Received: 10 February 2020 | Revised: 12 August 2020 | Accepted: 30 September 2020

DOI: 10.1111/idh.12475

International Journal of Dental Hygiene

WILEY

ORIGINAL ARITCLE

Clinical comparison of an electric-powered ionic toothbrush and a manual toothbrush in plaque reduction: A randomized clinical trial

Takahiro Ikawa[1,2] | Koji Mizutani[1] | Takeaki Sudo[1] | Chihiro Kano[1] | Yuichi Ikeda[1] | Tatsuya Akizuki[1] | Hiroaki Kobayashi[1] | Yuichi Izumi[1,3] | Takanori Iwata[1]

[1]Department of Periodontology, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan

[2]Department of Periodontology, Faculty of Odontology, Malmö University, Malmö, Sweden

[3]Oral Care Perio Center, Southern TOHOKU General Hospital, Southern TOHOKU Research Institute for Neuroscience, Fukushima, Japan

Correspondence
Koji Mizutani, Department of Periodontology, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo, 113-8549, Japan.
Email: mizuperi@tmd.ac.jp

Funding information
JSPS KAKENHI Grant-in-Aid for Young Scientists, Grant/Award Number: 18K17061

Abstract

Objectives: This study aimed to evaluate the plaque removal efficacy of a newly developed electric-powered ionic toothbrush vs. a manual toothbrush.

Materials and Methods: Manual or electric-powered ionic toothbrushes were randomly assigned to 30 healthy volunteers divided into two groups (Phase I). After 2 min of brushing, all tooth surfaces were stained with a plaque staining solution, and blinded examiners performed scoring using the Rustogi Modification of the Navy Plaque Index. Plaque removal rate was calculated at the central incisors, first premolar and first molar, as representative teeth, in the maxilla and mandibula. One week following Phase I, the same examinations were repeated in all subjects using another toothbrush (Phase II), as a crossover design.

Results: Electric ionic toothbrushes demonstrated a significantly higher plaque removal rate than manual toothbrushes in the premolar and molar areas ($p < .05$). However, in the central incisor area, no statistically significant difference was observed.

Conclusions: Compared with manual toothbrushes, electric-powered ionic ones were significantly efficient in removing plaque in the premolar and molar areas.

KEYWORDS
dental plaque, electric-powered toothbrush, manual toothbrush, randomized controlled trial, toothbrushing, young adult

1 | INTRODUCTION

Dental plaque triggers changes in gingival health, which results in slight swelling and bleeding from the gingival margin.[1,2] Residual dental plaques cause such gingival changes, which suggest that good oral hygiene by effective toothbrushing plays an important role in oral health.[3] Effective toothbrushing depends on a number of factors (eg. age, knowledge, manual dexterity and motivation). Maintenance of periodontal health is an essential aspect of personal oral hygiene.[4–6] Using toothbrushes is the most commonly accepted method of removing dental plaque.

Toothbrushes have various forms and designs to suit different functional and scientific requirements. Ionic toothbrushes are expected to work by changing the tooth surface's polarity, therefore facilitating plaque removal. The principle of polarity showed

that every element in nature has a positive or negative charge.[7] In brief, teeth and plaque are generally negatively charged. The plaque is absorbed onto the tooth surface via positive ions in the saliva. Ionic toothbrush adopted lithium battery as the built-in electric power and formed circuit through the two electrodes portions (grip and head of toothbrush). Negative ions were generated from this electric circuit and blocked the adsorption caused by the cross-linking. Previous studies suggest that an ionic toothbrush is more effective in plaque removal than a negative ionic toothbrush.[7–9] On the contrary, a few studies show that ionic toothbrushes were different from conventional toothbrushes,[10] especially in terms of a reduction in Gingival Index.[11–13] There is a need to develop ionic toothbrushes capable of efficiently and effectively removing dental plaque.

Manual and powered toothbrushes are equally effective in reducing signs of clinical gingival inflammation and plaque removal.[14] However, recent clinical trials and systematic reviews have shown that powered toothbrushes are safer than manual ones. Additionally, powered toothbrushes removed 11% and 21% more plaque than manual toothbrushes in short- and long-term studies, respectively.[15] These results demonstrate that powered toothbrushes represent an alternative to manual toothbrushing.[16] Generally, powered toothbrushes require a high level of plaque removal with a less-than-ideal brushing technique. For example, the focus has been placed on designing toothbrushes that allow for greater access and more effective plaque removal at more difficult-to-reach areas of the mouth, including interproximal sites. Thus, over time, there have been numerous variations, which have led to significant product improvements.[17] However, it remains unclear whether the combination of ionic and electric-powered toothbrushes offers any additional benefit in plaque reduction. The aim of this randomized, crossover clinical trial study was to evaluate plaque reduction efficacy of a new electric-powered ionic toothbrush and compare it to that of a manual toothbrush in a single use.

2 | MATERIALS AND METHODS

2.1 | Electric-powered ionic toothbrush

The toothbrushes used in the test group were new electric-powered ionic toothbrushes (Figure 1A; IONPA®, Ionic Co., Ltd.). This powered toothbrush was slightly larger than the conventionally used manual one. In this study, the powered and manual toothbrushes had same-sized brush heads (approximate width 30 mm × length 240 mm × height 15 mm). It has replaceable brush heads, and the sonic waves move with a speed of up to approximately 22,000 strokes per minute. An ion activation is expected to occur by holding a metal part, being generated from the brush bristles (Figure 1B). The toothbrushes used in the control group had the same design as the electric-powered ionic toothbrushes, with no electricity or anion activation.

2.2 | Subjects

Dental Research Ethics Committee of Tokyo Medical and Dental University (D 2017-046) approved this study. Before enrolment in the study, all subjects provided informed consent.

Thirty systemically healthy dentist volunteers (ie 23 males, seven females, between the ages of 25 and 32 years) with at least 20 natural teeth were recruited in this study. The inclusion criteria were as follows: five evaluable teeth in each quadrant (excluding all canine and third molars); no professional oral care during the study period; abstinence of any oral hygiene care and procedures for 24 h before data collection; and healthy periodontal oral condition (<3 mm of probing pocket depth, <10% bleeding on probing, and no attachment loss). Exclusion criteria were as follows: presence of any physical limitation or restriction that might preclude normal oral hygiene procedures, removable prosthesis or orthodontic appliance, signs of periodontitis (ie recession >2 mm and acute symptoms), treatment with antimicrobial agents in the preceding 3 months, use of mouth rinse, pregnancy and breastfeeding.

2.3 | Study design

According to a previous study,[18] the sample size was calculated based on the percentage of plaque scores with differences of 0.11 between the groups, with an standard deviations (SD) of 0.1, significance level of 5% and power of 80% (n = 14.0).

Figure A1 in Appendix 1 illustrates the study design. This study was designed as a randomized, single-blinded, crossover clinical trial with two visits. Volunteers were instructed not to brush their teeth and perform any other oral hygiene procedures (ie chewing gum, mouthwash) for 24 h before each visit. Additionally, volunteers had to refrain from eating, drinking or smoking in the past 4 h. During each visit, subjects underwent an oral examination, including probing pocket depth and bleeding on probing. Staining was performed with plaque staining solution (Red-Cote®; Sunstar). First, a full-mouth oral photography (facial and lingual/palatal tooth surfaces) was performed on all volunteers to evaluate prebrushing plaque scores. Then, they were randomly assigned to one of the two toothbrush groups by a computerized balance and assignment programme (Appendix Figure A1): (a) electric-powered ionic toothbrush (test) and (b) manual toothbrush without anion activation (control). The volunteers brushed with the assigned toothbrush for 2 min without using a mirror. Immediately after teeth brushing, oral photography was performed for post-brushing plaque scores. All the volunteers performed manual toothbrushing using the Bass technique. Investigators (CK and TS) instructed the subjects in using the power toothbrush by same contents before the timed brushing session. The investigators, who did not make the plaque assessment, supervised brushing. After 1 week, the volunteers returned for the final visit and repeated the procedures using another toothbrush. Pre- and post-brushing plaque (Appendix Figure A2) was scored using the Rustogi Modification of the Navy Plaque Index (RMNPI),

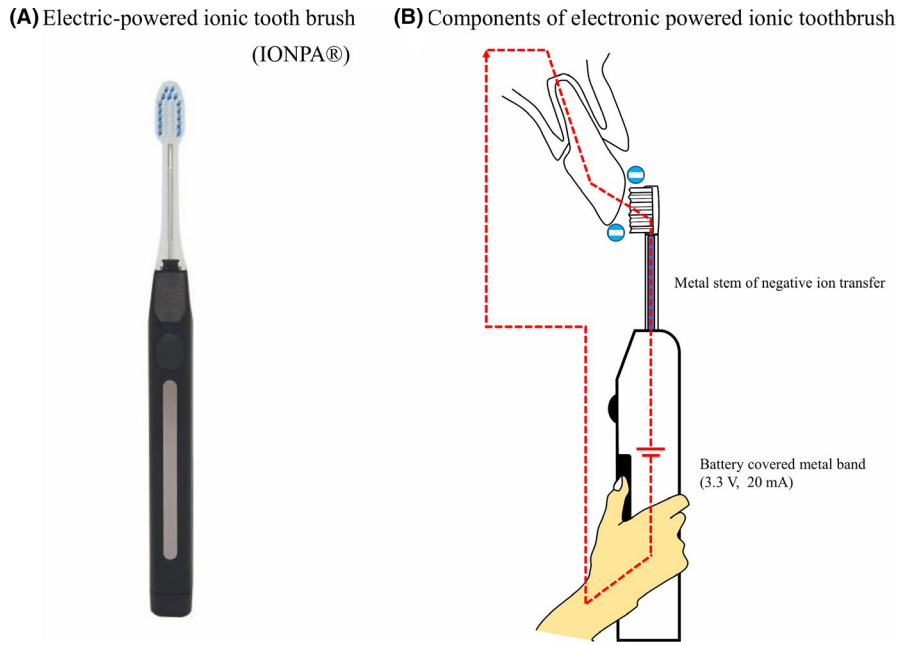

FIGURE 1 New electronic-powered ionic toothbrush. A, Device (IONPA®). B, Components of electronic-powered ionic toothbrush

TABLE 1 RMNPI scores

	Test groups	Control groups
Baseline (Pretoothbrush)	0.61 ± 0.13	0.63 ± 0.11
Post-toothbrush	0.11 ± 0.08*,†	0.22 ± 0.09*

Note: Mean ± standard deviation was analysed for statistical significance by Student's *t* test, $p < .05$; $n = 30$.

*Significantly different from the baseline.

†Significantly different from the control group.

as previously reported.[19,20] Briefly, the buccal and lingual surfaces of each tooth were divided into nine areas and disclosed plaque was scored as present (scored as 1) or absent (scored as 0). It assesses the amount of plaque on marginal (3 areas), interproximal (2 areas), and buccal and lingual (nine areas). Plaque removal rates were calculated at the following locations: central incisors, first premolars and first molars. The following calculation was used:

Plaque removal rate = RMNPI (Pre) − RMNPI (Post)/RMNPI (Pre) × 100 (%).

A single, experienced dental examiner (TI) who was blinded to the randomized toothbrush assignment made all the plaque scores with an interval of >72 h. Intra-examiner agreement produced a Cohen's kappa (κ) of 0.729.

2.4 | Statistical analysis

Data were compared between test and control sites and expressed as means and SDs. Sample distribution was investigated using the Shapiro-Wilk test, with Analysis Soft (EZR, Saitama Medical Center, Jichi Medical University, Saitama). Statistical analysis between sites was performed using Student's *t* test for paired observations ($p < .05$) for normally distributed samples or Wilcoxon's rank-sum tests ($p < .05$) for the rest of them.

3 | RESULTS

During the study, any product-related adverse events were not observed.

Table 1 outlines the RMNPI scores. The RMNPI scores of the two groups were significantly smaller in the post-toothbrush groups vs. the pretoothbrush groups ($p < .05$). Furthermore, the test groups were more effective than control groups in terms of post-toothbrush RMNPI scores ($p < .05$).

Plaque reduction percentages are shown in Table 2. Plaque reduction was significantly higher in the electric-powered ionic toothbrush group (85.4% ± 9.2% and 85.1% ± 10.33%, respectively) than in the manual toothbrush group (58.9% ± 14.6% and 58.4% ± 13.7%, respectively) at the premolar and molar areas. Particularly, reduction of interdental plaque in the electric-powered toothbrush increased by 85.6% and 96.5% compared with manual ones. However, the plaque reduction in central incisor did not significantly differ between the test and control groups at all sites ($p = .31$, 0.11, 0.82 and 0.09, respectively).

4 | DISCUSSION

Despite the limitations of this randomized, single-blinded, and cross-over clinical trial study, compared with the manual toothbrushes,

TABLE 2 Mean ± standard deviation of plaque removal rate (%)

Tooth type	Brush type	Facial	Lingual/Palatal	Marginal	Interproximal	Whole
Incisor	Manual	77.38 ± 15.77	68.39 ± 15.19	79.04 ± 14.40	54.56 ± 26.23	73.50 ± 12.60
	Electric-powered	81.40 ± 17.36	74.39 ± 18.00	76.69 ± 24.43	67.43 ± 23.61	78.36 ± 13.98
Premolar	Manual	63.16 ± 19.15	54.79 ± 14.65	60.26 ± 16.77	44.86 ± 21.47	58.84 ± 14.64
	Electric-powered	87.21 ± 10.11*	83.93 ± 10.84*	84.54 ± 11.91*	83.26 ± 14.55*	85.39 ± 9.20*
First molar	Manual	60.72 ± 18.34	56.52 ± 15.56	58.25 ± 14.22	43.13 ± 21.46	58.39 ± 13.70
	Electric-powered	88.35 ± 9.32*	81.09 ± 13.55*	82.96 ± 11.70*	84.72 ± 16.79*	85.09 ± 10.33*

Note: The removal plaque rate for facial, lingual/palatal, marginal, Interproximal and whole mouth at incisor, first premolar and first molar.
*$p < .05$, significant difference between manual and electric-powered toothbrush by Student's t test; $n = 30$.

plaque reduction in the electric-powered ionic toothbrushes was more effective at the premolar and molar areas, and similar at the central incisor area. Additionally, there was no report of adverse or mechanical problems. Thus, the newly developed electric-powered ionic toothbrush was as effective and safe as the manual one.

In this study, we used toothbrushes with the same design and evaluated them as an effective device for powered and ionic, which can provide additional benefits to toothbrush in terms of plaque reduction. In plaque reduction, this new electric-powered ionic toothbrush was effective in sites that are difficult to reach for effective brushing, such as the interproximal region at the premolar and molar sites. However, the fact that we did not explore the complete potential of ionic toothbrush for plaque reduction is a study limitation. Further research is warranted to compare this electric-powered ionic toothbrush with other powered toothbrushes. Another study limitation was the inclusion of volunteers who were young dentists with oral health who had motivation and dental skills. Furthermore, considerably more male subjects than the female ones were enrolled in our study. However, there was no significant sex-based difference (the data were not shown). Therefore, our results suggested no benefit in terms of the effectiveness of toothbrushing among the subjects.

Previous studies,[9,12–14] comparing an ionic toothbrush with a manual one, suggested that ionic toothbrushes are predictably effective in plaque scores at short-term evaluation (4 weeks,[11] 6 weeks[12] and 3 months[7]) and also gingivitis scores at long-term trial (6 months[7]). Nevertheless, another study[3] has suggested that electric toothbrushes' effect on established plaque and gingivitis did not show a significant difference in a five-month clinical trial period. Furthermore, our previous study[21] concluded that periodontal parameters and total bacteria, including *Porphyromonas gingivalis*, were not statistically different between the ionic electric vs. manual toothbrush group. Therefore, to date, it remains unclear whether the ionic electric toothbrush offers any additional benefit in plaque and gingivitis scores.

Results of this revealed that ionic powered toothbrushes had significantly better outcomes compared with the manual ones in reducing plaque, especially at molar sites, in a single use. A previous study[13] compared the efficacy of sonic and ionic toothbrushes, and then, the sonic toothbrushes were superior to the manual ionic ones although no significant difference could be observed between two groups. In this randomized clinical study, a newly developed powered ionic device was used to improve the power and frequency. To the best of our knowledge, this is the first study to demonstrate the effects of electric-powered ionic toothbrush on plaque reduction in healthy volunteers. This study also evaluated whether an ionic powered toothbrush can serve as a suitable device for ionic, therefore providing additional benefits to the tooth surface in terms of plaque reduction. As shown in previous studies[18,22] and systematic reviews,[15,23] powered toothbrushes were recognized as useful devices in plaque removal compared with manual ones. Since the additional effect of ionic for plaque removal has not shown so far, further studies are warranted to compare other powered and manual toothbrushes without ionic in short- and long-term studies. Also, it will be necessary to test the efficacy of the electric-powered ionic toothbrushes in patients with periodontal disease, as well as in elderly subjects with hand motility difficulties.

In conclusion, the ionic powered toothbrush was significantly more effective than a manual one in reducing plaque. Such findings may provide an additional option for daily oral hygiene practices of patients aiming for the improvement in plaque control.

5 | CLINICAL RELEVANCE

5.1 | Scientific rationale for the study

Plaque reduction efficacy of a new electric-powered ionic toothbrush is unknown.

5.2 | Principal findings

Assessment of plaque removal rate between electric-powered ionic toothbrush and a manual toothbrush was performed. Owing to both electric-powered and anion activation, the plaque removal efficiency was improved in the molar area that showed low accessibility of brush.

5.3 | Practical implications

Electric-powered ionic toothbrush is a useful device for removing plaque and helps prevent dental problems caused by plaque.

ACKNOWLEDGEMENTS

The authors had full control of the data and analyses and received no commercial input in the preparation of the study. This study was supported by JSPS KAKENHI Grant-in-Aid for Young Scientists Number 18K17061. Dr Takahiro Ikawa has been an ITI Scholar at the Department of Periodontology, Faculty of Dentistry, Malmö University, Malmö, Sweden (Chair Prof. Andreas Stavropoulos) during the year 2019/2020. The Ionic Corporation, Chiba, Japan, supported this study to provide test and control brushes.

CONFLICTS OF INTEREST

The authors report no conflicts of interest related to this study.

AUTHOR CONTRIBUTIONS

K.M., T.I., T.S. and C.K. performed most of the experiments; T.A. and K.H. assisted in some studies; Y.Ik., T.S. and K.M. analysed the data; and Y.Iz., and T.I. critically reviewed the data and drafted the manuscript.

ORCID

Takahiro Ikawa https://orcid.org/0000-0001-9862-4281
Koji Mizutani https://orcid.org/0000-0002-1610-7430
Yuichi Ikeda https://orcid.org/0000-0001-7557-658X
Takanori Iwata https://orcid.org/0000-0002-5461-7298

REFERENCES

1. Löe H, Theilade E, Jensen SB. Experimental gingivitis in man. *J Periodontol*. 1965;36(3):177-187.
2. Kinane DF, Stathopoulou PG, Papapanou PN. Periodontal diseases. *Nat Rev Dis Primers*. 2017;3:17038.
3. Van der Weijden FA, Slot DE. Efficacy of homecare regimens for mechanical plaque removal in managing gingivitis a meta review. *J Clin Periodontol*. 2015;42(Suppl. 16):S77-S91.
4. Hancock EB. Consensus report. Periodontal disease: Prevention. *Ann Periodontol*. 1996;1:223-249.
5. Lamster IB. Antimicrobial mouthrinses and the management of periodontal diseases. Introduction to the supplement. *J Am Dent Assoc*. 2006;137(Suppl):S5-S9.
6. Van der Weijden FA, Slot DE. Oral hygiene in the prevention of periodontal diseases: the evidence. *Periodontol*. 2000;2011(55):104-123.
7. Van Swol RL, Van Scotter DE, Pucher JJ, Dentino AR. Clinical evaluation of an ionic toothbrush in the removal of established plaque and reduction of gingivitis. *Quintessence Int*. 1996;27:389-394.
8. Ansai T, Kasai S, Nakayama C, Hamasaki T, Awano S, Akifusa S. Effectiveness of an ionic toothbrush with a lithium battery in the removal of dental plaque. *J Kyushu Dent Soc*. 2000;54:321-325.
9. Deshmukh J, Vandana KL, Chandrashekar KT, Savitha B. Clinical evaluation of an ionic tooth brush on oral hygiene status, gingival status, and microbial parameter. *Indian J Dent Res*. 2006;17(2):74-77.
10. Moreira CH, Luz PB, Villarinho EA, Petri LC, Weidlich P, Rösing CK. A clinical trial testing the efficacy of an ionic toothbrush for reducing plaque and gingivitis. *J Clin Dent*. 2007;18(4):123-125.
11. Galgut PN. Efficacy of a new electronic toothbrush in removing bacterial dental plaque in young adults. *Gen Dent*. 1996;44(5):441-445.
12. Pucher JJ, Lamendola-Sitenga K, Ferguson D, Van Swoll R. The effectiveness of an ionic toothbrush in the removal of dental plaque and reduction on gingivitis in orthodontic patients. *J West Soc Periodontol Periodontal Abstr*. 1999;47(4):101-107.
13. Singh G, Mehta DS, Chopra S, Khatri M. Comparison of sonic and ionic toothbrush in reduction in plaque and gingivitis. *J Indian Soc Periodontol*. 2011;15(3):210-214.
14. Deery C, Heanue M, Deacon S, et al. The effectiveness of manual versus powered toothbrushes for dental health: a systematic review. *J Dent*. 2004;32(3):197-211.
15. Yaacob M, Worthington HV, Deacon SA, et al. Powered versus manual toothbrushing for oral health. *Cochrane Database Syst Rev*. 2014;6:CDOO2281.
16. Williams K, Ferrante A, Dockter K, Haun J, Biesbrock AR, Bartizek RD. One- and 3-minute plaque removal by a battery-powered versus a manual toothbrush. *J Periodontol*. 2004;75(8):1107-1113.
17. Rosema N, Slot DE, van Palenstein Helderman WH, Wiggelinkhuizen L, Van der Weijden GA. The efficacy of powered toothbrushes following a brushing exercise: a systematic review. *Int J Dent Hyg*. 2016;14(1):29-41.
18. Vorwerk L, Ghassemi A, Hooper W, Patel V, Milleman J, Milleman K. Comparative plaque removal efficacy of a new powered toothbrush and a manual toothbrush. *J Clin Dent*. 2016;27(3):76-79.
19. Rustogi KN, Curtis JP, Volpe AR, Kemp JH, McCool JJ, Korn LR. Refinement of the Modified Navy Plaque Index to increase plaque scoring efficiency in gumline and interproximal tooth areas. *J Clin Dent*. 1992;3(Suppl. C):C9-C12.
20. Sharma NC, Qaqish JG, Galustians HJ, Cugini MA, Thompson MC, Warren PR. Plaque removal efficacy and safety of the next generation of manual toothbrush with angled bristle technology: results from three comparative clinical studies. *Am J Dent*. 2005;18:3-7.
21. Aoyama N, Kobayashi H, Tanaka K, et al. An analysis of improving parameters by using an ionic electronic toothbrush – a pilot study with healthy subjects. *J Stomatol Soc Jpn*. 2017;84:19-24.
22. Pizzo G, Licata ME, Pizzo I, D'Angelo M. Plaque removal efficacy of power and manual toothbrushes: a comparative study. *Clin Oral Investig*. 2010;14(4):375-381.
23. Elkerbout TA, Slot DE, Rosema NAM, Van der Weijden GA. How effective is a powered toothbrush as compared to a manual toothbrush? A systematic review and meta-analysis of single brushing exercises. *Int J Dent Hyg*. 2020;18(1):17-26.

How to cite this article: Ikawa T, Mizutani K, Sudo T, et al. Clinical comparison of an electric-powered ionic toothbrush and a manual toothbrush in plaque reduction: A randomized clinical trial. *Int J Dent Hygiene*. 2020;00:1–6. https://doi.org/10.1111/idh.12475

APPENDIX A

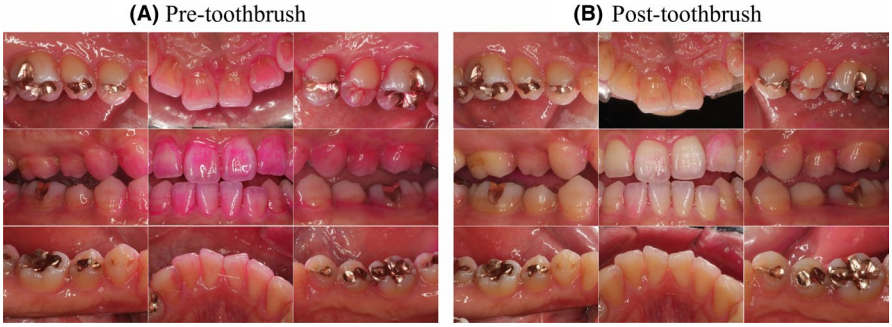

Figure A1 Study design. This study was designed as a randomized, single-blinded, crossover clinical trial with single use

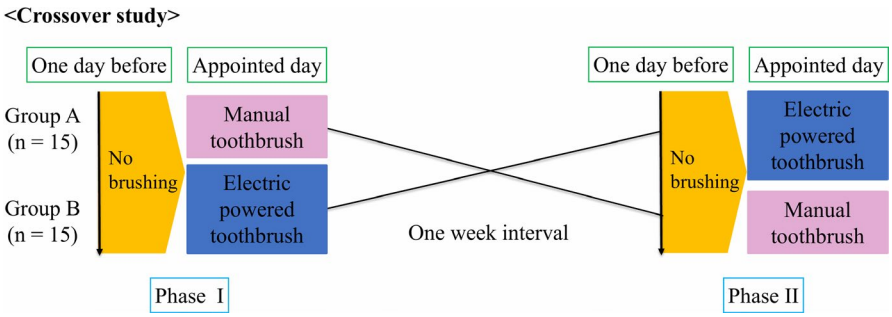

Figure A2 Oral Photographs. Teeth surfaces were stained with plaque staining solution. Oral photographs were taken before (a)/after (b) brushing the teeth