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ORIGINAL ARTICLE

In-vitro comparison of two different toothbrush bristles about peri-implant sulcus penetration

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Abstract

Objective: The aim of this preclinical study was to compare the ability of tapered and cylindrical bristles to penetrate the peri-implant sulcus.

Methods: A full mandibular dental arch was reproduced in plaster cast. In site #3.6 a hollow glass cylinder was positioned simulating a 4 mm diameter implant and the gingival component was recreated by using dedicated silicone. A Bass brushing technique was performed from the vestibular side in humid environment. During it, the penetration of the bristles between the gum and the implant was recorded by mean of an optic fibre fixed inside the cylinder. The protocol included 5 toothbrushes per group and 10 tests per toothbrush, for a total of 50 assessments for each of the two groups.

A scale of 5 grades for bristle penetration was defined: grade 0 ($x < 2$ mm), grade 1 ($2 \leq x < 3$ mm), grade 2 ($3 \leq x < 4$ mm), grade 3 ($4 \leq x < 5$ mm) and grade 4 ($5 \leq x < 8$ mm). From the video recordings the highest value of penetration was identified for each test.

Results: The tapered bristles showed an 8 times greater penetration capacity ($p = 0.001$) in respect to the cylindrical bristles (multilevel analysis). The percentage of tests reaching depths ≥3 mm was 86% for tapered group and 28% for the cylindrical group.

Conclusion: This preclinical study shows a clear and superior penetration capacity of the tapered bristles in respect to traditional cylindrical ones. For tapered bristles, a potentially greater hygienic efficacy around dental implants is suggested.

KEYWORDS
dental implant, implant maintenance, oral hygiene, toothbrushing

1 | INTRODUCTION

Prevention and early diagnosis of peri-implant inflammation are crucial for long-term success of dental implants. Peri-implant mucositis is characterized by reversible inflammation of the peri-implant mucosa without bone loss. If untreated it can progress into peri-implantitis, which represents the main cause for implant failure due to bone loss.[1,2]

In the literature there seems to be an agreement about the cause-effect relation between biofilm and inflammation, with both preclinical and clinical studies confirming that biofilm deposition and adhesion onto implant-prosthetic structures is the main factor responsible for the onset and persistence of the peri-implant inflammation.[3,4] It is further worthy to mention that supragingival biofilm deposits significantly affect the formation of subgingival biofilm.[5–7]

Several studies have shown the importance of self-performed oral hygiene for the long-term stability of implants,[8] underlining that the hygienic maintenance of peri-implant tissues is a key point for peri-implantitis prevention.[9] As a consequence, all strategies aimed to reach a thorough plaque control must be considered as preventive/treatment measures to manage peri-implant inflammation.[10,11]

The main function of a manual or powered toothbrush is to break up and remove bacterial plaque,[12] making its use as essential for implant hygiene care as it is for natural dentition. Among the toothbrush bristles now available on the market, synthetic tapered bristles are longer and thinner than the classical round-ended ones, specifically in their terminal portion.

Clinical and preclinical studies have shown that these kinds of bristles are more effective in plaque removal around marginal soft tissues, from interproximal surfaces and into the occlusal fissures than rounded bristles.[13–19]

Checchi et al. (2007) in a clinical study showed that tapered bristles reduce plaque index quicker and are stronger than an ADA standard toothbrush with rounded bristles.[16] In a subsequent clinical study by the same authors, the participants perceived the tapered bristles as more comfortable and effective, especially at interproximal areas than rounded ones.[20]

Ni et al. (2017) investigating gingival and dental hygienic parameters come to support the superior plaque control and gingivitis reduction benefits of this specific bristles with respect to rounded ones.[21]

A recent systematic review and meta-analysis of clinical studies confirms that toothbrushes with tapered bristles seem to give an additional benefit in reducing gingival inflammation when compared to cylindrical ones; though concluding that scientific evidence is still insufficient to recommend their use.[22]

Given the greater flexibility of these bristles and the apparent ability to penetrate into hidden areas like interproximal spaces, it would be interesting to investigate the ability to reach the subgingival spaces. Paraphysiological conditions such as residual periodontal pockets, pseudo-pockets or deep peri-implant sulcus all demand for specific hygienic care where this new opportunity must be tested.

2 | AIM

The aim of this in-vitro study was to compare standard round-ended bristles with tapered bristles on their ability to penetrate the peri-implant sulcus during brushing.

The null hypothesis affirms that no difference in the level of penetration exists between the two types of bristles.

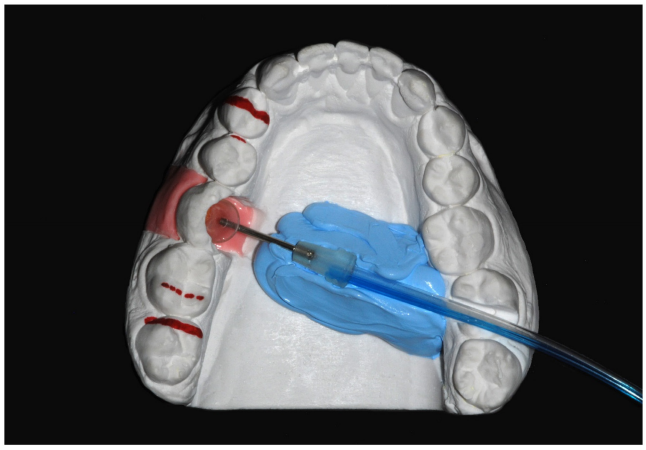

FIGURE 1 Occlusal view of the plaster cast. It is possible to see the vestibular silicon gingiva, the 4 mm glass cylinder simulating the dental implant and the herein stabilized endoscopic fibre.

3 | MATERIALS AND METHODS

This preclinical study was performed on a full arch mandibular plaster cast to simulate natural anatomy. The cast was properly treated to make it waterproof. The element #3.6 was defined as the area of testing and prepared to simulate a peri-implant rehabilitation. Using burs, the cast was carefully carved, and a bucco-lingual tunnel was made respecting the gingival margin as the coronal limit and the #3.6 contact points as the mesio-distal limits. The vestibular aspect of soft tissues corresponding to the part removed were faithfully reproduced in silicone. The lingual part of the #3.6 crown was removed and then placed a 4 mm-wide hollow glass cylinder simulating the implant neck. The glass cylinder was wrapped in a 0.2 mm plastic film before placing the artificial gingiva. This film was then removed acting as a space maintainer to recreate the peri-implant sulcus. Through a lingual perforation of the cylinder, an endoscopic fibre (DV2 Perioscopy System) was inserted to visualize the submarginal area from 2 mm up to 8 mm apically. A groove on the occlusal surface of #4.7 and a silicone stent in the lingual area stabilized the fibre (Figure 1).

The cast was then fixed on a weight scale to control the pressure during the toothbrush movements. The two manual toothbrushes examined in this study were one with soft-tapered bristles (Meridol®, GABA International AG) and the other with standard round-ended bristles (American Dental Association) (Figure 2). The two models had the same length and width of the head with all bristles perpendicular inserted. Every toothbrush was stored at least for 48 h at 20°C before the test.

In this assay, the Bass brushing motion,[23] consistently performed by the same operator (L.B.), was used for 60 s in a wet environment obtained using water spray over the model right before the test. The interval of weight-pressure exerted was between 300 g and 400 g, reaching an ideal weight-pressure of 350 g with a stroke length of 5 mm. To control the stroke length, two straight lines were drawn on the vestibulo-occlusal side of plaster cast. Referring to the same midpoint the length of the toothbrush head was marked with dotted lines (Figure 3).

FIGURE 2 Toothbrush models used for the study. From left to right flat ADA standard end-rounded bristles and Meridol® tapered bristles.

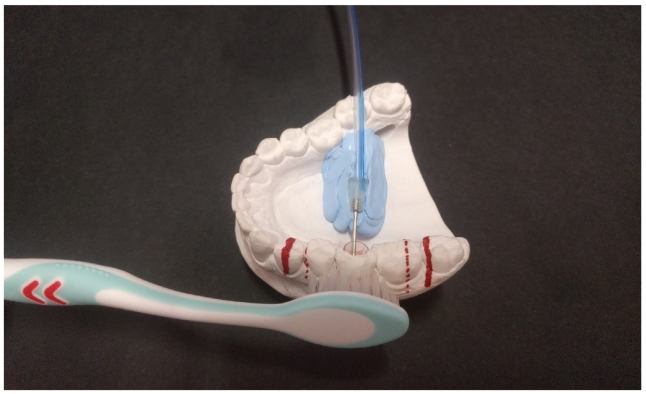

FIGURE 3 Experimental set. It is possible to distinguish dotted and straight lines: the first ones identify the toothbrush head length, the second ones are the brushing limits.

On the registration clip, the circular endoscopic view was divided into 4 areas by means of parallel horizontal lines corresponding to the periodontal probe marks (periodontal probe PCP15, HuFriedy). The most apical line identifies also the half of the circular area (Figure 4).

To classify the bristles penetration degree a scale of 5 grades was created as follows:

1. Grade 0: bristles are not visible in the endoscope, and penetration depth is below 2 mm ($x < 2$ mm).
2. Grade 1: bristles are barely visible, and penetration depth is between 2 and 3 mm ($2 \le x < 3$ mm).
3. Grade 2: bristles are clearly visible, and penetration depth is between 3 and 4 mm ($3 \le x < 4$ mm).
4. Grade 3: bristles are clearly visible but do not reach the half of the circular view, penetration depth is between 4 and 5 mm ($4 \le x < 5$ mm).

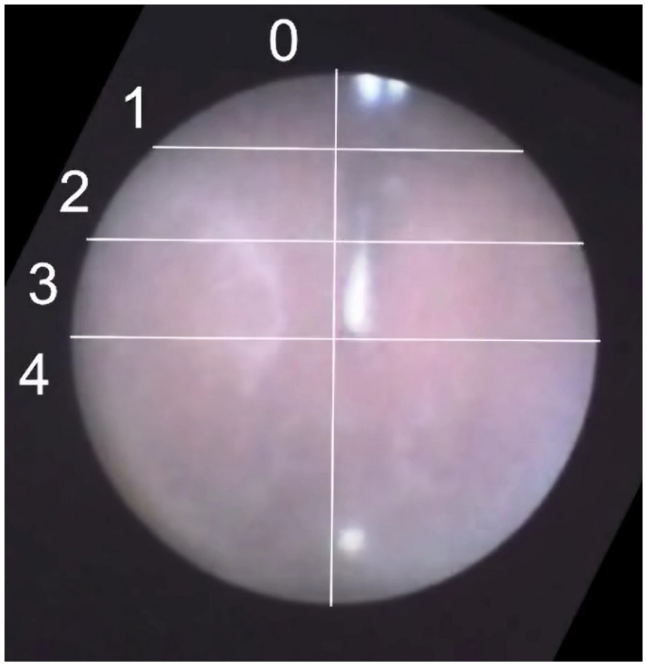

FIGURE 4 Endoscopic view and specific lines defining four areas of possible bristles penetration. The vertical line identifies the corono-apical axe, it is possible to see the periodontal probe in between.

5. Grade 4: bristles are clearly visible and reach or pass over the half of the circular view, and penetration depth is between 5 mm and 8 mm ($5 \le x < 8$ mm).

The grade assigned during data collection was the highest one reached during the 1-min endoscopic recording.

3.1 | Sample size

At an α level of 0.05 for a one-sided test and a power of 80%, with a superiority margin of 40%, based on clinician's opinion, a total sample of 10 toothbrushes was needed; the experimental setting consisted of 5 brushes with tapered bristles and 5 with rounded bristles with 10 evaluations for each toothbrush.

3.2 | Statistical analysis

Intra-observer variation was evaluated by means of K-statistics.

Frequency distributions were used to describe the results.

A mixed effect model was applied considering as primary outcome the level of bristle penetration of the ten toothbrushes (five with tapered and five with rounded bristles) in the experimental setting (ten not independent events for each type of bristles) and as a fixed effect the type of bristles. Being that the outcome is an ordered categorical variable, a multinomial link function was used in the multilevel analysis. The level of significance α was a priori set at 0.05 for a one-sided test.

4 | RESULTS

Excellent agreement was obtained between the measurements performed by the observatory (K-statistics = 1). The percentage of global agreement between observed and expected level of penetration according to multilevel analysis was 60%; the agreement percentage of the estimated model with the observed values was 82% for level 1, 69% for level 2 and 92% for level 3.

The comparison of level of penetration (Table 1) denotes that with tapered bristles the level of penetration ≥3 mm is observed in 86% of the results, with rounded bristles the percentage decreases to 28%.

Considering the average value of each degree multiplied by its frequency, the average penetration value is 2.03 mm for rounded bristles and 3.72 mm for tapered bristles. Based on the observed data the tapered bristles have a mean penetration capacity of 1.07 mm greater.

Tapered bristles proved to be 8.37 times more effective than round-ended bristles ($p = 0.001$, 95% CI 3.550–19.749).

The data shown in Table 2 reported also the cumulative probability of each threshold in comparison with Grade 4 (intercept of the multilevel analysis).

In the absence of any device, the lowest intercept level is 0.198. Based on the statistical model, as the penetration level is 8.373 times greater, the level of penetration of tapered bristles is 1.6 mm higher than rounded bristles.

TABLE 1 Level of penetration of the two types of bristles.

Level of penetration	Tapered bristles	Rounded bristles
Grade 0 (x < 2 mm)	—	5 10%
Grade 1 (2 ≤ x < 3 mm)	7 14%	31 62%
Grade 2 (3 ≤ x < 4 mm)	29 58%	13 26%
Grade 3 (4 ≤ x < 5 mm)	12 24%	1 2%
Grade 4 (5 ≤ x < 8 mm)	2 4%	—

TABLE 2 Comparison between tapered and round-ended bristles: results of multilevel analysis.

	Terms of model	Odds ratio	*p*-value	95% confidence interval	
Level of penetration	Intercept				
	0	0.198	0.001	0.096	0.407
	1	2.079	0.015	1.158	3.732
	2	20.172	0.001	8.652	47.046
	3	76.083	0.001	25.122	230.426
	4[a]				
Type of bristles	Tapered vs Round-ended[a]	8.373	0.001	3.550	19.749

[a]Reference category.

5 | DISCUSSION

Implant-prosthetic reconstructions can present anatomical conditions that may render an effective daily oral hygiene difficult to perform. The presence of physiologically deep peri-implant sulcus, particular implant long axis angulations and prosthetic crowns with large diameters are some of the conditions that can make it hard to control bacterial biofilm accumulation.

In this laboratory assay, the penetration capacity of tapered bristles was tested in an in vitro model and they were found to be superior in peri-implant subgingival access compared to standard round-ended bristles. These results can be considered in line with those from in vitro studies that analysed the penetration capacity of toothbrush bristles in periodontal sulcus.[13,15,19]

We can presume that changes in design can yield improved performance characteristics: a longer and thinner bristle may have resulted in higher flexibility, allowing a deeper penetration into the artificial peri-implant sulcus. In addition, differently from Yankell et al. (2003) study,[13] the Bass brushing technique was used in this study: this movement is oriented towards the marginal and subgingival cleaning so it is more specific than the horizontal scrub. A previous in vitro study using the horizontal brushing stroke showed that tapered bristles were also more effective in removing an experimental gold coating from interproximal surfaces than the conventional toothbrush.[17]

This preclinical study wanted to emulate real intra-oral conditions during toothbrushing. However, the mouth is a complex microenvironment whose conditions are difficult to recreate in a laboratory setting. For example, even the consistency of saliva could modify the bristle characteristics: a smoother saliva may wet the bristles early, while a more viscous one may interfere with the brushing motion. Intraoral temperatures could also modify the mechanical properties of the toothbrush: the heat inside the mouth is generally higher than the room temperature at which the toothbrush is stored and this may increase the bending capacity of the bristles. The possible effect of these conditions in the clinical outcomes could not be evaluated.

The plaster model was replicated from a natural dentition in order to mimic real conditions as much as possible: it allowed to use real crown shapes and to reproduce the direction assumed by bristles during the brushing motion. In fact, the crown shape at the sites where the brushing motion happens, as well as the toothbrushing technique, may condition the direction of the bristles regarding the peri-implant sulcus. Unlike previous studies where the horizontal technique was used,[13] in the case of our study, the Bass motion was selected for its better ability to cleanse below the gumline.

As described by its author, the Bass technique requires that "the ends of the filaments should be applied to the area to be cleaned with firm pressure and the brush moved back and forth with short strokes".[23] There is no clear evidence of how much pressure is correct to exercise with the toothbrush. The pressure chosen in this study is quite similar with that clinically detected in a normal, non-supervised, brushing regime,[24,25] and it does not seem to damage hard and soft tissues when performed with a correct brushing technique.[26–28]

Implant-prosthetic reconstructions and peri-implant tissues share some common clinical features with the periodontum around natural teeth. However, there are structural and anatomical differences that may underlie the different biological behaviours observed between the two scenarios. One in particular is represented by the mucous tunnel depth. In fact, the new peri-implant classification underlines how an implant with probing depth up to 5 mm can be considered physiological and healthy.[29] Vice versa, this represents a mostly pathological condition in the presence of a natural teeth.

To date, the devices for implant hygiene are mostly mutualized from generical dental hygiene not taking in account the peculiarity of the anatomy implant derived, in particular the depth of sulcus.

Supra- and subgingival bacterial biofilm is composed by communicating colonies so every single millimetre of extra penetration during brushing is important for breaking down the dental plaque at a deeper level.[7] It is also true that by eliminating the more superficial plaque, the deeper and more dangerous subgingival plaque may be affected.[5–7] In any case, daily plaque disruption may hinder the growth of pathogenic microorganisms. In addition to the effect on the peri-implant plaque, tapered bristles may have other clinical benefits, as reported by some authors who have detected the toothbrush ability to reduce gingivitis through mechanical intermittent brushing stress[30,31]; the higher penetration capacity of tapered bristles may provide these benefits also in the peri-implant tissues.

The hygienic capacity at these depths is uncertain as stated above and it is therefore important to understand which home oral hygiene tools may be more suitable for implant conditions without neglecting their safety. Dental floss, for example, is generally considered safe in the periodontal area but should be used with care on implants. It has been shown how it could tear in correspondence with certain implant-prosthetic conditions, leaving potentially dangerous residues.[32–34]

In a study by Montevecchi et al., patients felt that toothbrushes with tapered bristles were more comfortable and some retained they were more effective in food removal at interproximal areas in comparison to round-ended ones.[20] These perceived benefits lead to assume that tapered bristles could improve patient compliance increasing the time and commitment employed during toothbrushing, leading to improved peri-implant tissue health.

It would be interesting to investigate in future studies the reason why the same bristle design had different penetration values into the sulcus. Checchi et al. (2001) found differences in the number and disposition of filaments among different toothbrush brands and even within the same brand,[35] this could change the penetration capacity of the bristles. Comparative analysis on various commercial toothbrushes with different number of tufts, disposition, length and thickness of tapered bristles is strongly suggested. The interpretation of these results must take into account the peculiarity of the study model specifically focused on the implant sulcus. The prosthetic connection, the implant surface as well as other aspects closely related to an implant-supported tooth are not reproduced in this model. We only took into consideration the highest penetration value perceived during the 60 s trial. However, this value could also have been affected by the different weight pressures exercised during brushing, even if within a controlled selected range.

6 | CONCLUSIONS

Tapered bristles are able to penetrate deeper into a simulated peri-implant sulcus than the standard round-ended ones. It can be hypothesized that toothbrushes with tapered bristles could be more effective in preventing plaque related peri-implant diseases. Future studies are strongly recommended.

7 | CLINICAL RELEVANCE

Scientific rationale for study: implant rehabilitation implies new anatomy that need to be properly maintained. It is still not known whether the design of the toothbrush bristles can influence the penetration below the mucous margin.

Principal findings: in an in-vitro implant setting under endoscopic evaluation, tapered bristles have shown a clearly greater penetration capacity than cylindrical ones.

Practical implication: dental implants may present deep mucous tunnels and a toothbrush with tapered bristles seems to be the most appropriate for its hygienic maintenance.

AUTHOR CONTRIBUTIONS

M.M. and L.V. conceived the ideas; L.B. collected the data; M.M. analysed the data; L.V. and M.M. led the writing; M.S. and G.Z. review and edit the manuscript.

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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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REFERENCES

1. van Steenberghe D, Klinge B, Lindén U, Quirynen M, Herrmann I, Garpland C. Periodontal indices around natural and titanium abutments: a longitudinal multicenter study. *J Periodontol*. 1993;64(6):538-541. doi:10.1902/jop.1993.64.6.538
2. Derks J, Tomasi C. Peri-implant health and disease. A systematic review of current epidemiology. *J Clin Periodontol*. 2015;42(S16):S158-S171. doi:10.1111/jcpe.12334

3. Pontoriero R, Tonelli MP, Carnevale G, Mombelli A, Nyman SR, Lang NP. Experimentally induced peri-implant mucositis. A clinical study in humans. *Clin Oral Implants Res*. 1994;5(4):254-259.
4. Salvi GE, Aglietta M, Eick S, Sculean A, Lang NP, Ramseier CA. Reversibility of experimental peri-implant mucositis compared with experimental gingivitis in humans. *Clin Oral Implants Res*. 2012;23(2):182-190. doi:10.1111/j.1600-0501.2011.02220.x
5. Katsanoulas T, Reneè I, Attström R. The effect of supragingival plaque control on the composition of the subgingival flora in periodontal pockets. *J Clin Periodontol*. 1992;19(10):760-765. doi:10.1111/j.1600-051x.1992.tb02167.x
6. Tezal M, Scannapieco FA, Wactawski-Wende J, Grossi SG, Genco RJ. Supragingival plaque may modify the effects of subgingival bacteria on attachment loss. *J Periodontol*. 2006;77(5):808-813. doi:10.1902/jop.2006.050332
7. Schaumann S, Staufenbiel I, Scherer R, et al. Pyrosequencing of supra- and subgingival biofilms from inflamed peri-implant and periodontal sites. *BMC Oral Health*. 2014;14:157. doi:10.1186/1472-6831-14-157
8. Louropoulou A, Slot DE, Van Der WF. Mechanical self-performed oral hygiene of implant supported restorations: a systematic review. *J Evidence-Based Dental*. 2014;14 (SUPPL):60-69.e1. doi:10.1016/j.jebdp.2014.03.008
9. Jepsen S, Berglundh T, Genco R, et al. Primary prevention of peri-implantitis: managing peri-implant mucositis. *J Clin Periodontol*. 2015;42(Suppl 16):S152-S157. doi:10.1111/jcpe.12369
10. Westfelt E, Rylander H, Dahlén G, Lindhe J. The effect of supragingival plaque control on the progression of advanced periodontal disease. *J Clin Periodontol*. 1998;25(7):536-541. doi:10.1111/j.1600-051x.1998.tb02484.x
11. Ximénez-Fyvie LA, Haffajee AD, Som S, Thompson M, Torresyap G, Socransky SS. The effect of repeated professional supragingival plaque removal on the composition of the supra- and subgingival microbiota. *J Clin Periodontol*. 2000;27(9):637-647. doi:10.1034/j.1600-051x.2000.027009637.x
12. Westfelt E. Rationale of mechanical plaque control. *J Clin Periodontol*. 1996;23(3 Pt 2):263-267.
13. Yankell SL, Shi X, Emling RC. Laboratory evaluations of two toothbrushes for removal of artificial plaque above, around and below the gingival margin. *J Clin Pediatr Dent*. 2003;14(1):19-22.
14. Hotta M, Sekine I, Imade S, Sano A. Evaluation of tapered-end toothbrush bristles regarding efficacy of access to occlusal fissures. *J Clin Dent*. 2002;13(6):225-227.
15. Hotta M, Yoshida T, Sekine I, Imada S, Sano A. Evaluation of tapered-end toothbrushes regarding subgingival access efficacy. *J Clin Dent*. 1997;8(6):156-158.
16. Checchi L, Montevecchi M, Gatto RM, Moreschi A, Checchi V. Clinical efficacy of two toothbrushes with different bristles. *Int J Dent Hyg*. 2007;5(4):242-246. doi:10.1111/j.1601-5037.2007.00258.x
17. Hotta M, Imade S, Kotake H, Sano A, Yamamoto K. Artificial plaque removal from interproximal tooth surfaces (maxillary premolar and molar) of a jaw model. *Oral Health Prev Dent*. 2009;7(3):283-287.
18. Langa GPJ, Muniz FWMG, Wagner TP, Silva CFE, Rösing CK. Anti-plaque and anti-gingivitis efficacy of different bristle stiffness and end-shape toothbrushes on interproximal surfaces: a systematic review with META-analysis. *J Evid Based Dent Pract*. 2021;21(2):101548. doi:10.1016/j.jebdp.2021.101548
19. Sgan-Cohen HD, Vered Y. A clinical trial of the meridol toothbrush with conical filaments: evaluation of clinical effectiveness and subjective satisfaction. *J Clin Dent*. 2005;16(4):109-113.
20. Montevecchi M, Moreschi A, Gatto MR, Checchi L, Checchi V. Evaluation of clinical effectiveness and subjective satisfaction of a new toothbrush for postsurgical hygiene care: a randomized split-mouth double-blind clinical trial. *Scientific World Journal*. 2015;2015:1-6. doi:10.1155/2015/828794
21. Ni L, Tang R, He T, et al. Clinical effect of a manual toothbrush with tapered filaments on dental plaque and gingivitis reduction. *Am J Dent*. 2017;30(5):272-278.
22. Hoogteijling F, Hennequin-Hoenderdos NL, Van der Weijden GA, Slot DE. The effect of tapered toothbrush filaments compared to end-rounded filaments on dental plaque, gingivitis and gingival abrasion: a systematic review and meta-analysis. *Int J Dent Hyg*. 2018;16(1):3-12. doi:10.1111/idh.12272
23. Bass CC. An effective method of personal oral hygiene. *J La State Med Soc*. 1954;106(2):57-73.
24. Van der Weijden GA, Timmerman MF, Danser MM, Van der Velden U. Relationship between the plaque removal efficacy of a manual toothbrush and brushing force. *J Clin Periodontol*. 1998;25(5):413-416. doi:10.1111/j.1600-051x.1998.tb02464.x
25. Ganss C, Schlueter N, Preiss S, Klimek J. Tooth brushing habits in uninstructed adults—frequency, technique, duration and force. *Clin Oral Investig*. 2009;13(2):203-208. doi:10.1007/s00784-008-0230-8
26. Van der Weijden GA, Timmerman MF, Versteeg PA, Piscaer M, Van der Velden U. High and low brushing force in relation to efficacy and gingival abrasion. *J Clin Periodontol*. 2004;31(8):620-624. doi:10.1111/j.1600-051x.2004.00529.x
27. Ranzan N, Muniz FWMG, Rösing CK. Are bristle stiffness and bristle end-shape related to adverse effects on soft tissues during toothbrushing? A systematic review. *Int Dent J*. 2019;69(3):171-182. doi:10.1111/idj.12421
28. Hamza B, Svellenti L, Körner P, Attin T, Wegehaupt FJ. Effect of tapered-end and round-end bristles on the abrasive dentine wear applying increasing brushing forces. *Acta Odontol Scand*. 2022;11:1-5. doi:10.1080/00016357.2022.2035816
29. Renvert S, Persson GR, Pirih FQ, Camargo PM. Peri-implant health, peri-implant mucositis, and peri-implantitis: case definitions and diagnostic considerations. *J Clin Periodontol*. 2018;45(Suppl 20):S278-S285. doi:10.1111/jcpe.12956
30. Hanioka T, Nagata H, Murakami Y, Tamagawa H, Shizukuishi S. Mechanical stimulation by toothbrushing increases oxygen sufficiency in human gingivae. *J Clin Periodontol*. 1993;20(8):591-594.
31. Agematsu H, Watanabe H, Fukayama M, et al. Histological studies on the effects of tooth brushing on repair of alveolar bone after periodontal osseous surgery in the rat incisor. *Bull Tokyo Dent Coll*. 1993;34(3):95-105.
32. Montevecchi M, De Blasi V, Checchi L. Is implant flossing a risk-free procedure? A case report with a 6-year follow-up. *Int J Oral Maxillofac Implants*. 2016;31(3):e79-e83. doi:10.11607/jomi.4263
33. van Velzen FJJ, Lang NP, Schulten EAJM, Ten Bruggenkate CM. Dental floss as a possible risk for the development of peri-implant disease: an observational study of 10 cases. *Clin Oral Implants Res*. 2016;27(5):618-621. doi:10.1111/clr.12650
34. Montevecchi M, Valeriani L, Franchi L, Sforza NM, Piana G. Evaluation of floss remnants after implant flossing in three different implant conditions: a preclinical study. *Int J Oral Maxillofac Implants*. 2021;36(3):569-573. doi:10.11607/jomi.8350
35. Checchi L, Minguzzi S, Franchi M, Forteleoni G. Toothbrush filaments end-rounding: stereomicroscope analysis. *J Clin Periodontol*. 2001;28(4):360-364.

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