Functional evaluation among three types of toothbrushes in bristles

[Subtitle: The efficacy evaluation of the toothbrushes with bumpy-bristles]

- **Research period: Oct. 2016 - Dec. 2016**
- **Research Institution: Namseoul University**
- **Research Director: Su-Young Lee/Ph.D.**

Ⅰ. Background

● Toothbrushing is the most effective method to control dental plaque, which is the main cause of dental caries and periodontal diseases. Toothbrushing not only prevents the plaque accumulation by eliminating food debris on the tooth surface (i.e. dental cleaning effect) but also polishes the tooth surface to make it smooth after removing the already-formed or imperfectly-formed dental calculus (i.e. dental polishing effect). Therefore, it effectively controls reattachment of food debris or reformation of dental plaque. It is known that, only with toothbrushing, it is possible to remove about 71-86% of dental plaque on the buccolingual surface and 60-74% on the proximal surface.

● Toothbrush should be designed so that it can achieve efficiently these purposes of toothbrushing and at the same time not harmful action on tooth and periodontal tissue. The toothbrush has been the principal instrument in general use for oral care and is a necessary part of oral disease control. Clinical studies on the external dimensions of the toothbrush and in-vitro studies comparing the ability to remove dental plaque according to the shape of the bristles ends were mainly performed. In previous studies, the curved bristle toothbrush improved the condition of the gingival tissue and showed better efficacy of removal of the dental plaque in the interdental surface than a flat bristle toothbrush.

● Most of those studies said that most basic tool to remove dental plaque on the tooth surface is a toothbrush, and especially the length and shape of the bristles have a meaningful effect on removal of dental plaque. Previous studies showed that plaque removal effects with bristles having different section shapes; for those studies, only the shapes of bristle ends were changed to have, for instance, flat-shape, wave-pattern, inclined-shape, etc., while keeping the shapes of bristle bottoms identical. Likewise, various ways to increase the effect of removing dental plaque have been attempted (e.g. changing the shapes of toothbrushes or of bristle ends).

● Fine-bristle toothbrushes have also been developed and marketed actively for recent years, and many researches on the effect of removing dental plaque and improving periodontal diseases using fine bristles have been reported. However, it has been pointed out that the micro-toothbrush produces gum scratches and the biofilm removal effect is low. Recently, toothbrushes with micro-bumps on bristle ends have been developed to improve remove deposits on the tooth surface more effectively. This study intends to evaluate toothbrushes with bumpy bristles, flat bristles, and fine bristles to verify their effects on plaque removal and gingivitis relief and to provide basic data for selecting appropriate toothbrushes for individuals.

Ⅱ. Purpose of Research

● This study aimed to evaluate the biofilm reduction and gingivitis relief of three types of toothbrushes with different bristle ends such as bumpy bristles, flat bristles, and fine bristles in a clinical, single-blind controlled trial.
The specific objectives of this study are as follows;

1) The reduction effect of dental plaque after conducting an in-vivo test for adult subjects;
2) The improving effect of gingivitis and periodontal diseases
3) The utilize of QLFD analysis to remove of dental plaque

Ⅲ. Research method

1. Subjects

About 40-50 healthy adults who agreed with the purpose of this study were selected as subjects.
This study was approved by the Namseoul University ethical Committee (NSU-161107-03), and all participants gave written informed consent before study-related procedures were carried out.

[Inclusion criteria]

· No systemic disease; physically healthy
· Subjects who have more than 20 natural teeth

[Exclusion criteria]

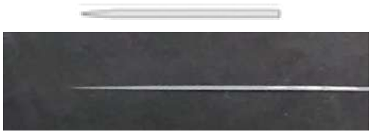
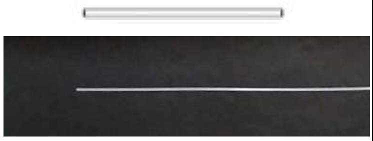
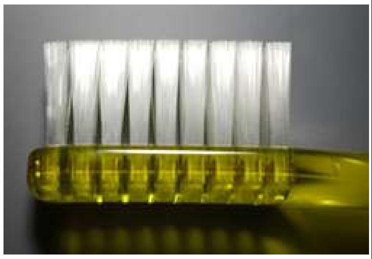
· Orthodontic patients
· Pregnant women

Sample size
We used G*Power 3.1.3 to calculate the sample size for this study; it turned out that 22 people are needed for each group at effect size f= 0.40, α=0.05, and power (1- β) = 0.80.

2. Research Tools

1) Toothbrushes Studied

(1) Group 1 (bumpy bristle toothbrush): Toothbrushes with bristle ends having micro-bumps
(2) Group 2 (tapered thin bristle toothbrush): Toothbrushes with finely-tapered bristle ends
(3) Group 3 (general straight toothbrush): Toothbrushes with flat-shaped bristle ends

		
		
Bumpy-bristle Toothbrush	Tapered-bristle Toothbrush	General straight-bristle Toothbrush

[Fig. 1] Shapes of Toothbrush Bristles

2) Clinical measurements used for Evaluation

• **Plaque Index**: The buccolingual (buccal/lingual) sides of all natural teeth in the oral cavity of the subjects were evaluated. After staining the plaque using a disclosing agent (2 TONE: Young, MO, USA), plaque index was measured at six sites per tooth for whole dentition using the Turesky modificarion of the Quigley and Hein Plaque Index (PI). The closer it is to 5, the greater the degree of attachment of dental plaque to the tooth is.

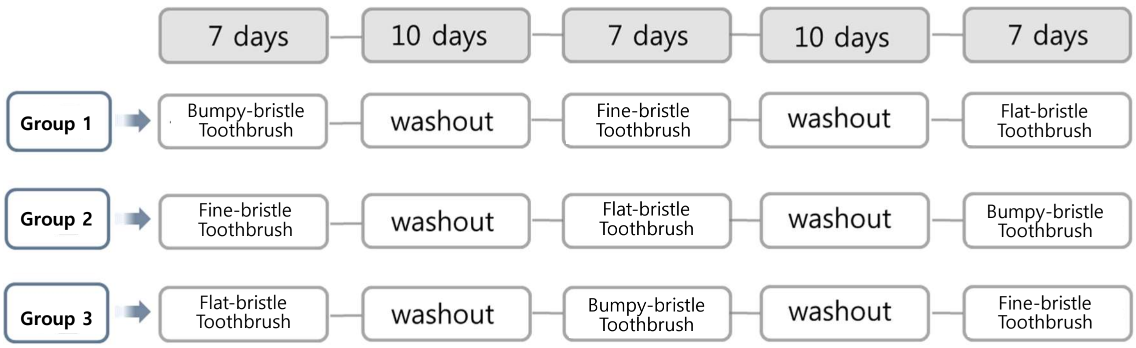
• **Evaluation of Plaque through QLF-D Analysis**: The Quantitative light-induced fluorescence-Digital (QLF-D) is a diagnosis device for the detection of early caries lesion and dental plaque in human enamel. It is possible to be quantitative analysis with 405nm fluorescent light. The degree of dental plaque was evaluated; the SPS and ΔR values that appeared in the image were used. The images photographed were analyzed using the QA2 version 1.25 (a dedicated QLF-D image program, Inspektor Research System bv, Amsterdam, Netherland).

• **Gingival index**: Four gingival areas (buccal, lingual, mesial and distal surface) are examined systematically for each tooth. Each of the four gingival surfaces is given a score of 0-3 using the Loe & Silness gingival index (GI).
[0- Normal gingival, 1- Mild inflammation, 2- Moderate inflammation, 3- Severe inflammation]

• **Gingival Bleeding index**: The evaluation was made by dividing all natural teeth in the oral cavity of the subject into 6 surfaces (i.e. buccal mesial, buccal cenral, buccal distal, lingual mesial, lingual central, and lingual distal). In the PPD and GI examinations, whether there is bleeding after periodontal probe was recorded, and bleeding, color change, edema, and ulceration on the entire test teeth were observed and assessed.

3) Treatment protocols

● As a crossover-design clinical trial study, this research randomly divided the subjects into three groups, and the subjects of each group were asked to use three toothbrushes sequentially.



[Fig. 2] Diagram of Crossover Design

● The purpose, description, and process of the study was explained to the subjects who wished to participate in the study and written consents from the subjects were received.

● Dental checkups including oral examination, gingival examination and dental plaque test were conducted on the first visit to collect initial data.

● PI, GI, GBI, SPS, and △R were measured; the measurement was done regularly at the designated time, except immediately after brushing teeth or having a meals.

● Subjects who completed the initial examination were given a set of toothbrushes (three different toothbrushes for each group) and were instructed to practice the rolling brushing technique for a week and adapt to it. .

● All subjects brushed their teeth with the same toothpaste during the study period in order to decrease variability of the outcome.

● The subjects were given a 10-day washout period after using the 1st toothbrush. With the 2nd toothbrush, they were instructed to brush teeth in the same manner for a week.

● After a second 10-day washout period, the brush was replaced with the 3rd one, and the 3rd toothbrush was used in the same manner for a week.

● Seven weeks later, all the three groups were re-examined in the same manner as the baseline checkups.

4) Side Effects and Precautions

● During the study period, toothbrushing was done two to three times a day in an ordinary manner, and the toothbrushes were returned after this study ends.
● If pain occurs while using the given toothbrushes during the study period, the subjects were guided to immediately stop using them.

5) Analysis of data
● This study used the SPSS Version 20.0 (Statistical Package for the Social Science, IBM, USA) to analyze the data at 95% significance level. Frequency analysis was conducted to interpret the general characteristics of the subjects; the pre-post-intervention results by group and the difference between groups were statistically analyzed through the paired t-test and independent t-test respectively.

Ⅳ. Results

1. Reduction Effect of Dental Plaque

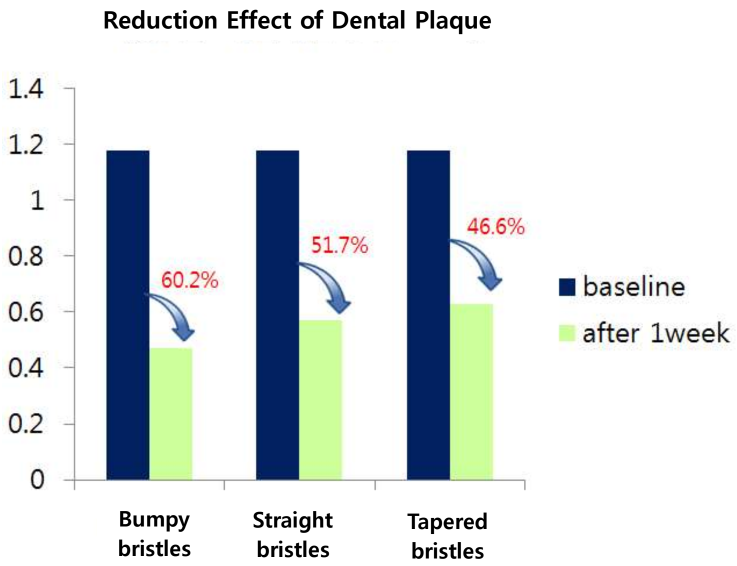
1) Evaluation by Q&H Plaque Index

◦ From the evaluation using the Q&H PLAQUE index, it was found that the plaque index fell after toothbrushing, compared to the pre-toothbrushing state; all the three types of toothbrushes committed to reduction of dental plaque, but among them, the toothbrush with micro-bump bristle ends showed the greatest reduction rate (by 60%).

◦ In conclusion, bumpy bristle toothbrushes were 13% more effective in reducing dental plaque than tapered bristle toothbrushes, and 8% more effective than straight bristle toothbrushes.

Table 1. Difference of Dental Plaque Index by Toothbrush

Group	N	Baseline Mean (SD)	1week Mean (SD)	Difference value	Remark
Bumpy-bristle	27	1.18 (0.53)	0.47 (0.25)	0.71 (0.59)	60% Reduction
Straight-bristle	27	1.18 (0.53)	0.57 (0.33)	0.61 (0.58)	52% Reduction
Tapered -bristle	27	1.18 (0.53)	0.63 (0.51)	0.56 (0.59)	47% Reduction
p*			0.34	0.75	



2) Evaluation of Dental Plaque by QLFD Analysis

◦ To objectively evaluate the change of the dental plaque, the thickness, strength, and maturity of the dental plaque were evaluated by using ΔR value after taking the QLFD.

◦ΔR value indicates the ratios of healthy tooth structure (green fluorescence) and of dental plaque (red fluorescence); the larger ΔR value means the greater degree of plaque maturation.

◦From the QLFD analysis, it was confirmed that bumpy bristle toothbrushes more effectively reduced dental plaque than straight or tapered bristle toothbrushes at ΔR30 and ΔR70.
◦ On the other hand, in ΔR120, all the three toothbrushes showed an increase in dental plaque; especially with straight and tapered bristle toothbrushes, mature dental plaque (old plaque) increased by three times compared to the baseline.

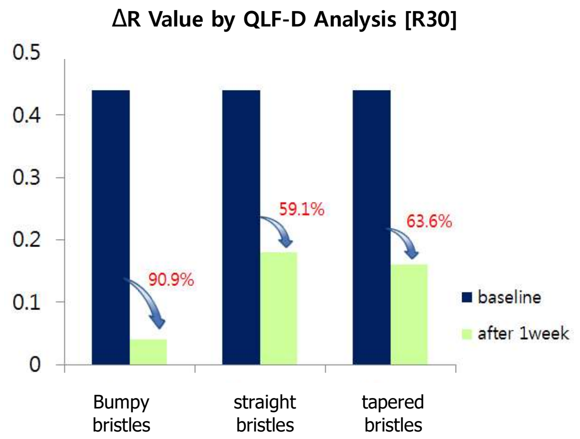
◦ In conclusion, it was found that, from the dental plaque evaluation using the QLFD, bumpy bristle toothbrushes had a superior dental plaque reduction effect compared to the other two types.

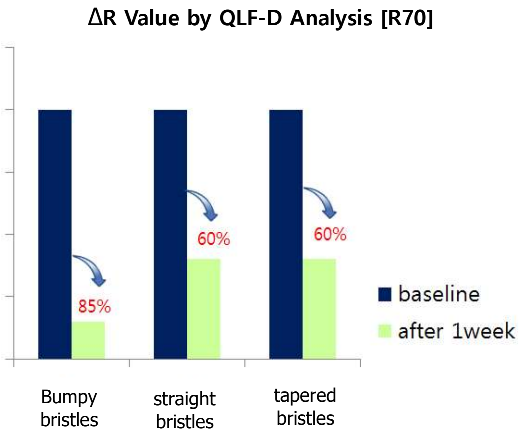
Table 2. The difference in ΔR value by toothbrushes

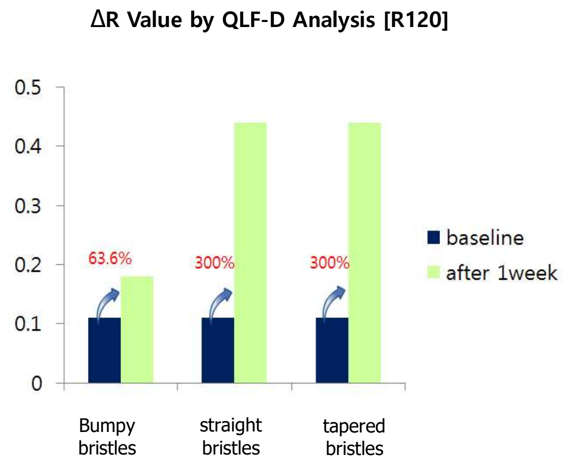
	Group	Baseline Mean (SD)	1week Mean (SD)	Difference value	Remark
ΔR30	Bumpy-bristle	0.44 (0.64)	0.04 (0.19)	0.41 (0.64)	91% Reduction
	Straight-bristle	0.44 (0.64)	0.18 (0.56)	0.26 (0.77)	59% Reduction
	Tapered-bristle	0.44 (0.64)	0.16 (0.51)	0.19 (0.62)	64% Reduction
p*			0.27	0.59	
ΔR70	Bumpy-bristle	0.20 (0.31)	0.03 (0.87)	0.17 (0.30)	85% Reduction
	Straight-bristle	0.20 (0.31)	0.08 (0.25)	0.12 (0.37)	60% Reduction

	Tapered-bristle	0.20 (0.31)	0.08 (0.20)	0.12 (0.25)	60% Reduction
p*			0.49	0.89	
ΔR120	Bumpy-bristle	0.11 (0.20)	0.18 (0.62)	0.09 (0.19)	**0.6 x Increase**
	Straight - bristle	0.11 (0.20)	0.44 (0.13)	0.06 (0.24)	**3 x Increase**
	Tapered-bristle	0.11 (0.20)	0.44 (0.16)	0.07 (0.14)	**3 x Increase**
p*			0.70	0.63	

※ In the QLFD analysis, ΔR120 represents the old plaque having the highest maturity; the increase in the ΔR120 value after using the toothbrush, compared to the baseline, means that the removal effect of old plaque is low. In this experiment, while the old plaque deposition increased by three times when brushed with general or tapered-bristle toothbrushes, it only rose by 0.6 times when brushed with bumpy-bristle toothbrushes. Toothbrushes with micro-bumps bristle ends were definitely more effective in eliminating plaque. As the experiment time environment of all subjects was poor and some toothbrushing was not done as intended, it is somewhat difficult to generalize the results. However, the reason for superior plaque removal effect of bumpy-bristle toothbrushes, compared to the rest, is presumed to be the micro-bumps located on the bristle ends.







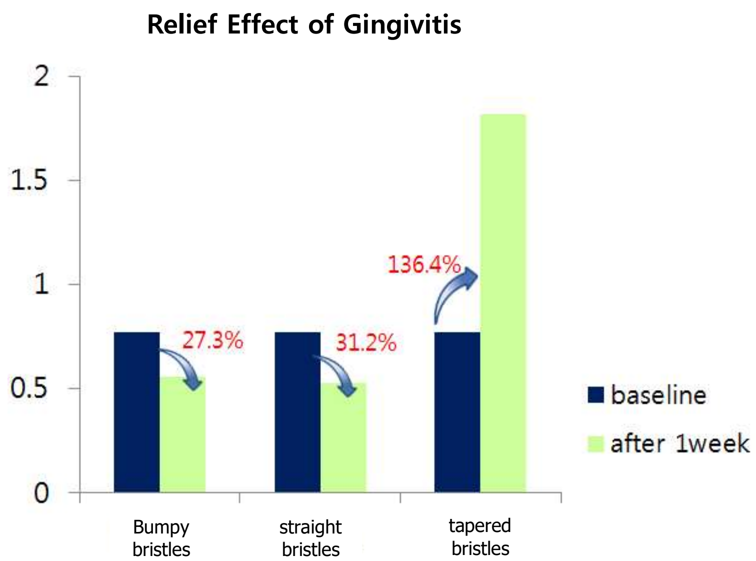
2. Relief effect of Gingivitis

◦ As a results of gingivitis evaluation using the gingival index, both bumpy-bristle and straight-bristle toothbrushes showed a gingival reduction effect after use by 27.3% and 31.2% respectively, whereas the tapered-bristle toothbrushes presented rather an increased gingival index.

◦ This means both bumpy-bristle and straight-bristle toothbrushes are more effective in relieving gingivitis than tapered-bristle toothbrushes.

Table 3. Difference in gingival index according to toothbrush

Group	N	Baseline Mean (SD)	1week Mean (SD)	Difference value	Remark
Bumpy-bristle	27	0.77 (0.22)	0.56 (0.17)	0.20 (0.21)	27% Reduction
Straight-bristle	27	0.77 (0.22)	0.53 (0.14)	0.25 (0.22)	31% Reduction
Tapered-bristle	27	0.77 (0.22)	1.82 (6.03)	-1.05 (6.03)	136% Worsened
p*			0.31	0.14	



Ⅴ. Conclusion

◦ After clinical trials using toothbrushes with different bristle shapes for 7-weeks, the toothbrushes with micro-bumps on the bristle ends were more effective in removing dental plaque than straight or tapered-bristle toothbrushes. Bumpy-bristle toothbrushes also presented a superior gingivitis relief and effect of dental plaque reduction than that with tapered-bristle toothbrushes.

◦ On the other hand, tapered-bristle toothbrushes turned out to stimulate the gingiva due to its rough bristle shapes.

◦ Therefore, it is considered that the bumpy-bristle toothbrushes are very suitable for those who have difficulty in toothbrushing often in routine daily to remove plaque.

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