, CO)	Rechargeable	Extrasoft bristles; standard head
	Waterpik Small (WATP2)	Rechargeable	Extrasoft bristles; compact head

*Children PTBs

The surface characteristics were noted using the 40x and 200x SEM horizontal photos. When reviewing the surface characteristics, the bristle ends were analyzed for acceptable or unacceptable end-rounding using Silverstone and Featherstone scale (Figure 4).[29] The Adrians Grading Scale was used to categorize the bristle shape.[30] In addition, the bristles were also characterized as to roughness of the lateral surfaces.

Descriptive statistics for different TBs on tuft count, bristle count and bristle diameter are shown in Table III. Data analysis was performed with SAS (Statistical Analysis System, version 9.1.3; SAS Inc., Cary, NC). A 2 group t-test was used to compare the difference between MTB and PTB on bristle count, tuft count and bristle diameter. A 1-way analysis of variance (ANOVA) and Ryan-Einot-Gabriel-Welsch Q (REGWQ) multiple comparison post-hoc analysis were utilized

Figure 4: Silverstone and Featherstone Scale (A. Examples Of Acceptable And Non-Acceptable End-Rounding of Bristles;[29] B. Modified Silverstone and Featherstone Grading Scale)



Bristles 4 through 6 are acceptable, whereas 1 through 3 and 7 through 10 have an unacceptable rating.[28]

Table III: Manual and Power Toothbrush Average Tuft Count, Bristle Count and Bristle Diameter

MTB Head	Tuft Counts	Bristle Counts X±std	Bristle Diameter X±std µ	PTB Head	Tuft Counts	Bristle Counts X±std	Bristle Diameter X±std µ
Biotene Supersoft (BIO)	30	310±199	79±4µ	Arm & Hammer Spin-brush Sonic (AHSO)	23	155±115	141±5 µ
Butler Gum (BMTB)	31	38±13	178±9 µ	Arm & Hammer Spin-brush (AHSP)†	33	70±8‡	131±4 µ
Butler Gum Technique (GBTE)	30	34±10	176±10µ	Colgate Motion (COMO)	31	52±12‡	177±8 µ
Butler Gum Summit (GS)	31	45±2	113±59µ	Oral-B Power Polisher (OBPD)	16	107±20‡	141±6 µ
Butler Gum Crayola (BCB)	25	67±2	146±3 µ	Oral-B (OBP)	24	34±8	146±23 µ
Butler Gum Kids (BCHI)	19	51±1	182±4 µ	Oral-B Power Tip (OBPT)	4	69±10	157±2 µ
Colgate Wave (COWA)	35	54±3	169 ±5µ	Oral-B Pulsar (OBPU)	19	183±144	141±4µ
Crest Dual Action Clean (CRDA)*	38	82±27‡	161±48µ	Oral-B Pulsonic (PULSE)	30	52±5	329±12 µ
Crest Complete (CRRM)	25	62±13	168 ±10µ	Oral-B CrossAction Dual Clean (OBDC)†	38	90±39‡	156±7µ
Oral-B Advantage Artic (OBAA)	36	58±9	150±14µ	Oral-B Dual Action (OBDU)†	37	81±30‡	145±2µ
Oral-B Advantage Glide (OBAG)	37	81±9	154 ±5µ	Sonicare Elite Compact (SECP)	31	42±2	149 ±0µ
Oral-B Advantage Plus (OBAP)	33	61±13	146±12µ	Oral-B Stages Power Ages 3+ (OB3B)*†	30	127±53	127 ±34 µ
Oral-B Advantage (OBA)	33	52±6	193±8µ	Oral-B Kids 3+ (OBKP)	22	57±21‡	143±21 µ
Oral-B Advantage Sensitive (OBAS)	33	72±1	147±5µ	Sonciare Eilte Standard (SESP)	32	60±1	133±7 µ
Oral-B Cross Action (OBCR)	25	234±313	172±6 µ	Sonicare Flexcare Compact (SFCP)	22	67±20	172±13 µ
Oral-B Indicator (OBIC)	30	43±2	203±9 µ	Sonicare Flexcare Standard (SSFB)	32	63±25	161±2 µ
Oral-B Indicator Designs (OBID)	23	52±1	188 ±8µ	Sonicare Kid Age 4+ (SKID1)*	22	97±26	122±28 µ
Oral-B Indicator (OBIN)	30	40±1	204±6 µ	Sonicare Kid Age 7+ (SKID2)*	32	62±9	117±19µ
Oral-B Pro-Health CrossAction (OBPH)	30	72±29	172±9 µ	Waterpik Large (WATP1)	28	52±2	173±9 µ
Oral-B Ortho (OBOR)	30	46±1	202±2 µ	Waterpik Small (WATP2)	20	50±1	182±3 µ
Oral-B Stages One 4-24 months (OBS1)	32	62±1	135±5 µ				
Oral-B Stages 2-4 years (OBS2)	20	100±4	129±4 µ				
Oral-B Stages Mixed Dentition (OBSM)	34	52±4	145±7µ				
Oral-B Stages 5-7 years (OBSS)	33	62±4	149±2 µ				

to compare the diameter of TB bristles based on an unbalanced dataset. Level of significance was set at α=0.05.

Results

The average bristle diameter, average number of bristles per brush head and exact number of tufts per brush head for MTBs and PTBs are reported in Table III. There were no significant differences (p>0.05) in the mean bristle diameter, bristle count nor tuft counts between MTBs and PTBs (Table IV).

Table V reports the surface characteristics of TB heads and shapes of bristles. Oral-B Sonic (Procter & Gamble Company, Cincinnati, OH) revealed spiral bristles. Butler Gum (Sunstar Americas, Inc., Chicago, Ill.) middle section of bristles split into 4 and shredded. Crest Dual Action Clean (Procter & Gamble Company, Cincinnati, OH) has small bristles in the middle of the brush head and large bristle tips on the outside. Butler Gum Summit bristles appear spongy and some appear as an upside down cone and cut off. Oral-B Pulsar (Procter & Gamble Company, Cincinnati, OH) has a rubber bristle. Sonicare Kids PTB (Philips Electronics North America Corporation, Andover, Mass.) had a design with every other bristle on the periphery of the brush head small and all the middle section of the brush head small.

Bristle diameters, number of tufts and number of bristles among the MTB and PTB were not significantly different among types (p>0.05). For MTB, there was no significant difference (p>0.05) between flat tip with straight rims and pointed tip, but there were significant differences (p≤0.05) in diameter between round tip, flat tip with round rim and mushroom-shaped bristles. There was no significant difference in bristle diameter among different bristle shapes for PTB. Within each bristle shape, there was no significant difference in diameter between MTBs and PTBs (Table VI).

SEM of bristles of TBs that had multiple types of bristle sizes are shown in Table VII. The Arm and Hammer Spinbrushes (Church & Dwight Co., Inc., Princeton, NJ) revealed diamond shaped bristles along with the end-rounded bristles. Butler Gum toothbrush contained bristles that appear to be split into fours. Oral-B brushes had differences in terms of shape of bristles and texture. The Oral-B Pulsar had 3 types of bristles. Crest Dual Action Clean revealed texture differences and various bristle types.

Table IV: MTB versus PTB for Bristle Counts, Tuft Counts and Bristle Diameters

Variable	MTB (n=24)	PTB (n=21)
Bristle Count	76±63[a]	78±38[a]
Tuft Count	30±5[a]	26±8[a]
Bristle Diameter (um)	161±30[a]	157±43[a]

Discussion

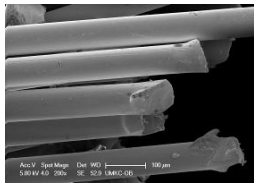
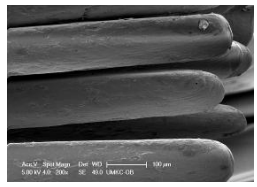
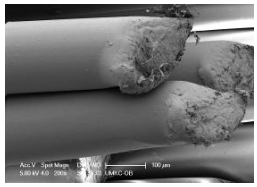
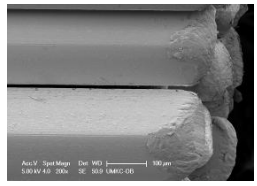
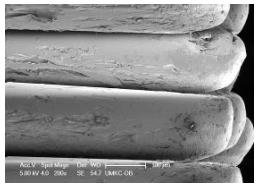
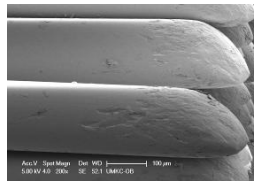
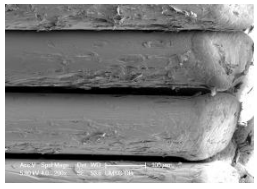
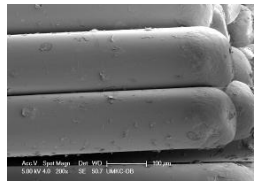
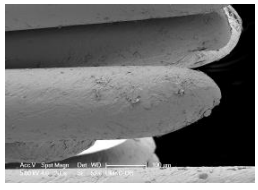
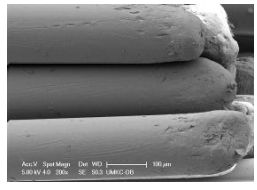
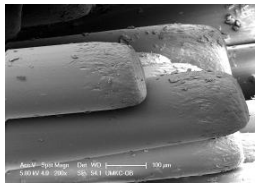
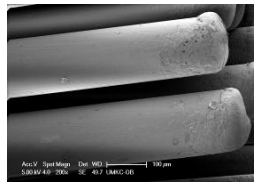
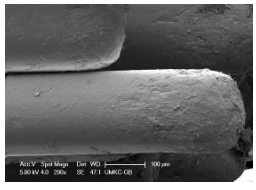
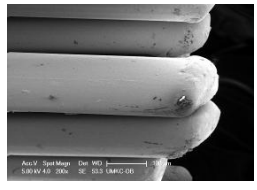
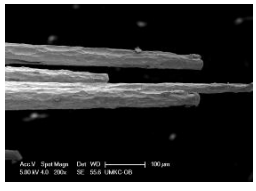
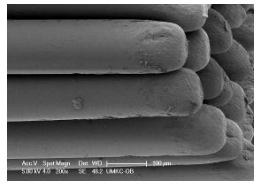
There was quite a range of bristle end shapes and numbers among the range of MTB and PTBs examined. Comments are divided into discussion of limitations of the present study, interpretation of the results, comparison of results to published information, clinical interpretation of the meaning of the results and suggestions for future research.

A limitation of the study was that only 1 TB head per type was analyzed (inter-brush variability) rather than determining "intra-type variability." This is important to utilize multiple TBs from each manufacturer to measure brush to brush variability. Often a wide variation among shapes of bristle tips exists even within an individual brush.[28] It has also been shown that the average number of "acceptable" rounded filaments differed significantly between 2 and 4, but not between 4 and 6 brushes studied per brand.[31] Studies that have compared characteristics within MTB bristles types have analyzed 30 TB heads for each brand[22,28] and a PTB study used 5 for analysis to account for intra-type variability.[21]

In the current study, brush heads were analyzed intact. Previous studies in the literature separated the bristles or tufts from the heads to be analyzed with the SEM.[32] The current study chose this path to avoid damaging or distorting the dimensions of the bristles.

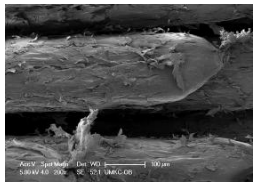
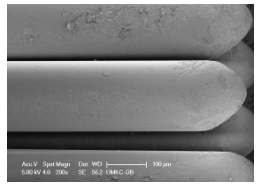
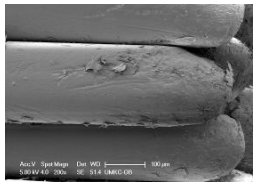
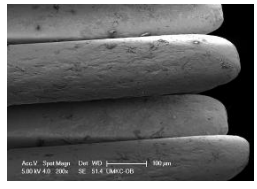
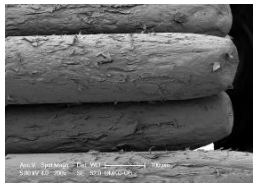
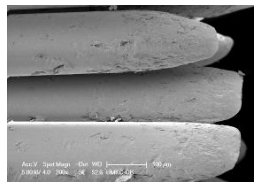
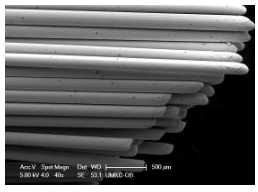
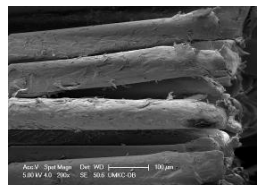
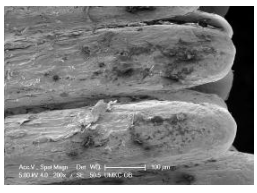
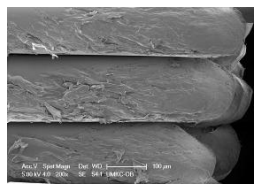
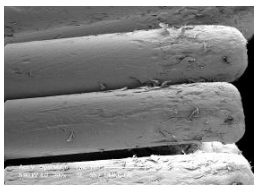
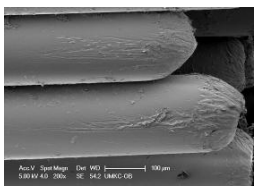
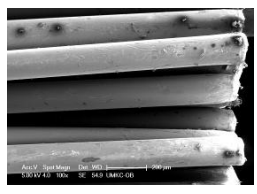
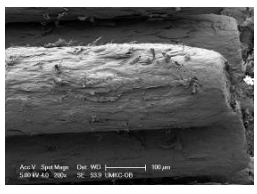
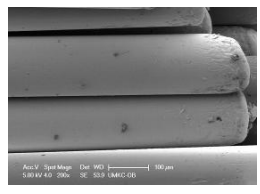
The results revealed no significance (p>0.05) between the MTB vs. PTB regarding the bristle diameter, bristle count and tuft count. However, there was a significance difference (p≤0.05) noted regarding the bristle diameters and bristle shape. The significance was found between flat tip with straight rims bristles (118μ) and round tip bristles (158μ), pointed tip shaped bristles (113μ) and round tip bristles (158μ), mushroom shaped bristles (177μ) and flat tip with straight rims bristles (118μ), and mushroom shaped bristles (177μ) and pointed tip bristles (113μ). The typical ranges for TB bristle diameter are 150μ to 400μ in diameter.[5] It appears that the TB bristles that are not the typical rounded tip has either

Table V: SEM surface characteristic and bristle shape of MTBs and PTBs

TB Name	Type	Shape	Surface Characteristic	TB Name	Type	Shape	Surface Characteristic
BIO	MTB	3		AHSP	PTB	1	
BMTB	MTB	7		AHSO	PTB	3	
BCHI	MTB	1		COMO	PTB	1	
BCB	MTB	1		OBP	PTB	2	
COWA	MTB	1		OBDC	PTB	1	
CRRM	MTB	2		OBDU	PTB	1	
CRDA	MTB	1		OBKP	PTB	1	
GS	MTB	4		OBPD	PTB	1	

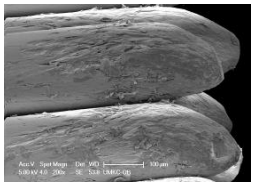
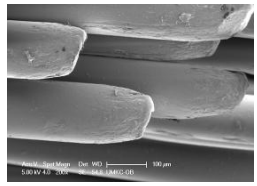
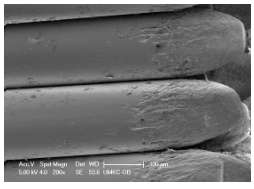
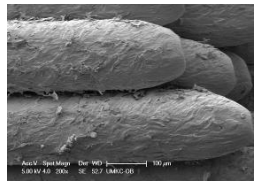
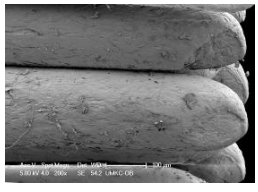
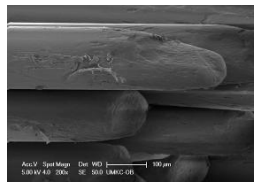
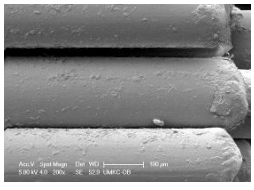
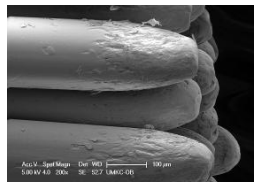
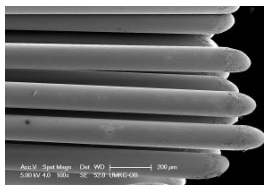
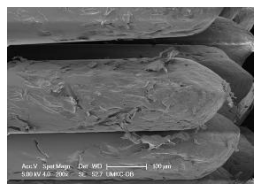
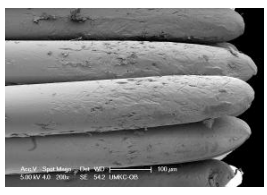
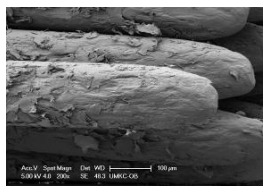
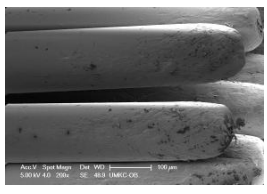
Adrians Grading Scale30 was used to determine shape: 1. round tip, 2. flat tip with rounded rims, 3. flat tip with straight rims, 4. pointed tip, 5. knife-shaped tip, 6. chisel-shaped tip, 7. mushroom-shaped

Table V: SEM surface characteristic and bristle shape of MTBs and PTBs (continued)

GBTE	MTB	7		OBPT	PTB	2	
OBA	MTB	1		OBPU	PTB	1	
OBAA	MTB	1		OBSO	PTB	1	
OBAG	MTB	1		OB3B	PTB	1	
OBAP	MTB	1		PULSE	PTB	1	
OBAS	MTB	2		SECP	PTB	2	
OBCR	MTB	1		SESP	PTB	3	
OBIC	MTB	2		SFCP	PTB	1	

Adrians Grading Scale30 was used to determine shape: 1. round tip, 2. flat tip with rounded rims, 3. flat tip with straight rims, 4. pointed tip, 5. knife-shaped tip, 6. chisel-shaped tip, 7. mushroom-shaped

Table V: SEM surface characteristic and bristle shape of MTBs and PTBs (continued)

OBIN	MTB	1		SSFB	PTB	2	
OBID	MTB	1		SKID1	PTB	1	
OBOR	MTB	1		SKID2	PTB	2	
OBPH	MTB	2		WATP1	PTB	1	
OBS1	MTB	1		WATP2	PTB	1	
OBS2	MTB	1					
OBSS	MTB	1					
OBSM	MTB	1					

Adrians Grading Scale[30] was used to determine shape: 1. round tip, 2. flat tip with rounded rims, 3. flat tip with straight rims, 4. pointed tip, 5. knife-shaped tip, 6. chisel-shaped tip, 7. mushroom-shaped

a greater diameter (mushroom shaped) or decreased diameter than normal range (flat tip with straight rim bristles or pointed tip bristles). This suggests that the shape of the bristle had an influence on the diameter of the bristle. The pointed bristles diameter and flat tip with straight rims bristles diameter were not within the typical diameters of TB bristles.

End-rounding is important due to studies that have revealed a rounded bristle causes less damage to hard and soft tissues while brushing.[32] To produce end-rounded bristles, bristle tips go through a process of grinding and polishing that is traditionally done by placing a trimmed brush against a flat, rotating grinding surface.[28] With a rippled brush containing short and long bristles, the same process would grind and polish some of the bristles while leaving others untouched.[28] Previous studies have suggested that this type of traditional end-rounding on a rippled brush may not be adequate to completely reduce oral soft tissue trauma.[33,34] A study conducted by Mulry compared a rippled TB with a traditional non-rippled TB and concluded that close to 90% of the bristles in the rippled bristle pattern design show adequate end-rounding well above the 52% observed for a flat brush due to new technology that accounted for grinding the short and long bristles of a rippled brush.[28]

Though there is evidence of the importance of end rounded TBsm,[32] inconsistent end-rounding of TB bristles was demonstrated in previous MTB studies.[28-30,35] A study regarding PTB bristles revealed when evaluating the bristle shapes that a good quality of filament tips could be found for most of the products.[21] Former studies of Oral-B[22,24,29,36-38] found some bristles were not acceptable among the tufts, where Colgate[22,29,36,37] were evaluated inconsistently, which would suggest a great variance in end-rounding quality. Butler showed a high number of not acceptable filaments in former studies[22,24,27,36,39] which were confirmed in the study by Meyer-Lueckel.[21] The first study to analyze PTB bristles concluded that most of the brands (13 out of 15) examined among the PTBs were of an acceptable quality,[21] and this study concluded the same (9 PTB out of 21 and 9 MTB out of 24).

The Adrians Grading Scale[30] and Silverstone and Featherstone scale[29] represent categories and not steps on a continuous scale. The scale that is most representative of TB designs of preference was the Adrians Grading Scale,[30] because it includes the various TB shape categories. The Silverstone and Featherstone scale assisted in determining only what is acceptable or not acceptable regarding bristle end-rounding.[29,30]

Table VI: Comparison of MTB versus PTB bristle diameter to Adrians shape scale

	Bristle Diameter (um)	
Shape Category:	MTB	PTB
1 (round tip)	164±24 (n=16)^{aA}	164±51 (n=14)^{aA}
2 (flat tip w/rounded rims)	173±23 (n=4)^{aA}	146±17 (n=5)^{aA}
3 (flat tip w/ straight rims)	79 (n=1)^{aB}	137±6 (n=2)^{aA}
4 (pointed tip)	113 (n=1)^{B}	----
5 (knife-shaped tip)	----	----
6 (chisel-shaped tip)	----	----
7 (mushroom-shaped)	177±1 (n=2)^{A}	----

Different superscripts represent significant differences at α=0.05. Small letter value between columns. Capital letter value between rows.

Although this study analyzed only 1 TB per type, further studies could evaluate a larger sample of each type to determine if there is variability in bristle diameter and shape as well as bristle and tuft count due to the manufacturing process. Other future studies could include evaluating brushes with the Adrian and Silverstone scales[29,30] before and after some time of TB use to determine what happens to the bristles over time. For example, there may be a possibility that regardless of irregular shapes at the beginning, the first change may be toward bristle rounding. After rounding, the wear on the bristles of average diameter may be reduced so that they probably last longer for the average person. In addition, one could see if the wear corresponds well to any color markers for changing brushes. Other studies could include using radically different dentifrices over time to determine how the dentifrice might affect bristle shape and end-rounding. Deterioration patterns of bristles are not known, therefore conducting a study to see if the shape of the tip remains the same over time of use and even determining if an un-rounded tip becomes round upon use or remains the same is important, since studies have determined that end-rounded tip is safer.[32]

Overall brush head design is important for both cleaning efficacy and safety.[11,13,15,17,18,40] The design needs to be considered when determining which TB to utilize or recommend. Since there were no differences in design for certain param-

Table VII: Toothbrush Heads that Included More than 1 Bristle Type

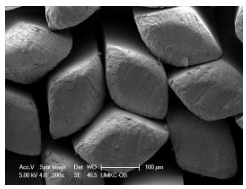
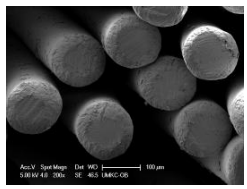
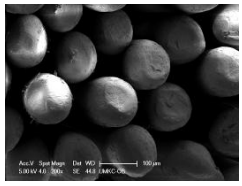
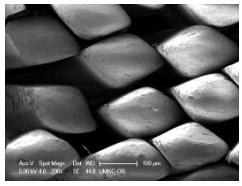
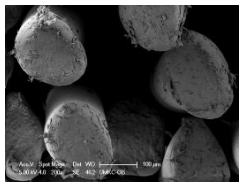
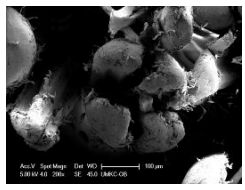
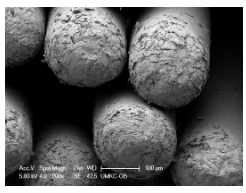
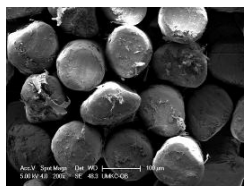
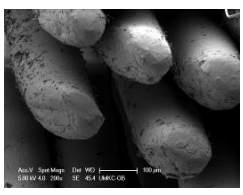
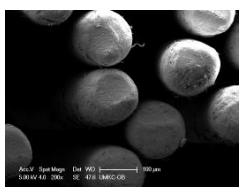
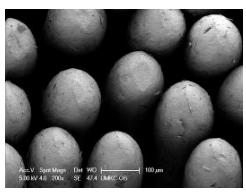
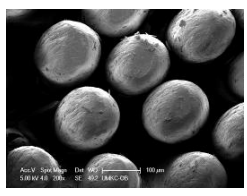
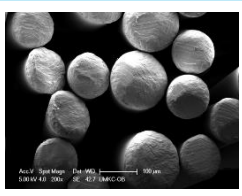
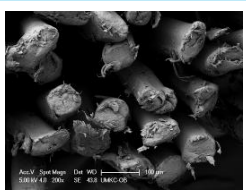
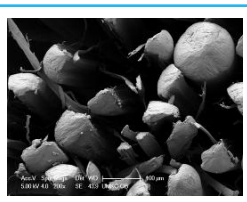
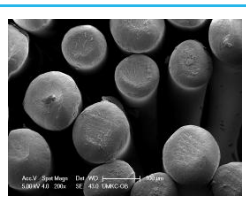
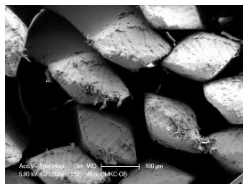
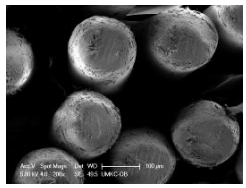
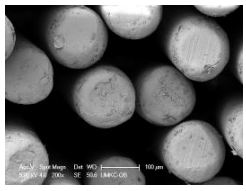
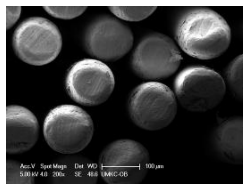
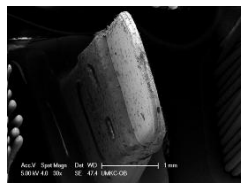
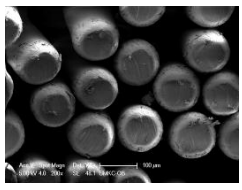
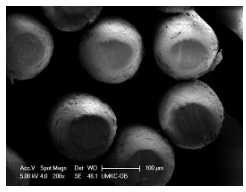
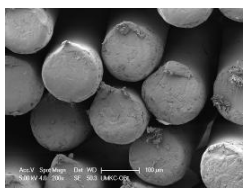
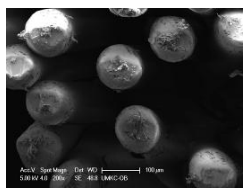
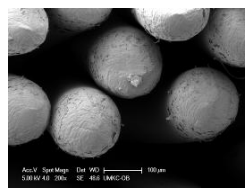
TB Brand/Type	SEM Depicting Multiple Bristle Types		
Arm & Hammer Spinbrush Sonic (AHSO) PTB			
Arm & Hammer Spinbrush (AHSP) PTB			
Butler Gum (BMTB) MTB			
Crest Dual Action Clean (CRDA) MTB			
Oral-B Advantage Plus (OBAP) MTB			
Oral-B Pulsar (OBPU) PTB			
Oral-B Stages Power Ages 3+ (OB3B) PTB			
Oral-B Kids 3+ (OBKP) PTB			

Table VII: Toothbrush Heads that Included More than 1 Bristle Type (continued)

Sonicare Elite Standard (SESP) PTB			
Sonicare Flexcare Compact (SFCP) PTB			
Sonicare Kid Age 4+ (SKID1) PTB			
Sonicare Kid Age 7+ (SKID2) PTB			

eters for the TBs analyzed in the current study, one could determine that if a new brush came out with similar design that one could predict it would have similar characteristics.

Conclusion

Although there are numerous TB head designs, based on the parameters measured in this study, there were minimal differences between the TBs that were evaluated. Within the limitations of the present investigation, the following can be concluded:

1. There was a significant difference ($p \leq 0.05$) in bristle diameters and bristle shape among the MTBs. No significant difference ($p > 0.05$) among the PTBs for bristle diameter and bristle shape.
2. No significant differences ($p > 0.05$) between MTB vs. PTB bristles count and diameters among the various manufacturers.
3. There were no significant differences ($p > 0.05$) in the tuft counts between MTB vs. PTB.

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