INTRODUCTION

Periodontitis and caries are the most commonly occurring dental diseases worldwide (Marcenes et al., 2013) and account for about 60% of tooth loss (Glockmann, Panzner, Huhn, Sigusch, & Glockmann, 2011). The main aetiology for both diseases is accumulation of bacterial plaque on tooth surfaces (Löe, Theilade, & Jensen, 1965; Marsh & Nyvad, 2008; Newman, 1986; Theilade, Wright, Jensen, & Löe, 1966). It has been well established that the cornerstone for prevention of periodontitis and caries is through supragingival plaque control and fluoride usage, respectively. Although personal oral hygiene methods such as toothbrushing can prevent biofilm accumulation and gingivitis (Tonetti et al., 2015), it has to be noted that proper brushing skills are vital to achieve this. Effective brushing is linked to a number of influencing factors. Usually, brushing skills are acquired through parents, and it takes time to actually master them perfectly (Unkel, Fenton, Hobbs, &
Frere, 1995). If an improper technique is detected at a later point of life, it is difficult to modify it (Alcouffe, 1988). Furthermore, the fine motor skills might degrade with ageing and could impair maintaining proper oral hygiene in elderly people (Felder, Reveal, Lemon, & Brown, 1994; Hitz Lindenmüller & Lambrecht, 2011).

Powered toothbrushes (PTB) are advertised as having better biofilm removal capacity than manual toothbrushes (Verma & Bhat, 2004), which was attested by in vitro studies (Hunt, 2002; Schmidt, Zaugg, Weiger, & Walter, 2013). Under clinical settings, they were effective in removing plaque (Rosema, Slot, van Palenstein Helderman, Wiggelinghuijzen, & Van der Weijden, 2016) and tackling gingivitis (Yaacob et al., 2014). However, studies assessing the long-term effectiveness of PTBs on slowing initiation or progression of periodontitis are limited (Dentino et al., 2002; Dörfer, Staehle, & Wolff, 2016; Moritis, Jenkins, Hefti, Schmitt, & McGrady, 2008; Schmalz et al., 2017; Wilson, Levine, Dequincey, & Killoy, 1993); these studies mainly focused on plaque, calculus or gingivitis. In addition to having employed small sample sizes (maximum of 180 subjects) and short follow-up times ranging from a few weeks to a maximum of 3 years, these studies did not include tooth loss as an outcome, which is of paramount importance for patients. A recently published Cochrane review concluded “Powered toothbrushes reduce plaque and gingivitis more than manual toothbrushing in the short and long term. The clinical importance of these findings remains unclear” (Yaacob et al., 2014). Similarly, studies associating PTB usage with caries are limited (Papas et al., 2007; Willershausen & Watermann, 2001). Furthermore, prospective population-based cohort studies assessing the effectiveness of PTBs are unavailable as of now.

Therefore, in this study, we aimed to estimate the longitudinal effects of PTB usage on (a) periodontal health in terms of mean probing depths (PD) and mean clinical attachment loss (CAL), (b) coronal caries experience using decayed, missing and filled surfaces (DMF) and decayed and filled surfaces (DFS) scores and (c) number of teeth present using 11-year data from the representative population-based cohort, Study of Health in Pomerania (SHIP).

2 | MATERIAL AND METHODS

2.1 | Study population

The study sample was obtained from the ongoing prospective cohort study (SHIP), which adapted a two-stage cluster design (Keil et al., 1988). The cohort was initiated in 1997–2001 (SHIP-0) and was followed up after 5 (SHIP-1), 11 (SHIP-2) and 16 years (SHIP-3) (Völzke et al., 2011). Since information about the PTB usage was not available in SHIP-0, we considered the data from SHIP-1 as baseline examination and SHIP-2 and SHIP-3 as the 6- and 11-year follow-ups, respectively. Participants with information on exposure, outcomes and covariates within at least one examination were included in the study. The study started with a sample of 3,300 participants at baseline. The flow of study participants in the study is shown in Figure 1. The study protocol was approved a priori by the ethics committee of the University of Greifswald, and written informed consent for the interviews, clinical and dental examinations was obtained from all the participants.

2.2 | Dental examination

Dental examinations were performed by calibrated and licensed dentists. Initial training was conducted by a periodontist (TK). The intra-rater and inter-rater reliability values are shown in Table S1. Identical recording protocols were used for all time points. From the dental examination, number of teeth present (full mouth), PD, CAL, DMFS score and DFS score were calculated. Detailed information on the dental examination can be found in the supplementary material.

2.3 | Interviews and medical examination

Trained and certified interviewers conducted computer-assisted personal interviews for participants during all the visits to collect information on the exposure and covariates. Participants were asked whether they used powered or manual toothbrush at each time point from SHIP-1 to SHIP-3. Based on the toothbrushing frequency, participants were categorised into irregular (<2 times/day) or regular brushers (≥2 times/day). Classification of covariates considered in the study (educational status at the start of study, smoking status, toothbrushing frequency, dental visit in the last 12 months, periodontal treatment in the last 5 years, diabetes, physical activity and Centers for Disease Control and Prevention/American Academy of Periodontology (CDC/AAP) case definition of periodontitis) are mentioned in Table 1. Body mass index (BMI) was calculated as weight in kg/(height in m)². At baseline (SHIP-1), known diabetic cases, defined as diagnosed cases according to self-reported physician’s diagnosis or treatment with anti-diabetic drugs (Anatomical Therapeutic Chemical Classification System code A10), were recorded. Prevalent cases based on information from SHIP-0 were combined with incident cases between SHIP-0 and SHIP-1. Blood samples were drawn at non-fasting status to determine HbA1c levels using HPLC method (Bio-Rad Diamat, Munich, Germany).
### 2.4 Statistical analyses

All analyses were performed using Stata/SE 14.2 (StataCorp 2015, College Station, TX, USA). The following time-varying outcomes were considered: (a) mean PD, (b) mean CAL, (c) DMFS, (d) DFS and (e) number of teeth present. Continuous and categorical variables were compared using Student’s t test and chi-square test, respectively. To assess the longitudinal effects of PTB usage on different outcomes, mixed-effects linear regression models over three time points were constructed for each outcome using the entire sample. The time variable was divided by 11, to obtain estimates that reflect the effect of PTB usage 11 years from baseline, which was the time span between SHIP-1 and SHIP-3. All covariates were selected a priori, based on the clinical knowledge. Models were constructed with subject ID and time as random intercept and slope, respectively, so that they took into effect the repeated measurements within subjects at different follow-ups, which denote the multiple levels. The advantage with mixed-effects modelling approach is that it requires complete datasets at each follow-up separately, but not across examinations. All models were adjusted for baseline (SHIP-1) covariates, such as age, sex, BMI, education, smoking, diabetic status, HbA1c values, frequency of toothbrushing and history of dental visit in the last 12 months. Physical activity was included as additional covariate in the number of teeth present models. Mean PD and CAL models were additionally adjusted for physical activity and history of periodontal treatments during the past 5 years; but the random slope was excluded as the models did not converge. Age was included in the model as a restricted cubic spline with three knots. The adjusted estimates ($\hat{\beta}$), 95% confidence intervals (95% CI) and their corresponding p-values were calculated. After obtaining the adjusted estimates, percentage change for MTB and PTB users after 11 years of follow-up time was calculated using the formula $\left(\frac{\beta_{PTB} - \beta_{MTB}}{\beta_{MTB}}\right) \times 100$ (United States.
Analyses were restricted to the following subsets: (a) regular brushers (n = 2,464 at SHIP-1), (b) younger subjects (25–55 years, n = 1,617) and (c) younger regular brushers (n = 1,403). After initial analyses, participants were stratified based on the CDC/AAP case definition of periodontitis to observe if the severity of periodontal disease had an influence on the association with PTB, and all models were repeated. Furthermore, sensitivity analyses were performed on the entire sample models by including subjective influence on oral hygiene, inter-dental aids usage, screening for preventive medicine and cancer or preventive dental screening (Table S5). Additionally, to avoid over-adjustment, we performed directed acyclic graphs (DAGs) for each outcome spectrum (periodontitis, caries and no. of teeth present) (Textor, Hardt, & Knüppel, 2011). DAGs for each outcome resulted in adjusting for age, sex, education, toothbrushing frequency, dental visit in the last 12 months and history of periodontal treatment within the last 5 years (Figure S1). Thereafter, models were constructed adjusting for these variables under each outcome. The recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies were applied for reporting (von Elm et al., 2014).

### RESULTS

#### 3.1 Baseline characteristics

A total of 2,819 participants with mean age of 52.1 ± 14.4 years were included in the model (Table 1). PTB users were younger (46.3 years) than the MTB users (53.4 years). PTB users fared well in education, toothbrushing frequency, dental visit in the last 12 months, diabetic

| Variable                         | Group              | Total   | MTB user | PTB user | p-value |
|----------------------------------|--------------------|---------|----------|----------|---------|
| Sample size for SHIP 1 in model  |                    | 2,819   | 2,304    | 515      | -       |
| Age (in years)                   |                    | 52.1 ± 14.4 | 53.4 ± 14.5 | 46.3 ± 12.4 | <0.001** |
| Sex                              | Male               | 1,353 (48.0) | 1,156 (50.2) | 197 (38.3) | <0.001  |
|                                   | Female             | 1,466 (52.0) | 1,148 (49.8) | 318 (61.7) |          |
| Education                        | <10 years          | 868 (30.8) | 788 (34.2) | 80 (15.5) | <0.001  |
|                                   | 10 years           | 1,408 (50.0) | 1,103 (47.9) | 305 (59.2) |          |
|                                   | >10 years          | 543 (19.2) | 413 (17.9) | 130 (25.3) |          |
| Smoking status                   | Non-smoker         | 1,207 (42.8) | 999 (43.4) | 208 (40.4) | 0.36    |
|                                   | Former smoker      | 870 (30.9) | 710 (30.8) | 160 (31.1) |          |
|                                   | Occasional smoker  | 97 (3.4) | 74 (3.2) | 23 (4.4) |          |
|                                   | Current smoker     | 645 (22.9) | 521 (22.6) | 124 (24.1) |          |
| Toothbrushing frequency          | Irregular brushes  | 442 (15.7) | 391 (17.0) | 51 (9.9) | <0.001  |
|                                   | Regular brushes    | 2,377 (84.3) | 2,193 (83.0) | 464 (90.1) |          |
| Dental visit in the last 12 months | No               | 200 (7.1) | 176 (7.6) | 24 (4.6) | 0.02    |
|                                   | Yes                | 2,619 (92.9) | 2,192 (92.4) | 491 (95.4) |          |
| Periodontal treatment in the last 5 years | No | 2,513 (89.2) | 2,076 (90.1) | 437 (85.0) | 0.002   |
|                                   | Yes                | 304 (10.8) | 227 (9.9) | 77 (15.0) |          |
| Diabetes                         | No                 | 2,568 (91.1) | 2,090 (90.7) | 478 (92.8) | 0.13    |
|                                   | Yes                | 251 (8.9) | 214 (9.3) | 37 (7.2) |          |
| HbA1c (in %)                     |                    | 5.4 ± 0.8 | 5.4 ± 0.8 | 5.2 ± 0.8 | <0.001** |
| BMI (in kg/m²)                   |                    | 27.8 ± 4.8 | 27.9 ± 4.8 | 27.0 ± 4.9 | <0.001** |
| Physical activity                | <1 hr sport/week   | 1,784 (63.3) | 1,510 (65.6) | 274 (53.2) | <0.001  |
|                                   | 1-2 hr sport/week  | 490 (17.4) | 381 (16.5) | 109 (21.2) |          |
|                                   | >2 hr sport/week   | 545 (19.3) | 413 (17.9) | 132 (25.6) |          |
| CDC/AAP case definition          | No/mild periodontitis | 1,187 (48.3) | 885 (44.7) | 302 (63.2) | <0.001  |
|                                   | Moderate periodontitis | 877 (35.7) | 740 (37.3) | 137 (28.7) |          |
|                                   | Severe periodontitis | 395 (16.0) | 356 (18.0) | 39 (8.1) |          |

Note: Data are presented as mean ± standard deviation or number (column percentages). Abbreviations: MTB: manual toothbrush; PTB: powered toothbrush; BMI: body mass index; CDC/AAP: Centers for Disease Control and Prevention/American Academy of Periodontology.

*p-Values were obtained using chi-square test for categorical variables. **p-Values were obtained using Student's t test for continuous variables. Bold numbers indicate statistically significant effect (p-Value < 0.05). Census Bureau, 2015). p-Values ≤ 0.05 were considered as indicator of statistical significance.
3.2 | Association between PTB usage and periodontal measures

After adjustment, PTB usage was significantly associated with reduced mean PD and mean CAL progression in the entire sample as well as all subsets (Table 3). "PTB usage" denotes the effect of PTB usage on dependent variable for time = 0 (baseline/SHIP-1). Time (per 11-year increase) reflects the rate of change in MTB users over 11-year follow-up (SHIP-3). Interaction denotes exposure-dependent (PTB vs. MTB) difference in the rates of change over 11-year follow-up period. For example, in the entire sample, PTB users had −0.03 mm smaller mean PD than MTB brushers at baseline. However, after 11 years, MTB users had 0.41 mm of mean PD progression, while the PTB users had 0.09 mm significantly less mean PD, that is 0.32 mm mean PD progression. This difference could also be translated as PTB users having 22% less mean PD progression over a period of 11 years (Figure 2 and Table S2). On exploring the subsets of study participants, PTB users had a significantly low mean PD progressions (estimates ranging from −0.09 to −0.11). Similarly, PTB usage was associated with low mean CAL progression in the entire sample [−0.19 (−0.32; −0.07)] as well as in all subsets (estimates ranging from −0.19 to −0.26). On stratifying the study population based on the CDC/AAP definition (Table 4 and Figure 2), PTB usage in the entire sample and regular brushers was associated with less mean PD progression among subjects with no/mild and moderate periodontitis, and less mean CAL progression in subjects with moderate periodontitis only. Subjects with severe periodontitis did not benefit from the usage of PTB.

3.3 | Association between PTB usage and caries

With respect to caries, PTB users had lower DMFS and DFS scores throughout the study period (Table 2). On further exploring the data after adjustment (Table 3), PTB users in the entire sample and in the regular brushers’ subset had 1.32 surfaces (half-mouth) less DMFS progression, corresponding to 17.7% significantly less DMFS progression than the MTB users; but this association was not present among other subsets of participants. PTB usage had no influence on the DFS scores (Table 3), even after stratifying the subjects based on CDC/AAP definition (Table S3).

3.4 | Association between PTB usage and number of teeth present

PTB users also had significantly less number of teeth lost over 11-year follow-up, indirectly leading to more number of teeth present (Table 2). After adjustment, reduction in the number of teeth present was about

| TABLE 2 | Distribution of dental variables in participants included in the models, stratified by examination time points |
|-----------------|-----------------|-----------------|-----------------|
| Outcome | Examination (N) | Mean ± SD | Total | MTB user | PTB user | p-Valuea |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Mean PD | SHIP-1 (2,616) | 2.31 ± 0.71 | 2.34 ± 0.76 | 2.13 ± 0.57 | <0.001 |
| | SHIP-2 (1,847) | 2.64 ± 0.58 | 2.69 ± 0.60 | 2.52 ± 0.51 | <0.001 |
| | SHIP-3 (1,372) | 2.49 ± 0.59 | 2.55 ± 0.65 | 2.38 ± 0.45 | <0.001 |
| Mean CAL | SHIP-1 (2,482) | 2.23 ± 1.72 | 2.38 ± 1.78 | 1.62 ± 1.31 | <0.001 |
| | SHIP-2 (1,758) | 2.85 ± 1.53 | 3.02 ± 1.62 | 2.44 ± 1.20 | <0.001 |
| | SHIP-3 (1,294) | 2.54 ± 1.45 | 2.76 ± 1.59 | 2.21 ± 1.13 | <0.001 |
| DMFS | SHIP-1 (2,787) | 33.1 ± 16.4 | 34.1 ± 16.7 | 28.6 ± 14.3 | <0.001 |
| | SHIP-2 (1,925) | 34.6 ± 15.8 | 36.0 ± 16.2 | 30.8 ± 14.0 | <0.001 |
| | SHIP-3 (1,417) | 36.0 ± 15.8 | 38.1 ± 16.4 | 32.6 ± 14.3 | <0.001 |
| DFS | SHIP-1 (2,709) | 32.5 ± 16.2 | 33.4 ± 16.5 | 28.6 ± 14.3 | <0.001 |
| | SHIP-2 (1,902) | 34.3 ± 15.7 | 35.8 ± 16.2 | 30.7 ± 14.0 | <0.001 |
| | SHIP-3 (1,417) | 36.0 ± 15.8 | 38.1 ± 16.4 | 32.6 ± 14.3 | <0.001 |
| No. of teeth present | SHIP-1 (2,819) | 19.9 ± 7.5 | 19.2 ± 7.8 | 23.1 ± 5.0 | <0.001 |
| | SHIP-2 (1,975) | 20.0 ± 7.6 | 18.9 ± 8.1 | 22.9 ± 4.9 | <0.001 |
| | SHIP-3 (1,471) | 20.1 ± 7.6 | 18.5 ± 8.4 | 22.8 ± 5.0 | <0.001 |

Note: Data are presented as mean ± standard deviation. Abbreviations: MTB: manual toothbrush; PTB: powered toothbrush; PD: probing depth, CAL: clinical attachment loss, DMFS: decayed, missing, filled surfaces; DFS: decayed, filled surfaces. a-p-Values were obtained using Student’s t test. Bold numbers indicate statistically significant differences (p < 0.05). Mean values do not allow directly comparing the time course of the variables, since the three follow-ups are not identical in terms of included SHIP participants.
Published short-term studies on PTB usage showed better plaque control and reduced gingivitis, but the present longitudinal study showed for the first time that these effects are likely to get translated into reduced progression of PD and CAL. Also, more retained teeth speak in favour of a clear tangible health benefit of PTB.

The main strength of the present study is that prospective data from a population-based cohort with a follow-up time of 11 years have been analysed. Our study had the benefit of extensive dental data in terms of surface-level periodontal measures and caries data. We identified and adjusted for commonly observed covariates such as age, sex, BMI, education, smoking, diabetic status, HbA1c values, toothbrushing frequency and history of dental visits, in addition to periodontal treatment history and physical activity in some models. Our study also had its share of limitations. It might be argued that PTB users were younger in age, with better education, and oral health awareness, in addition to having better physical activity. However, the associations observed in this study were not lost even after adjusting for all the relevant factors, although residual confounding cannot be excluded. Furthermore, when the entire sample models were additionally adjusted for subjective influence on oral hygiene, inter-dental

20% lesser in PTB users, that is PTB users retained on average 0.36 teeth more than their counterparts. Regularly brushing PTB users retained 0.39 teeth more. On analysing the strata of study sample based on CDC/AAP definition categories, PTB users in the entire sample with no/mild periodontitis had 0.19 more teeth retained (Table S4).

### DISCUSSION

This study assessed the longitudinal association of PTB usage on periodontitis, caries and number of teeth present from a prospective population-based cohort. Our main findings suggest that PTB usage over a period of 11 years had an effect in reducing the progression of mean PD and mean CAL in the study participants. This protective effect translated into more retained teeth in the whole cohort over the 11-year study period. However, PTB usage did not influence caries (DFS) progression. These data circumvent the critique of the latest Cochrane review on this subject: *Empirical data on thresholds for clinically important differences in plaque and gingivitis levels would help to determine whether oral hygiene aids provide important health benefits* (Yaacob et al., 2014).
aids usage, screening for preventive medicine and cancer or preventive dental screening, none of these variables failed to elicit significant effect on the estimates. To avoid over-adjustment, based on the information from DAGs, models were adjusted only for age, sex, education, toothbrushing frequency, dental visits in the last 12 months and history of periodontal treatment within the last 5 years. This conservative approach did not alter any of our results (Table S6).

Periodontal and caries examinations were recorded using half-mouth basis, which might not reflect the absolute values, although it has less bias in comparison with full-mouth method (Tran et al., 2016). Furthermore, caries was recorded only on cavitation level. Leaving out non-cavitated caries lesions would have under-represented the caries burden in this study. Information on PTB usage was obtained only through a simple question with binomial answer possibility. In addition to usage of PTB in combination with MTB, differentiation between different types of PTB, that is oscillatory vs. vibratory, battery-powered vs. electric, sonic vs. ultra-sonic, was not measured, especially when there were studies reporting differences among them (Deacon et al., 2010; Rosema et al., 2016). However, the differences between the different types of PTB are not well studied, and more focus in this direction is needed. Because it is not plausible to perform a long-term randomized controlled trial to test the effectiveness of PTBs over MTBs, evidence from well-designed population-based cohorts/practice-based research is relevant for the dental community.

Although the effectiveness of PTB on periodontitis has been well documented in the literature (Forrest & Miller, 2004; de Jager, Rmaile, Darch, & Bikker, 2017; Yaacob et al., 2014), the evidence arriving from long-term studies is limited (Ainamo, Xie, Ainamo, & Kallio, 1997; Dentino et al., 2002; Dörfer, Joerss, & Wolff, 2009; Dörfer et al., 2016). In a 12-month longitudinal study, Ainamo et al. (1997) found PTBs to be effective in controlling gingivitis in terms of reducing bleeding on probing, but they were not significantly better in removing plaque. Dörfer et al. (2016) performed a randomized study with the longest follow-up time of 3 years, in which they did not find any significant differences in PD and CAL progression between PTB and MTB users with pre-existing recessions >2 mm. However, as shown in a recent meta-analysis (Yaacob et al., 2014), the use of a PTB results in less supragingival plaque, which in consequence prevents or decreases the magnitude of gingivitis. An improved oral hygiene has an effect on preventing the transition from gingivitis to periodontitis rather than the progression of periodontitis (Hellström, Ramberg, Krok, & Lindhe, 1996; Ramseier et al., 2017; Schätzle et al., 2004). In line with this observation, we could see that PTB had a distinct effect in reducing the PD and CAL progression in subjects affected with no/mild or moderate periodontitis, whereas the subjects with severe periodontitis did not benefit from the better oral hygiene through PTB usage (Hellström et al., 1996). Although the magnitude of change in PD and CAL among subjects with severe periodontitis was in line with the moderate periodontitis subjects, the effects were not significant, presumably due to the reduced sample size. Furthermore, it could be observed that the mean age of the PTB users was significantly lower than the MTB users. In addition to oral hygiene, progression of the periodontal disease in elderly people is influenced by many other factors (Lamster, 2016), which might not be counteracted by toothbrushing alone. Ramseier et al. (2017) concluded from the 40-year results of the Sri Lanka study that gingivitis control in young subjects is essential in preventing progression of
TABLE 4  Results from mixed-effects linear models evaluating the effects of powered toothbrush usage on rates of change in periodontitis models stratified by CDC/AAP definition

| Outcome                  | Variable                  | Entire sample | Regular brushers | Younger subjects | Younger regular brushers |
|--------------------------|---------------------------|---------------|------------------|------------------|-------------------------|
|                         |                           | β (95% CI)    | β (95% CI)       | β (95% CI)       | β (95% CI)              |
| CDC/AAP definition = no/mild periodontitis | Mean PD \[a\] | PTB usage | -0.00 (-0.05; 0.04) | 0.01 (-0.04; 0.06) | 0.01 (-0.11; 0.13) | 0.03 (-0.09; 0.16) |
|                          |                           | Time (per 11-year increase) | 0.42 (0.38; 0.45) | 0.43 (0.39; 0.47) | 0.37 (0.30; 0.45) | 0.40 (0.32; 0.48) |
|                          |                           | Interaction  | -0.06 (-0.13; -0.00) | -0.08 (-0.14; -0.01) | -0.05 (-0.22; 0.12) | -0.08 (-0.26; 0.10) |
| CDC/AAP definition = moderate periodontitis | Mean PD \[a\] | PTB usage | -0.02 (-0.11; 0.07) | 0.01 (-0.09; 0.10) | 0.06 (-0.21; 0.33) | 0.10 (-0.19; 0.39) |
|                          |                           | Time (per 11-year increase) | 0.82 (0.75; 0.89) | 0.83 (0.75; 0.91) | 0.67 (0.50; 0.83) | 0.73 (0.55; 0.92) |
|                          |                           | Interaction  | -0.07 (-0.19; 0.06) | -0.09 (-0.22; 0.04) | -0.09 (-0.47; 0.29) | -0.15 (-0.55; 0.25) |
| CDC/AAP definition = severe periodontitis | Mean PD \[a\] | PTB usage | 0.04 (-0.04; 0.13) | 0.05 (-0.04; 0.14) | -0.04 (-0.17; 0.09) | -0.05 (-0.18; 0.09) |
|                          |                           | Time (per 11-year increase) | 0.27 (0.22; 0.33) | 0.28 (0.22; 0.34) | 0.29 (0.21; 0.36) | 0.28 (0.20; 0.37) |
|                          |                           | Interaction  | -0.16 (-0.27; -0.05) | -0.17 (-0.29; -0.05) | -0.04 (-0.21; 0.13) | -0.05 (-0.23; 0.13) |
| CDC/AAP definition = Severe periodontitis | Mean PD \[a\] | PTB usage | 0.04 (-0.12; 0.21) | 0.03 (-0.14; 0.20) | 0.00 (-0.25; 0.25) | -0.04 (-0.30; 0.22) |
|                          |                           | Time (per 11-year increase) | 0.64 (0.55; 0.74) | 0.65 (0.55; 0.76) | 0.63 (0.50; 0.76) | 0.61 (0.47; 0.75) |
|                          |                           | Interaction  | -0.32 (0.51; -0.12) | -0.33 (0.54; -0.13) | -0.17 (-0.46; 0.12) | -0.17 (-0.48; 0.14) |

Note: All models were adjusted for baseline covariates, such as, age, sex, education, smoking, BMI, diabetic status, HbA1c values, toothbrushing frequency, dental visit in the last 12 months, physical activity and history of periodontal treatment in the last 5 years. Subject ID was constructed as random intercept.

Abbreviations: β: beta coefficient; 95% CI: 95% confidence interval. CDC/AAP: Centers for Disease Control and Prevention/American Academy of Periodontology. PD: probing depth; CAL: clinical attachment loss; DMFS: decayed, missing, filled surfaces; DFS: decayed, filled surfaces. PTB usage: Effects of powered toothbrush usage on dependent variable for time = 0 (baseline/SHIP-1). Time (per 11-year increase): Rate of change for manual toothbrush user over 11-year follow-up period. Interaction: Exposure-dependent (PTB versus MTB) difference in the rates of change over 11-year follow-up period.

[a]Models were performed without the inclusion of random slope. Bold numbers indicate statistically significant effect (p-value < 0.05).

Periodontitis, further loss of attachment and ultimately tooth loss. Our data may be interpreted that subjects using a PTB experience less attachment loss, which after 11-year follow-up resulted on average 0.36 more teeth than the MTB users. Furthermore, subjects with no/mild periodontitis had 0.19 more teeth retained than their MTB counterparts.

To our knowledge, the number of studies assessing the relationship between caries and PTB is rare. In an interventional study among drug-induced xerostomia patients (N = 80) with a follow-up time of 1 year, Papas et al. (2007) recorded a significant reduction of root caries among PTB users. Willershausen and Watermann (2001) performed an interventional study (N = 40) with a 3-year follow-up on elementary school children, but did not observe any benefit of PTB on caries prevalence. A systematic review conducted on seven studies assessing influence of oral hygiene in the absence of fluoride on dental caries concluded “Personal oral hygiene in the absence of fluorides has failed to show a benefit in terms of reducing the incidence of dental caries” (Hujoel, Hujoel, & Kotsakis, 2018). In line with this argumentation, lack of association between PTB usage and DFS seems plausible. However, PTB usage was associated with less DMFS progression, and this was due to the influence from the M-component, which is a predominant feature in the elderly population.

There has been a significant association of PTB usage with more number of teeth retained in the entire sample and in the regular brushers’ subset. Based on this, it is evident that the PTB usage on the long run helps in preventing tooth loss and maintaining the number of teeth in the oral cavity. From this study, it could be seen that the
PTB usage may have a long-term protective effect on the oral health in general. It could also be seen that there has been a gradual increase in the usage of PTB over time. The reasons for this might be increased advertisements and dentist recommendations. German Oral Health Study showed that recently there has been an increase in the usage of inter-dental cleaning aids (Jordan & Micheiels, 2016). This, in addition to increased PTB usage as observed in the SHIP cohort, reflects the increased awareness of German population towards oral hygiene.

5 CONCLUSION

From the results in this study, it could be seen that the PTB usage has a long-term protective effect on the oral health in terms of reduced probing depths, clinical attachments and number of teeth lost. Based on this, it seems that the PTB usage in the long run helps in maintaining the number of teeth in the oral cavity and reducing the progression of periodontal disease burden.

ACKNOWLEDGEMENTS

The authors thank the study participants and all contributions to the SHIP data collection by dental and medical examiners, technicians, interviewers and assistants.

CONFLICTS OF INTERESTS

Prof. Dr. Thomas Kocher had received grants from Procter and Gamble Co. to pay the salary for a scientist for 6 months, which did not have any influence on the study design, data analysis and interpretation of the results. The authors declare no potential conflicts of interest with respect to the authorship and publication of this article, and this includes financial interests.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Pitchika V, Pink C, Völzke H, Welk A, Kocher T, Holtfreter B. Long-term impact of powered toothbrush on oral health: 11-year cohort study. J Clin Periodontol. 2019;46:713–722. https://doi.org/10.1111/jcpe.13126

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