Received: 29 June 2023 | Revised: 14 November 2023 | Accepted: 2 December 2023

DOI: 10.1111/jcpe.13936

ORIGINAL ARTICLE

Journal of Clinical Periodontology

WILEY

Interdental cleaning aids are beneficial for oral health at 7-year follow-up: Results from the Study of Health in Pomerania (SHIP-TREND)

Birte Holtfreter[1] | Elena Conrad[1] | Thomas Kocher[1] | Sebastian-Edgar Baumeister[2] | Henry Völzke[3,4] | Alexander Welk[1]

[1]Department of Restorative Dentistry, Periodontology, Endodontology and Preventive and Pediatric Dentistry, University Medicine Greifswald, Greifswald, Germany

[2]Institute of Health Services Research in Dentistry, University of Münster, Münster, Germany

[3]Institute for Community Medicine, University Medicine Greifswald, Greifswald, Germany

[4]German Center for Cardiovascular Research (DZHK), Partner Site Greifswald, Greifswald, Germany

Correspondence

Birte Holtfreter, Department of Restorative Dentistry, Periodontology, and Endodontology and Preventive and Pediatric Dentistry, University Medicine Greifswald, Fleischmannstr. 42, 17475 Greifswald, Germany.

Email: birte.holtfreter@med.uni-greifswald.de

Funding information

Deutsche Gesellschaft für Parodontologie (DGParo) e.V.; German Federal State of Mecklenburg-West Pomerania

Abstract

Aim: To estimate association between the use of interdental cleaning aids (IDAs) and type on 7-year follow-up levels of interdental plaque, interdental gingival inflammation, interdental periodontitis severity, the number of interdental sound surfaces and the number of missing teeth in a population-based cohort study.

Materials and Methods: We used 7-year follow-up data of 2224 participants from the Study of Health in Pomerania (SHIP-TREND). We applied generalized linear and ordinal logistic models, adjusting for confounding and selection bias using inverse probability treatment weighting and multiple imputation.

Results: Flossers were 32% less likely to have higher interdental plaque (iPlaque) levels than non-users of IDAs (odds ratio [OR] = 0.68; 95% confidence interval [CI]: 0.50–0.94); flossing resulted in 5% lower means of iPlaque. Effects on interdental bleeding on probing (iBOP), mean interdental probing depths and mean interdental clinical attachment levels were direction-consistent but statistically non-significant. Interdental brushing was associated with lower follow-up levels for interdental plaque (OR = 0.73; 95% CI: 0.57–0.93) and iBOP (OR = 0.69; 95% CI: 0.53–0.89). IDAs were more effective in reducing iPlaque in participants with periodontitis, whereas iBOP reduction was more pronounced in participants with no or mild periodontitis. The analyses did not suggest that the use of IDAs affected caries. Finally, applying change score analyses, flossing reduced tooth loss incidence (incidence rate ratio [IRR] = 0.71) compared with non-users of IDAs.

Conclusions: Recommending flossing and interdental brushing in dental practices represents an approach to the prevention of gingivitis and consequently periodontitis.

KEYWORDS

dental flossing, interdental brushing, periodontitis, prospective cohort study, Tooth loss

Clinical Relevance

Scientific rationale for study: Limited data are available on the effectiveness of interdental cleaning aids (IDAs) on dental outcomes in longitudinal population-based settings.

Principal findings: Using 7-year follow-up data from the population-based Study of Health in Pomerania (SHIP-TREND), daily dental flossing and interdental brushing were associated with lower 7-year follow-up levels of interdental plaque, interdental bleeding on probing and mean interdental probing depth. The effects were somewhat more pronounced with no or mild periodontitis cases.

Practical implications: There is evidence that recommending IDAs in dental practice may have positive effects on gingival inflammation and pocket formation among the general population.

1 | INTRODUCTION

Oral health is an important part of general health and refers to the unrestricted functionality and freedom from inflammation and symptoms of all organs of the oral cavity. Coronal caries and periodontitis are still among the most common infectious diseases worldwide (Kassebaum et al., 2014, 2015). However, in Germany the prevalence of caries in children and adults has decreased over the past decades (Jordan & Micheelis, 2016). In parallel, probing depth severity has remained unchanged, while attachment levels have decreased across all ages (Schutzhold et al., 2015). These downward trends are likely the result of the use of fluorides and improved mechanical plaque control (Figuero et al., 2017) such as the increased use of powered tooth brushes and interdental cleaning aids (IDAs) (Pitchika et al., 2021). Early prevention of caries and periodontitis, as well as its precursor gingivitis, is therefore an important pillar of comprehensive dental treatment.

Supra-gingival plaque control constitutes a major target in the prevention and treatment of caries, gingivitis and periodontitis. To prevent and reduce (interdental) plaque formation and gingival inflammation, professional plaque removal combined with reinforcement of home oral hygiene (including the use of powered tooth brushes and IDAs), is strongly recommended in addition to regular toothbrushing with a fluoridated toothpaste (Chapple et al., 2015). Starting in 2015, there was a fierce debate about whether flossing has any benefit for oral health. In August 2016, the Associated Press released information that the 'medical benefits of dental floss are unproven' (Donn, 2016). In the following years, meta-analyses summarized evidence from randomized clinical trials (Salzer et al., 2015; Worthington et al., 2019), showing that use of IDAs in addition to regular toothbrushing may reduce plaque and gingival inflammation more than toothbrushing alone. However, there was weak evidence of unclear or low magnitude (Salzer et al., 2015; Worthington et al., 2019). Furthermore, only short-term effects of IDA use were evaluated and most of the participants had a low level of gingival inflammation at baseline. Thus, there was 'limited evidence supporting efficacy to prevent advanced oral disease endpoints' (Chaffee et al., 2020) such as (interproximal) caries and periodontitis (Worthington et al., 2019).

In contrast to randomized clinical trials, cross-sectional (Cepeda et al., 2017; Kim & Han, 2021; S. J. Kim, Lee, et al., 2022; Y. J. Kim, Gil, et al., 2022; Lang et al., 1995; Lee et al., 2018; Marchesan et al., 2018) and cohort studies (Chaffee et al., 2020; Kressin et al., 2003; Marchesan et al., 2020) predominantly reported that both flossing and interdental brushing in addition to toothbrushing were associated with lower levels of periodontitis, caries and tooth loss among different populations with a predominantly wide age range (19+/30+ years). In three repeated cross-sectional studies, IDA use explained a significant portion of explainable changes in the mean probing depth (PD), the number of caries-free healthy surfaces and the number of teeth (Pitchika et al., 2021). Obviously, there is a great need for well-designed randomized clinical trials and population-based cohort studies to strengthen the evidence in this regard, with special consideration of the IDA type.

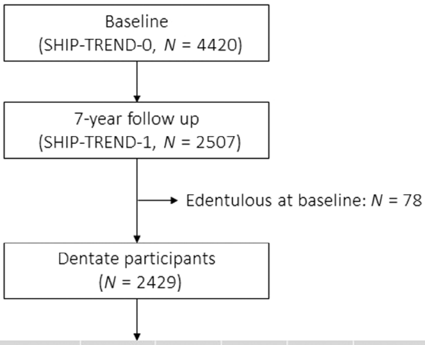
Therefore, we aimed to investigate the effects of self-performed IDAs, distinguishing between three different types of IDA, in addition to regular toothbrushing on 7-year follow-up levels of a wide range of oral-health-related variables, including interdental plaque (iPlaque), gingival inflammation (interdental bleeding on probing [iBOP]), periodontitis severity (mean interdental PD [iPD]; mean interdental clinical attachment levels [iCAL], percentage of sites with iPD ≥4 mm [iPD4mm], Centers for Disease Control and Prevention [CDC]/American Academy of Periodontology [AAP] case definitions), coronal caries experience (number of interdental caries-free sound surfaces [iSS]) and the number of missing teeth using 7-year follow-up data of the prospective population-based Study of Health in Pomerania (SHIP-TREND).

2 | MATERIALS AND METHODS

2.1 | Study design

SHIP-TREND is a population-based observational study conducted in the northeast of Germany (Volzke et al., 2022). A stratified random sample of 10,000 adults aged 20–79 years was drawn from population registries. Stratification variables were age, sex and city/county of residence. Migrated ($N = 851$) and deceased ($N = 323$) persons were excluded from the random sample of 10,000 adults, leaving 8826 persons in the net sample. Of those, 4420 subjects were finally recruited in the study (response 50.1%). Baseline examinations were conducted from 2008 to 2012 (SHIP-TREND-0). After 7 years, a first follow-up examination was performed (SHIP-TREND-1, 2014–2018), in which 2507 participants took part. Follow-up times varied between 4.9 and 10.3 years (mean 7.4 years). Exact information on sample derivation is shown in Figure 1.

The AppendixA1 gives detailed information about covariates and calibration data. The recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)



	Plaque	BOP	PD	CAL	CDC/AAP	H-S	NoMT
Baseline or follow-up outcome value missing, N	213	251	248	360	399	200	33
Resulting sample size	2216	2178	2181	2069	2030	2229	2396
Baseline confounders missing, *N*	95	92	92	83	77	86	172
Final sample size	2121	2086	2089	1986	1953	2143	2224

FIGURE 1 Flowchart of the study population. AAP, American Academy of Periodontology; BOP, bleeding on probing; CAL, clinical attachment level; CDC, Centers for Disease Control and Prevention; H-S, number of healthy caries-free surfaces; *N*, number; NoMT, number of missing teeth; PD, probing depth.

guidelines for observational studies were applied for reporting (von Elm et al., 2014).

2.2 | Exposure

Based on the dental interview, the use of IDAs was defined as the self-reported daily use of wooden sticks (toothpicks and wooden tooth sticks), dental floss or interdental brushes (IDBs). For multi-users, the most effective method (assuming that wooden sticks are less effective than floss, and floss is less effective than IDBs) was recorded.

2.3 | Caries examinations

All examinations were conducted in an illuminated dental chair and with the option to use aspiration or an air jet. Magnification glasses were not allowed. Coronal caries was diagnosed visually using a periodontal probe (PCPUNC 15, Hu-Friedy, Chicago, IL, USA) to touch the tooth surface softly. Coronal caries was examined excluding third molars on a surface level (occlusal, distal, buccal, mesial, palatinal/lingual) in order to determine the number of sound (excluding persisting teeth of the first dentition), carious (including dentine caries only and excluding enamel defects), missing (excluding front teeth extracted after trauma, symmetric extractions of premolars due to orthodontic treatments) and filled surfaces (excluding crowned front teeth after trauma) in a half-mouth design (randomly chosen left or right side).

The iSS was determined based on a maximum of 14 permanent teeth (excluding third molars) with two surfaces each (distal and mesial), resulting in 28 interdental surfaces being assessed in total.

2.4 | Periodontal examination

PD and CAL were measured at disto-buccal, mid-buccal, mesio-buccal and mid-lingual/mid-palatinal sites according to the half-mouth method excluding third molars (left or right side randomly selected) using a manual periodontal probe (PCPUNC 15, Hu-Friedy, Chicago, IL, USA). Measurements were mathematically rounded to the next whole millimetre. PD was measured as the distance between the free gingival margin (FGM) and pocket base. If the cemento–enamel junction (CEJ) was located sub-gingivally, CAL was calculated as PD minus the distance between FGM and CEJ. If recession was present at the examined site, CAL was directly measured as the distance between CEJ and the pocket base. Where the determination of the CEJ was indistinct (wedge-shaped defects, fillings and crown margins), CAL was not recorded.

At the participant level, mean iPD (disto-buccal and mesio-buccal sites), iPD4mm, and mean interdental CAL (iCAL) were calculated. Also, participants were classified according to the CDC/AAP case definition of periodontitis (Page & Eke, 2007). BOP and plaque were recorded at four identical sites on the first incisor, the canine and the first molar in each probed quadrant. If teeth were missing, the next distally located tooth was assessed. The percentage of iBOP and iPlaque were determined. Finally, the number of missing teeth was calculated (excluding third molars).

2.5 | Statistical analyses

Medians with 25% and 75% quantiles were reported for continuous variables. Relative frequency distributions were computed for categorical variables.

Total effects of baseline IDA use on 7-year follow-up levels of dental outcomes were modelled using generalized linear models (for the iSS) or ordinal logistic regression models (periodontal variables) with adjustment for the baseline outcome status. Ordinal logistic models are recommended for skewed continuous responses (Harrell, 2015); various links were evaluated and the logit link was selected for all variables. Confounder-adjusted linear regression coefficients (β) or odds ratios (OR) with 95% confidence intervals (CIs) contrasting users of different IDA types with IDA non-users were reported. ORs from ordinal logistic models correspond to changes in odds of a higher outcome value for a specific IDA type compared with IDA non-users. Since for tooth loss it can be assumed that baseline exposure status precedes change in outcome status, tooth loss was modelled using change scores (Glymour, 2022). Accordingly, negative binomial regression models were fit and incidence rate ratios (IRRs) with 95% CIs were additionally reported. Analyses were repeated including only participants with identical self-reported information on IDA use and type at baseline and at 7-year follow-up (see Table A2 for cross-tabulations of IDA use and type at baseline and at 7-year follow-up).

Additionally, generalized linear models with gamma distribution and log link (iPD, iCAL) and fractional response models (iPlaque, iBOP, iPD4mm) were examined to retrieve marginal predictions for interpretation of effect sizes (see Table A1, supporting information). Effect estimates were presented as exp(β) with corresponding 95% CIs and interpreted as a percent change of the outcome (Manning et al., 2005). Confounders were chosen according to the modified disjunctive cause criterion (VanderWeele, 2019). Accordingly, we performed inverse probability treatment weighting (IPTW) using baseline levels of the outcome (except for change score analyses), age, sex, school education, equivalence household income, smoking, known diabetes mellitus, haemoglobin A1c, body mass index, dental visit within the last 12 months, toothbrushing frequency, powered tooth brush use, self-reported periodontal treatment within the last 5 years (except for iSS) and physical activity (except for iSS). We estimated a generalized propensity score using a convex Super Learner and adjusted for confounding using IPTW (Kreif et al., 2015). Super learning has been shown to provide optimal bias–variance trade-off by weighting a combination of several prediction algorithms (Benkeser et al., 2020). We assessed balance using weighted correlations between each covariate and the continuous exposure (Figure A1, supporting information), where standardized mean differences (SMDs) <0.10 and <0.25 indicate good and adequate balance, respectively. Variance ratios were additionally checked (good: 0.8–1.2; adequate: 0.5–2.0). Models were additionally adjusted for unbalanced covariates (Chesnaye et al., 2022).

We also assessed moderation effects using the CDC/AAP case definition (no or mild vs. moderate or severe; p for interaction <.10 indicates effect modification) for periodontal outcome variables. IPTW models were separately determined and evaluated within levels of the effect moderator. Weights were combined and weighted models including interaction terms were estimated. For all combinations of IDA use and type with the effect moderator, predicted means with 95% CIs were reported. p-Values for average marginal effects versus IDA non-users (ref.) were calculated.

To address the possibility of selection bias due to attrition, we multiply imputed missing values (Groenwold et al., 2012) using (i) non-linear additive transformation and imputation functions ('aregImpute') and (ii) chained equations ('mice' in R; 'mi impute chained' in Stata), generating 20 datasets each. We did not impute missing teeth at 7-year follow-up and at baseline interview items if participants refused examinations. Using imputed data, regression adjustment was performed, including the same covariates as for IPTW, modelling continuous variables as restricted cubic splines with three knots to allow for non-linearity. Robust sandwich variance estimates were incorporated into Rubin's rule.

A two-sided $p < .05$ was considered statistically significant. All analyses were performed using Stata/SE Version 17.0 (StataCorp, 2021), R 4.1.2 (R Core Team, 2021) and the rms, WeightIt, survey, cobalt, mice, MatchThem and predictions packages.

3 | RESULTS

3.1 | Characteristics of study participants

Table 1 shows the baseline characteristics of SHIP-TREND-0 participants stratified by IDA use and type. Risk factor profiles differed significantly across the four groups. Wooden stick users and interdental brushers were older and less often current smokers than IDA non-users and flossers. In contrast, flossers and interdental brushers were less often male and showed better oral hygiene and care patterns compared with IDA non-users and wooden stick users. Notably, percentages of powered tooth brush usage were about 8% higher in flossers and interdental brushers.

Profiles of dental variables stratified by IDA use and type are given in Table 2. Change in periodontal variables differed across IDA types. For example, mean iPD reduced in all IDA subgroups. While mean iCAL remained unchanged in IDA non-users, a decrease was observed in wooden stick users (from 2.63 to 2.46 mm), flossers (from 1.77 to 1.65 mm) and interdental brushers (from 2.37 to 2.26 mm). The iSS decreased by 2 and the number of missing teeth increased by 1 tooth (medians) in all subgroups.

3.2 | Effects contrasting wooden stick users, dental flossers and interdental brushers with IDA non-users

In ANCOVA and change score analyses, we compared wooden stick users, flossers and interdental brushers with IDA non-users (top part of Table 3). The odds of having higher iPlaque levels was 32% (OR = 0.68) lower for flossers than for IDA non-users. Furthermore, in terms of similar trend (but without statistical significance), flossing had positive effects on follow-up levels of iBOP (OR = 0.79), mean iPD (OR = 0.78) and mean iCAL (OR = 0.77). Beneficial effects of interdental brushing in terms of reduced 7-year follow-up levels were found for iPlaque (OR = 0.73), iBOP (OR = 0.69) and mean iPD (OR = 0.81). Wood stick users showed negative effects on iPlaque, iBOP and the CDC/AAP case definition. All IDA types were non-significantly associated with the iSS and the number of missing teeth. Finally, applying change score analyses, flossing reduced tooth loss incidence (IRR = 0.71) compared with IDA non-users.

Including only participants with identical self-reported information of IDA use and type at baseline and at 7-year follow-up (bottom part of Table 3), results were overall confirmative, showing smaller ORs for effects of flossing and interdental brushing on iPlaque, iBOP

TABLE 1 Baseline characteristics (SHIP-TREND-0) for participants present in the final model for the number of missing teeth in total and stratified by interdental cleaning aids usage and type.

	IDA non-user	Wooden stick user	Dental flosser	Interdental brusher	*p*-Value[a]
N	1576	156	230	262	
Age, years	47 (37; 58)	57 (47; 64)	47 (37; 56)	56 (45; 64)	<.001
Male sex, yes	833 (52.9%)	83 (53.2%)	72 (31.3%)	95 (36.3%)	<.001
School education					
<10 years	186 (11.8%)	26 (16.7%)	16 (7.0%)	43 (16.4%)	
10 years	880 (55.8%)	90 (57.7%)	126 (54.8%)	142 (54.2%)	
>10 years	510 (32.4%)	40 (25.6%)	88 (38.3%)	77 (29.4%)	.008
Household equivalence income, € ‡	1450 (1096; 1803)	1184 (836; 1761)	1450 (1096; 2050)	1450 (1096; 1803)	.006
Smoking status					
Never smoker	585 (37.1%)	60 (38.5%)	92 (40.0%)	114 (43.5%)	
Former smoker	600 (38.1%)	61 (39.1%)	90 (39.1%)	111 (42.4%)	
Current smoker	391 (24.8%)	35 (22.4%)	48 (20.9%)	37 (14.1%)	.017
Brushing ≥2 times/day, yes	1338 (84.9%)	133 (85.3%)	215 (93.5%)	249 (95.0%)	<.001
Toothbrush usage					
Manual toothbrush	1135 (72.0%)	113 (72.4%)	148 (64.4%)	169 (64.5%)	
Powered toothbrush	435 (27.6%)	41 (26.3%)	82 (35.6%)	91 (34.7%)	
None	6 (0.4%)	2 (1.3%)	0 (0%)	2 (0.8%)	.019
Dental visit within the last 12 months, yes	1426 (90.5%)	138 (88.5%)	220 (95.7%)	258 (98.5%)	<.001
Gum treatment within last 5 years, yes	278 (17.6%)	33 (21.2%)	50 (21.7%)	94 (35.9%)	<0.001
Known diabetes mellitus, yes	86 (5.5%)		4 (1.7%)	18 (6.9%)	.003
Haemoglobin A1c, %	5.2 (4.8; 5.5)	5.3 (4.9; 5.6)	5.1 (4.8; 5.4)	5.3 (4.9; 5.6)	.005
Body mass index, kg/m^2	27.1 (24.2; 30.1)	27.8 (25.8; 31.6)	25.7 (23.4; 28.8%)	26.9 (23.9; 29.7)	<.001
Physical activity, yes	1100 (69.8%)	110 (70.5%)	188 (81.7%)	205 (78.2%)	<.001
Last time consulting a doctor (except for a dentist)?					
Within the last 4 weeks	597 (37.9%)	63 (40.4%)	92 (40.0%)	97 (37.0%)	
Within the last 2–12 months	775 (49.2%)	80 (51.3%)	105 (45.7%)	149 (56.9%)	
More than a year ago	204 (12.9%)	13 (8.3%)	33 (14.3%)	16 (6.1%)	.015
Participation in cancer screening, yes	922 (%)	114 (%)	161 (%)	205 (%)	<.001

Note: Data are presented as median (25%; 75% quantiles) or as number (percentage).
Abbreviation: IDA, interdental cleaning aid.
[a]Kruskal–Wallis test or Chi-squared test, testing for distributional differences across all four groups.

and mean iPD; effects were slightly (but non-significantly) more pronounced for interdental brushing than for flossing. Effects of flossing on tooth loss were more pronounced (IRR = 0.56). Also, harmful effects of wooden stick and IDB use on tooth loss seen in the main analysis (IRR 1.45 and 1.44, respectively, top panel of Table 3) diminished.

Using imputed data (Table 4), beneficial effects of flossing for iPlaque, iBOP, mean iPD and mean iCAL in terms of reduced 7-year follow-up levels were consistently confirmed. Also, positive effects of interdental brushing on iPlaque and iBOP were confirmed. In contrast, interdental brushing was associated with higher odds of higher levels of the CDC/AAP case definition (OR = 1.42 and 1.52). However, effects of flossing on incident tooth loss (change score analyses) diminished completely.

Use of alternative modelling strategies yielded confirmative results (Table A1, supporting information). Flossing was marginally associated with a 25% decrease in iPlaque levels, while interdental brushing was significantly associated with a 28% decrease in iPlaque levels and a 23% decrease in iBOP levels.

3.3 | Moderation of effects by the CDC/AAP case definition

The baseline CDC/AAP case definition status did not moderate any effects of IDA use and type on periodontal variables (*p* for interaction >.10; Table 5). Nevertheless, we have tabulated predicted means of periodontal variables for all combinations of IDA use and type with the baseline CDC/AAP case definition status. Flossing and interdental brushing were more effective in reducing iPlaque in participants with moderate or severe periodontitis (by 11.6% and 9.4%, respectively),

TABLE 2 Baseline (SHIP-TREND-0) and 7-year follow-up (SHIP-TREND-1) dental data stratified by baseline interdental aids usage and type.

		IDA non-user		Wooden stick		Dental flosser		Interdental brusher		
		N	*N* (%) or median (Q25%; Q75%)	*N*	*N* (%) or median (Q25%; Q75%)	*N*	*N* (%) or median (Q25%; Q75%)	*N*	*N* (%) or median (Q25%; Q75%)	*p*-Value[a]
iPlaque, %	Baseline	1502	8.3 (0; 33.3)	149	10.0 (0; 33.3)	227	0 (0; 20.0)	243	8.3 (0; 33.3)	.0001
	Follow-up		16.7 (0; 41.7)		25.0 (12.5; 50.0)		8.3 (0; 25.0)		16.7 (0; 33.3)	.0001
iBOP, %	Baseline	1474	25.0 (8.3; 50.0)	147	25 (8.3; 50.0)	224	16.7 (0; 33.3)	241	16.7 (8.3; 40.0)	.0015
	Follow-up		16.7 (0; 33.3)		16.7 (8.3; 37.5)		8.3 (0; 25.0)		10.0 (0; 25.0)	.0001
Mean iPD, mm	Baseline	1478	2.75 (2.45; 3.18)	147	2.85 (2.57; 3.39)	224	2.57 (2.35; 2.83)	240	2.71 (2.39; 3.18)	.0001
	Follow-up		2.61 (2.35; 2.96)		2.68 (2.39; 3.10)		2.45 (2.22; 2.75)		2.57 (2.25; 2.98)	.0001
% sites with iPD ≥4 mm, %	Baseline	1478	9.1 (0; 29.2)	147	15.0 (4.2; 35.7)	224	3.8 (0; 12.0)	240	11.3 (3.7; 25.0)	.0001
	Follow-up		7.1 (0; 21.4)		10.7 (0; 27.3)		3.8 (0; 11.1)		8.3 (0; 21.4)	.0001
Mean iCAL, mm	Baseline	1397	1.85 (1.14; 2.96)	143	2.63 (1.75; 3.67)	216	1.77 (1.04; 2.69)	230	2.37 (1.55; 3.56)	.0001
	Follow-up		1.88 (1.50; 2.65)		2.46 (1.78; 3.29)		1.65 (1.29; 2.29)		2.26 (1.63; 3.41)	.0001
CDC/AAP case definition	Baseline	1376		139		212		226		
No/mild periodontitis			761 (55.3%)		54 (38.9%)		137 (64.6%)		74 (32.7%)	
Moderate periodontitis			425 (30.9%)		67 (48.2%)		61 (28.8%)		114 (50.4%)	
Severe periodontitis			190 (13.8%)		18 (12.9%)		14 (6.6%)		38 (16.8%)	<.001
CDC/AAP case definition	Follow-up	1376		139		212		226		
No/mild periodontitis			834 (60.6%)		54 (38.9%)		151 (71.2%)		92 (40.7%)	
Moderate periodontitis			421 (30.6%)		67 (48.2%)		44 (20.8%)		99 (43.8%)	
Severe periodontitis			121 (8.8%)		18 (12.9%)		17 (8.0%)		35 (15.5%)	<.001
Number of interdental sound surfaces	Baseline	1520	16 (10; 22)	149	14 (8; 19)	228	16 (10; 21)	246	13 (8; 18)	.0001
	Follow-up		14 (9; 21)		12 (6; 18)		14 (9.5; 20)		11.5 (7; 17)	.0001
Number of missing teeth	Baseline	1576	3 (1; 7)	156	4 (2; 9)	230	2 (1; 5)	262	5 (2; 9)	.0001
	Follow-up		4 (1; 9)		5 (2; 11)		3 (1; 6)		6 (2; 11)	.0001

Note: Data are presented as *N* (%) or median (25%; 75% quantiles).
Abbreviations: AAP, American Academy of Periodontology; CDC, Centers for Disease Control and Prevention; iBOP, percentage of interdental sites with bleeding on probing; iCAL, interdental clinical attachment level; IDA, interdental cleaning aids; iPD, interdental probing depth; iPlaque, percentage of interdental sites with plaque.
[a]Kruskal–Wallis test or Chi-squared test, testing for distributional differences across all four groups.

TABLE 3 Confounder-adjusted associations between different types of interdental cleaning aids (IDAs) users with non-users of IDAs (reference) and oral health variables in ANCOVA and change score models using complete case data of the Study of Health in Pomerania.

		IDA non-user	Wooden stick user		Dental flosser		Interdental brusher	
Outcome variable	*N* obs.	OR, *β* or IRR	OR, *β* or IRR (95% CI)	*p*-Value	OR, *β* or IRR (95% CI)	*p*-Value	OR, *β* or IRR (95% CI)	*p*-Value
Including all participants with self-reported information on IDA use and type at baseline								
ANCOVA								
iPlaque, %	2121	1.00 (ref.)	1.78 (1.38; 2.30)	<.0001	0.68 (0.50; 0.94)	.018	0.73 (0.57; 0.93)	.010
iBOP, %	2086	1.00 (ref.)	1.51 (1.06; 2.15)	.024	0.79 (0.56; 1.12)	.183	0.69 (0.53; 0.89)	.005
Mean iPD, mm	2089	1.00 (ref.)	1.10 (0.77; 1.55)	.608	0.78 (0.54; 1.11)	.163	0.81 (0.60; 1.10)	.173
% sites with iPD ≥4 mm, %	2089	1.00 (ref.)	1.33 (0.96; 1.84)	.085	0.81 (0.56; 1.17)	.258	1.04 (0.79; 1.37)	.761
Mean iCAL, mm	1986	1.00 (ref.)	0.96 (0.58; 1.58)	.869	0.77 (0.54; 1.11)	.166	1.27 (0.94; 1.70)	.117
CDC/AAP case definition	1953	1.00 (ref.)	1.53 (1.06; 2.21)	.024	0.85 (0.56; 1.28)	.431	1.21 (0.87; 1.69)	.266
Number of interdental sound surfaces	2143	0.00 (ref.)	−1.15 (−2.43; 0.13)	0.079	0.41 (−0.65; 1.46)	0.450	−0.48 (−1.51; 0.55)	.360
Number of missing teeth	2224	1.00 (ref.)	1.37 (0.99; 1.89)	0.054	0.99 (0.75; 1.31)	0.954	1.28 (0.99; 1.66)	.064
Change score analysis								
Tooth loss	2224	1.00 (ref.)	1.45 (1.29; 1.63)	<0.001	0.71 (0.63; 0.79)	<0.001	1.44 (1.31; 1.59)	<.001
Including only participants with identical self-reported information on IDA use and type at baseline and at 7-year follow-up								
ANCOVA								
iPlaque, %	1370	1.00 (ref.)	1.02 (0.56; 1.85)	.941	0.64 (0.40; 1.03)	.068	0.54 (0.37; 0.77)	.001
iBOP, %	1352	1.00 (ref.)	1.04 (0.62; 1.75)	.894	0.62 (0.40; 0.96)	.033	0.59 (0.41; 0.85)	.005
Mean iPD, mm	1355	1.00 (ref.)	1.76 (0.98; 3.15)	.058	0.64 (0.36; 1.12)	.120	0.71 (0.46; 1.08)	.112
% sites with iPD ≥4 mm, %	1355	1.00 (ref.)	1.79 (0.98; 3.29)	0.059	0.58 (0.31; 1.10)	0.096	0.91 (0.62; 1.32)	.608
Mean iCAL, mm	1286	1.00 (ref.)	1.46 (0.47; 4.51)	.516	0.70 (0.39; 1.24)	.222	1.13 (0.75; 1.70)	.553
CDC/AAP case definition	1262	1.00 (ref.)	1.61 (0.65; 3.98)	.299	0.78 (0.37; 1.68)	.531	1.08 (0.72; 1.60)	.717
Number of interdental sound surfaces	1388	0.00 (ref.)	−0.11 (−0.72; 0.50)	.719	0.46 (0.08; 0.84)	.018	−0.23 (−0.54; 0.07)	.139
Number of missing teeth	1398	1.00 (ref.)	1.08 (0.55; 2.11)	.833	0.96 (0.62; 1.49)	.867	1.26 (0.88; 1.80)	.206
Change score analysis								
Tooth loss	1398	1.00 (ref.)	0.54 (0.28; 1.07)	.059	0.56 (0.36; 0.88)	.011	0.98 (0.73; 1.33)	.885

Note: Confounder-adjustment using inverse probability treatment weighting. Models: iPlaque, iBOP, % sites with iPD ≥4 mm, mean iPD, mean iCAL, CDC/AAP case definition, number of missing teeth: ordinal logistic model; number of interdental sound surfaces: linear model; tooth loss: negative binomial model. Adjusted for baseline values of the outcome (except for change score analysis), age, sex, education, household equivalence income, smoking, body mass index, known diabetes mellitus, haemoglobin A1c, toothbrushing frequency, dental visits in the last 12 months and powered tooth brush usage; models for periodontal variables were additionally adjusted for physical activity and gum treatment within the last 5 years.

Abbreviations: AAP, American Academy of Periodontology; CDC, Centers for Disease Control and Prevention; CI, confidence interval; iBOP, percentage of interdental sites with bleeding on probing; iCAL, interdental clinical attachment level; iPD; interdental probing depth; iPlaque, percentage of interdental sites with plaque; IRR, incidence rate ratio; *N*, number; OR, odds ratio; β, beta regression coefficient.

TABLE 4 Confounder-adjusted associations between different types of interdental cleaning aids users with non-users of interdental cleaning aids (reference) and oral health variables in ANCOVA and change score models ($N = 4080$) using multiply imputed data of the Study of Health in Pomerania.

Outcome variable	IDA non-user OR, β or IRR	Wooden stick user OR, β or IRR (95% CI)	Dental flosser OR, β or IRR (95% CI)	Interdental brusher OR, β or IRR (95% CI)
Using non-linear additive transformation and imputation function				
iPlaque, %	1.00 (ref.)	1.27 (0.94; 1.71)	0.70 (0.53; 0.92)	0.71 (0.55; 0.91)
iBOP, %	1.00 (ref.)	1.06 (0.81; 1.39)	0.72 (0.57; 0.90)	0.75 (0.58; 0.95)
Mean iPD, mm	1.00 (ref.)	1.03 (0.75; 1.40)	0.75 (0.59; 0.95)	0.89 (0.71; 1.12)
% sites with iPD ≥4 mm, %	1.00 (ref.)	1.15 (0.86; 1.53)	0.81 (0.63; 1.03)	1.05 (0.85; 1.29)
Mean iCAL, mm	1.00 (ref.)	0.88 (0.66; 1.16)	0.69 (0.55; 0.87)	1.17 (0.93; 1.47)
CDC/AAP case definition	1.00 (ref.)	1.17 (0.82; 1.68)	0.88 (0.65; 1.19)	1.42 (1.06; 1.90)
Number of interdental sound surfaces	0.00 (ref.)	−0.36 (−0.52; −0.02)	0.06 (−0.09; 0.37)	0.13 (−0.20; 0.21)
Number of missing teeth	1.00 (ref.)	1.23 (0.91; 1.66)	1.06 (0.88; 1.29)	1.24 (0.99; 1.55)
Using multivariate imputation by chained equations				
iPlaque, %	1.00 (ref.)	1.16 (0.88; 1.54)	0.68 (0.54; 0.86)	0.71 (0.56; 0.92)
iBOP, %	1.00 (ref.)	1.06 (0.79; 1.43)	0.75 (0.62; 0.92)	0.75 (0.60; 0.93)
Mean iPD, mm	1.00 (ref.)	0.98 (0.75; 1.28)	0.83 (0.65; 1.05)	0.96 (0.75; 1.24)
% sites with iPD ≥4 mm, %	1.00 (ref.)	1.09 (0.82; 1.44)	0.91 (0.70; 1.17)	1.14 (0.92; 1.42)
Mean iCAL, mm	1.00 (ref.)	0.84 (0.63; 1.11)	0.76 (0.59; 0.98)	1.25 (1.01; 1.55)
CDC/AAP case definition	1.00 (ref.)	1.14 (0.83; 1.55)	1.00 (0.74; 1.35)	1.52 (1.17; 1.96)
Number of interdental sound surfaces	0.00 (ref.)	−0.41 (−0.46; 0.07)	0.08 (−0.14; 0.30)	−0.11 (−0.28; 0.12)
Number of missing teeth	1.00 (ref.)	1.28 (0.96; 1.70)	1.07 (0.88; 1.30)	1.37 (1.08; 1.73)
Change score analysis ($N = 4129$)				
Tooth loss	1.00 (ref.)	1.10 (0.84; 1.43)	0.91 (0.71; 1.16)	1.32 (1.06; 1.64)

Note: Confounder-adjustment using regression. Models: iPlaque, iBOP, % sites with iPD ≥4 mm, mean iPD, mean iCAL, CDC/AAP case definition, number of missing teeth: ordinal logistic model; number of interdental sound surfaces: linear model; tooth loss: negative binomial model. Adjusted for baseline values of the outcome (except for change score analysis), age, sex, education, household equivalence income, smoking, body mass index, known diabetes mellitus, haemoglobin A1c, toothbrushing frequency, dental visits in the last 12 months and powered tooth brush usage; models for periodontal variables were additionally adjusted for physical activity and gum treatment within the last 5 years. Continuous variables were modelled via restricted cubic splines with three knots.

Abbreviations: AAP, American Academy of Periodontology; CDC, Centers for Disease Control and Prevention; CI, confidence interval; iBOP, percentage of interdental sites with bleeding on probing; iCAL, interdental clinical attachment level; iPD; interdental probing depth; iPlaque, percentage of interdental sites with plaque; IRR, incidence rate ratio; *N*, number; OR, odds ratio; β, beta regression coefficient.

though effects were also significant in participants with no or mild periodontitis (by 6.4% and 5.0%, respectively). Effects of interdental brushing on iBOP were slightly more pronounced in participants with no or mild periodontitis (by 10.2%). With regard to mean iPD, effects of flossing and interdental brushing were comparable in participants with no or mild or with moderate or severe periodontitis (0.11–0.13 mm).

4 | DISCUSSION

4.1 | Main results

Using data from a large-scale prospective cohort study with on average 7.4 years of follow-up, the effects of IDA use and IDA type on the 7-year follow-up levels of a wide range of oral-health-related variables, namely plaque, gingival inflammation, periodontitis severity, coronal caries experience and tooth loss, were examined, making an important contribution to current knowledge. Flossing was associated with significantly reduced odds of higher 7-year follow-up levels of iPlaque by a factor of 32%. Marginal, but direction-consistent effects were observed for iBOP, mean iPD and mean iCAL. Beneficial effects of IDBs in terms of reduced odds for higher 7-year follow-up levels were found for iPlaque (by 27%) and iBOP (by 31%). Converted to predicted margins (Table A1, supporting information), flossing and interdental brushing resulted in 5%–6% lower means of iPlaque, 3%–5% lower means of iBOP and 0.05 mm lower means of mean iPD (for flossing) compared with IDA non-users. In change score analyses, flossing reduced the rate of tooth extractions by 29% compared with IDA non-users. None of the different IDA types was associated with coronal caries (iSS). Using imputed data, beneficial effects of dental flossing and interdental brushing were confirmed.

TABLE 5 Effect moderation by CDC/AAP case definition status (no/mild vs. moderate/severe periodontitis): Predicted means of oral health variables for combinations of the CDC/AAP case definition with interdental cleaning aids use and type using complete case data of the Study of Health in Pomerania.

Outcome variable	*N* obs.	CDC/AAP category	IDA non-user	Wooden stick user	Dental floss user	Interdental brush user	*p* for effect moderation
iPlaque, %	1038	No/mild	19.7 (17.8; 21.5)	24.1 (17.0; 31.3)	13.3 (9.8; 16.7)[a]	14.7 (10.0; 19.4)[a]	
	983	Moderate/severe	33.2 (31.0; 35.3)	37.1 (31.7; 42.4)	21.6 (16.4; 26.8)[a]	23.8 (20.0; 27.6)[a]	.910
iBOP, %	1031	No/mild	20.2 (18.6; 21.9)	22.7 (16.9; 28.4)	17.2 (13.7; 20.7)	10.0 (6.7; 13.3)[a]	
	966	Moderate/severe	24.0 (22.3; 25.8)	24.2 (20.0; 28.5)	18.7 (14.4; 23.0)	21.6 (18.3; 24.9)	.196
Mean iPD, mm	1030	No/mild	2.54 (2.50; 2.58)	2.62 (2.48; 2.76)	2.43 (2.35; 2.52)[a]	2.42 (2.31; 2.52)[a]	
	967	Moderate/severe	2.95 (2.90; 2.99)	2.84 (2.72; 2.96)	2.82 (2.70; 2.95)	2.82 (2.73; 2.91)[a]	.340
% sites with iPD ≥4 mm, %	1030	No/mild	7.3 (6.3; 8.3)	10.3 (6.3; 14.5)	5.8 (3.8; 7.9)	6.6 (3.9; 9.3)	
	967	Moderate/severe	22.9 (21.2; 24.7)	21.1 (16.9; 25.4)	17.5 (13.3; 21.8)	19.1 (15.8; 22.3)	.438
Mean iCAL, mm	1023	No/mild	1.82 (1.76; 1.87)	1.79 (1.58; 1.99)	1.69 (1.58; 1.81)[a]	1.75 (1.59; 1.91)	
	948	Moderate/severe	2.75 (2.67; 2.84)	2.72 (2.48; 2.95)	2.58 (2.34; 2.81)	2.82 (2.64; 3.00)	.826

Note: Confounder-adjustment using inverse probability treatment weighting performed within strata of the effect moderator. Models: iPlaque, iBOP, % sites with iPD ≥4 mm: Fractional response model; Mean iPD, mean iCAL: GLM with gamma distribution and log link. Adjusted for baseline values of the outcome, age, sex, education, household equivalence income, smoking, body mass index, known diabetes mellitus, haemoglobin A1c, toothbrushing frequency, dental visits in the last 12 months, and powered tooth brush usage; models for periodontal variables were additionally adjusted for physical activity and gum treatment within the last 5 years.
Abbreviations: AAP, American Academy of Periodontology; CDC, Centers for Disease Control and Prevention; CI, confidence interval; iBOP, percentage of interdental sites with bleeding on probing; iCAL, interdental clinical attachment level; iPD; interdental probing depth; iPlaque, percentage of interdental sites with plaque; IRR, incidence rate ratio; *N*, number; OR, odds ratio; β, beta regression coefficient.
[a]$p < .05$ for average marginal effects versus IDA non-users.

4.2 | Interdental cleaning potentially reduces plaque, gingival inflammation and periodontal inflammation

In SHIP-TREND, dental flossing and interdental brushing noticeably reduced 7-year follow-up levels of iPlaque and iBOP, while marginal effects were observed for mean iPD, thereby reflecting the aetiology from plaque accumulation to gingival inflammation to periodontitis severity. Our study contributes to the evidence stemming from clinical (Amarasena et al., 2019; Berchier et al., 2008; Hoenderdos et al., 2008; Kotsakis et al., 2018; Poklepovic et al., 2013; Salzer et al., 2015; Sambunjak et al., 2019; Slot et al., 2008; Worthington et al., 2019) and large-scale epidemiological studies (Cepeda et al., 2017; Chaffee et al., 2020; Kim & Han, 2021; Lang et al., 1995; Marchesan et al., 2018, 2020; Pitchika et al., 2021), confirming that regular effective flossing and interdental brushing can promote gingival and periodontal health. Nevertheless, limited, and partly low-quality, evidence from clinical and epidemiological studies warrants further research.

4.3 | Effects of dental flossing and interdental brushing on attachment loss

In this study, we observed positive effects of flossing on mean iCAL, which were even more pronounced in participants with no or mild periodontitis (predicted means of 1.69 vs. 1.82 mm in IDA non-users; Table 5). This is in line with a previous study which showed that subjects who exhibited acceptable flossing had less attachment loss (Lang et al., 1995). Also, analyses of the 65+ Piedmont Study (Marchesan et al., 2020) showed that elderly flossers had a lower percentage of iCAL ≥ 3 mm (38.2% vs. 48.8%) compared with non-flossers. Furthermore, frequent flossing (4–7 times/week) was associated with lower extents compared with less frequent flossing.

Interestingly, some models indicated an opposite effect on iCAL for interdental brushing (Tables 4 and A1, supporting information). Furthermore, in participants with moderate or severe periodontitis, predicted mean iCAL at follow-up was higher in IDB users than in IDA non-users (2.82 vs. 2.75 mm; Table 5). The reasons for this can be seen in the following facts. First, we did not have data on whether our participants were instructed in interdental cleaning by prophylaxis assistants or dental hygienists. The recommendation to floss the interproximal area when the mouth is primarily healthy is widespread because there must be enough space to allow the passage of an IDB without traumatizing the gingiva (Poklepovic et al., 2013). It is more likely that participants with periodontal problems generally have larger interdental spaces and have previously been instructed by prophylaxis assistants or dental hygienists to use IDBs instead of floss, regardless of whether they received periodontal treatment. If the conditions are met, IDBs are more effective than dental floss, especially on the concave tooth surfaces (Chapple et al., 2015; Schiffner et al., 2007). A study on the patient's compliance for interdental care reported that subjects were more than twice as likely to use IDBs compared with floss. They were also willing to use IDBs on a daily basis (Imai & Hatzimanolakis, 2010), whereas daily flossing showed low adherence among patients (Asadoorian & Locker, 2006). However, if IDBs are not used adequately, they can be harmful to the soft tissue. Similarly, for wood stick users, a review also reported potential soft-tissue trauma (Sambunjak et al., 2011). Taken together, results potentially indicate incorrect application of floss and IDBs and thus a need for general training for the use of interdental care products in dental practices.

4.4 | Interdental cleaning might be beneficial for coronal caries

The generally observed increase in caries-free surfaces was assumed to be mainly attributed to fluoridated toothpastes (Walsh et al., 2019), while the use of IDAs was so far regarded as a mainstay for preventing periodontitis. However, as the caries demineralization process is closely linked to plaque accumulation and biofilm development, and as in adults approximal surfaces are most affected, we assumed that we might detect beneficial long-term effects of plaque-control through interdental care on caries experience (Pitchika et al., 2021). However, while in SHIP-TREND, effect estimates for the iSS were non-significant, allowing no further conclusions, previously published studies suggest that, when performed effectively, flossing might potentially be an efficacious approach to prevent dental (proximal) caries (S. J. Kim, Lee, et al., 2022). Specifically, IDA use and flossing were cross-sectionally associated with lower levels of coronal (Marchesan et al., 2018, 2020) and proximal caries (S. J. Kim, Lee, et al., 2022). Furthermore, changes in IDA use explained a sizeable portion of changes in the number of sound surfaces in different age cohorts (Pitchika et al., 2021, 2022).

4.5 | Evidence for the endpoint tooth loss is inconsistent

SHIP-TREND results were mixed: flossing reduced tooth loss incidence by 29% compared with IDA non-users, while ANCOVA models indicated non-significant associations of IDAs with the number of missing teeth. Unfortunately, there is limited epidemiological data regarding the effects of IDA use on tooth loss. One of the few observational studies that served long-term data reported that baseline and long-term flossing in combination with brushing (and prophylaxis) was associated with increased baseline tooth counts and less tooth loss (Kressin et al., 2003). Later IDA use was cross-sectionally associated with fewer missing teeth (Marchesan et al., 2018), and flossing was associated with less 5-year tooth loss (Marchesan et al., 2020). Furthermore, changes in IDA use significantly contributed to observed changes in the number of teeth over the study period (Pitchika et al., 2021, 2022). In contrast, no prevention of tooth extractions by interdental cleaning in the following 12 months could be demonstrated using data from the Population Assessment of Tobacco and Health Study (adults aged 18+ years) (Chaffee et al., 2020), which is probably due to the short follow-up period. Thus, evidence for tooth loss is inconsistent, and further large-scale long-term surveys are demanded.

4.6 | Clinical relevance of interdental cleaning

Assessing the effects of IDA use on the progression of caries, gingivitis and periodontitis is complex and difficult. However, all the oral diseases mentioned here have one thing in common: they are caused by a pathogenic biofilm. And to prevent biofilm-induced oral diseases, patients should be encouraged to improve their oral hygiene. This includes regular toothbrushing (preferably using powered tooth brushes) and interdental care for mechanical plaque removal at home and (at least) yearly dental check-ups with a professional dental cleaning. In this study, the protective effect of dental floss and interdental brushes on iPlaque was particularly evident in periodontitis cases (Table 5), while, surprisingly, the effect of interdental brushing on iBOP was more pronounced in non-periodontitis cases. Furthermore, flossing and interdental brushing were equally effective in reducing mean iPD both in non-periodontitis and periodontitis cases (0.11–0.13 mm), which roughly corresponds to the natural 10-year increments of the mean PD in this cohort (Schutzhold et al., 2015). Encouragingly, IDA use among adults increased from 29.5% to 62.0% and among seniors from 7.8% to 49.7% between 1997 and 2014 (Pitchika et al., 2021), pointing to a substantially increased awareness of the German population for the need to interdentally clean their teeth. Imfeld has shown, however, that there is a big difference between the reported use of IDAs and their sales figures (Imfeld, 2010). Further, the reported frequencies of IDA use provide no information about regularity and correct use. Flossing, for example, is very difficult and technically demanding (Wolffe, 1976) and most people do not do it correctly (Lang et al., 1995). But even IDBs and wooden sticks are not easy to use for every patient. Therefore, it is very important that patients are motivated not only to use IDAs but also to use them correctly. Besides instruction in right timing, frequency, correct insertion and handling of IDAs (Carrouel et al., 2016), the dental hygienists have to install a self-efficacy, planning and self-regulatory mechanism in order to make interdental cleaning a daily behaviour (Hamilton et al., 2017).

4.7 | Strengths and limitations

The study had several strengths. First, this is one of the very few large-scale cohort studies evaluating the effects of IDA use on various oral disease variables, ranging from plaque to gingival inflammation, periodontitis severity, caries and tooth loss. Second, examinations were conducted according to high standards, and examiners were continuously trained and calibrated, ensuring high data quality. Third, we conducted IPTW to control for confounding; while IPTW summarizes all characteristics into a single covariate, it can be combined with advanced regression methods.

Among the limitations, there could be a selection bias, as mainly healthier subjects with better compliance and health awareness might have been selected. To tackle this issue, we multiplied imputed missing values, yielding confirmative results regarding direction and strength of effect estimates. Second, caries and periodontal measurements were recorded using a half-mouth protocol, which is known to underestimate disease severity (Heaton et al., 2018). For measurements such as mean iPD/iCAL, the level of bias associated with half-mouth partial recordings is nevertheless small. In general, effect estimates are shifted towards the null effect (Akinkugbe et al., 2015). Third, we do not know how long (prevalent user bias) and with what regularity IDAs were used before the baseline. Although participants reported using IDAs 'daily', detailed information was not available. Such information would have been relevant, however, as frequent use of IDAs was associated with improved periodontal health (Lang et al., 1995; Marchesan et al., 2018). Furthermore, as the quantity and quality of interdental brushings is often overestimated in self-reports (Imfeld, 2010), the effects of daily IDA use may even have been underestimated in this study, assuming a dose–response relationship. Fourth, methodological issues related to measurements of periodontal variables, including measuring inaccuracies and non-use of magnifying classes, might explain comparably low levels of iPlaque in this study. Fifth, we modelled effects of baseline IDA status and type on 7-year follow-up levels of oral health variables, thereby ignoring potential changes in the type of IDA used. Indeed, 29.3% of IDA non-users turned into regular IDA users, while 26.6% of regular IDA users turned into IDA non-users (Table A2). We thus repeated the analysis by including only participants with identical self-reported information on IDA use and type at baseline and at 7-year follow-up (Table 3), revealing that effects of flossing and interdental brushing were even more pronounced.

5 | CONCLUSIONS

We provide further evidence in favour of recommending IDAs, specifically dental floss and IDBs, in combination with daily toothbrushing. Using data from the population-based SHIP-TREND cohort, we found beneficial effects of IDA use on plaque, gingival inflammation and periodontitis severity at the 7-year follow-up. However, no conclusions for hard endpoints like caries and the number of missing teeth could be derived. Nevertheless, current evidence implies that self-reported home use of IDAs, even if quality and quantity is unknown in most cases, may prevent plaque accumulation, which is a necessary cause of caries, gingivitis and initially of periodontitis. Thus, recommending IDAs in dental practice could be a promising approach to prevent caries and periodontal diseases. Nevertheless, further large-scale, long-term epidemiological studies, including also hard endpoints like tooth loss, and well-designed long-term randomized clinical trials are needed.

AUTHOR CONTRIBUTIONS

Birte Holtfreter, Thomas Kocher and Alexander Welk substantially contributed to the conception or design of the work. Birte Holtfreter, Elena Conrad, Thomas Kocher, Sebastian-Edgar Baumeister, Henry Völzke and Alexander Welk contributed to the acquisition, analysis or interpretation of data. Birte Holtfreter, Elena Conrad and Alexander Welk drafted the work. Sebastian-Edgar Baumeister, Thomas Kocher and Henry Völzke revised the work critically for important intellectual content. All authors approved the final version of the manuscript and are accountable for all aspects of the work.

ACKNOWLEDGEMENT

Open Access funding enabled and organized by Projekt DEAL.

FUNDING INFORMATION

SHIP is part of the Community Medicine Research Network of the University Medicine Greifswald, which is supported by the German Federal State of Mecklenburg-West Pomerania. Birte Holtfreter was supported by the Deutsche Gesellschaft für Parodontologie (DGParo) e.V.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from Forschungsverbund Community Medicine. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from https://transfer.ship-med.uni-greifswald.de/FAIRequest/login with the permission of Forschungsverbund Community Medicine.

ETHICS STATEMENT

SHIP-TREND was positively evaluated by the ethics committee of the University of Greifswald (SHIP-TREND-0: BB 39/08a; SHIP-TREND-1: BB 174/15). All participants were informed about the study protocol and signed the informed consent and the privacy statement.

ORCID

Birte Holtfreter https://orcid.org/0000-0002-6541-3127
Elena Conrad https://orcid.org/0009-0004-2409-052X
Thomas Kocher https://orcid.org/0000-0001-9605-2822
Sebastian-Edgar Baumeister https://orcid.org/0000-0002-9391-6602
Henry Völzke https://orcid.org/0000-0001-7003-399X
Alexander Welk https://orcid.org/0000-0002-0279-6239

REFERENCES

Akinkugbe, A. A., Saraiya, V. M., Preisser, J. S., Offenbacher, S., & Beck, J. D. (2015). Bias in estimating the cross-sectional smoking, alcohol, obesity and diabetes associations with moderate-severe periodontitis in the atherosclerosis risk in communities study: Comparison of full versus partial-mouth estimates. *Journal of Clinical Periodontology*, *42*(7), 609–621. https://doi.org/10.1111/jcpe.12425

Amarasena, N., Gnanamanickam, E. S., & Miller, J. (2019). Effects of interdental cleaning devices in preventing dental caries and periodontal diseases: A scoping review. *Australian Dental Journal*, *64*(4), 327–337. https://doi.org/10.1111/adj.12722

Asadoorian, J., & Locker, D. (2006). The impact of quality assurance programming: A comparison of two Canadian dental hygienist programs. *Journal of Dental Education*, *70*(9), 965–971.

Benkeser, D., Cai, W., & van der Laan, M. J. (2020). A nonparametric superefficient estimator of the average treatment effect. *Statistical Science*, *35*, 511–517. https://doi.org/10.1214/20-sts789

Berchier, C. E., Slot, D. E., Haps, S., & Van der Weijden, G. A. (2008). The efficacy of dental floss in addition to a toothbrush on plaque and parameters of gingival inflammation: A systematic review. *International Journal of Dental Hygiene*, *6*(4), 265–279. https://doi.org/10.1111/j.1601-5037.2008.00336.x

Carrouel, F., Llodra, J. C., Viennot, S., Santamaria, J., Bravo, M., & Bourgeois, D. (2016). Access to interdental brushing in periodontal healthy young adults: A cross-sectional study. *PLoS One*, *11*(5), e0155467. https://doi.org/10.1371/journal.pone.0155467

Cepeda, M. S., Weinstein, R., Blacketer, C., & Lynch, M. C. (2017). Association of flossing/inter-dental cleaning and periodontitis in adults. *Journal of Clinical Periodontology*, *44*(9), 866–871. https://doi.org/10.1111/jcpe.12765

Chaffee, B. W., Persai, D., & Vora, M. V. (2020). Interdental cleaning and oral health status in an adult cohort, 2015 to 2018. *Journal of Dental Research*, *99*(10), 1150–1156. https://doi.org/10.1177/0022034520926139

Chapple, I. L., Van der Weijden, F., Doerfer, C., Herrera, D., Shapira, L., Polak, D., Madianos, P., Louropoulou, A., Machtei, E., Donos, N., Greenwell, H., Van Winkelhoff, A. J., Kuru, B. E., Arweiler, N., Teughels, W., Aimetti, M., Molina, A., Montero, E., & Graziani, F. (2015). Primary prevention of periodontitis: Managing gingivitis. *Journal of Clinical Periodontology*, *42*(Suppl 16), S71–S76. https://doi.org/10.1111/jcpe.12366

Chesnaye, N. C., Stel, V. S., Tripepi, G., Dekker, F. W., Fu, E. L., Zoccali, C., & Jager, K. J. (2022). An introduction to inverse probability of treatment weighting in observational research. *Clinical Kidney Journal*, *15*(1), 14–20. https://doi.org/10.1093/ckj/sfab158

Donn, J. (2016). *Medical benefits of dental floss unproven*. AP News.

Figuero, E., Nobrega, D. F., Garcia-Gargallo, M., Tenuta, L. M., Herrera, D., & Carvalho, J. C. (2017). Mechanical and chemical plaque control in the simultaneous management of gingivitis and caries: A systematic review. *Journal of Clinical Periodontology*, *44*(Suppl 18), S116–S134. https://doi.org/10.1111/jcpe.12674

Glymour, M. M. (2022). Modelling change in a causal framework. *International Journal of Epidemiology*, *51*(5), 1615–1621. https://doi.org/10.1093/ije/dyac151

Groenwold, R. H., Donders, A. R., Roes, K. C., Harrell, F. E., Jr., & Moons, K. G. (2012). Dealing with missing outcome data in randomized trials and observational studies. *American Journal of Epidemiology*, *175*(3), 210–217. https://doi.org/10.1093/aje/kwr302

Hamilton, K., Bonham, M., Bishara, J., Kroon, J., & Schwarzer, R. (2017). Translating dental flossing intentions into behavior: A longitudinal investigation of the mediating effect of planning and self-efficacy on young adults. *International Journal of Behavioral Medicine*, *24*(3), 420–427.

Harrell, F. E. J. (2015). *Regression modeling strategies. With applications to linear models, logistic and ordinal regression, and survival analysis* (2nd ed.). Springer.

Heaton, B., Sharma, P., Garcia, R. I., & Dietrich, T. (2018). Evaluating periodontal disease misclassification mechanisms under partial-mouth recording protocols. *Journal of Clinical Periodontology*, *45*(4), 422–430. https://doi.org/10.1111/jcpe.12874

Hoenderdos, N. L., Slot, D. E., Paraskevas, S., & Van der Weijden, G. A. (2008). The efficacy of woodsticks on plaque and gingival inflammation: A systematic review. *International Journal of Dental Hygiene*, *6*(4), 280–289. https://doi.org/10.1111/j.1601-5037.2008.00335.x

Imai, P. H., & Hatzimanolakis, P. C. (2010). Encouraging client compliance for interdental care with the interdental brush: The client's perspective. *Canadian Journal of Dental Hygiene*, *44*(2), 56–60.

Imfeld, T. (2010). Zahnseide zur Mundgesundheitsprophylaxe? *Die Quintessenz*, *61*(9), 1041–1048.

Jordan, A. R., & Micheelis, W. (2016). *Fünfte Deutsche Mundgesundheitsstudie (DMS V)* (Vol. 35). Institut der Deutschen Zahnärzte (IDZ).

Kassebaum, N. J., Bernabe, E., Dahiya, M., Bhandari, B., Murray, C. J., & Marcenes, W. (2014). Global burden of severe periodontitis in 1990-2010: A systematic review and meta-regression. *Journal of Dental Research*, *93*(11), 1045–1053. https://doi.org/10.1177/0022034514552491

Kassebaum, N. J., Bernabe, E., Dahiya, M., Bhandari, B., Murray, C. J., & Marcenes, W. (2015). Global burden of untreated caries: A systematic review and metaregression. *Journal of Dental Research*, *94*(5), 650–658. https://doi.org/10.1177/0022034515573272

Kim, E. J., & Han, S. J. (2021). The effect of proximal cleaning devices on periodontal status in Korean adults between 2016 and 2018. *International Journal of Environmental Research and Public Health*, *18*(4), 2116. https://doi.org/10.3390/ijerph18042116

Kim, S. J., Lee, J. Y., Kim, S. H., & Cho, H. J. (2022). Effect of interdental cleaning devices on proximal caries. *Community Dentistry and Oral Epidemiology*, *50*(5), 414–420. https://doi.org/10.1111/cdoe.12690

Kim, Y. J., Gil, Y. M., Bae, K. H., Kim, S. J., Ihm, J., & Cho, H. J. (2022). The use of interdental cleaning devices and periodontal disease contingent on the number of remaining teeth in Korean adults. *Scientific Reports*, *12*(1), 13853. https://doi.org/10.1038/s41598-022-17885-7

Kotsakis, G. A., Lian, Q., Ioannou, A. L., Michalowicz, B. S., John, M. T., & Chu, H. (2018). A network meta-analysis of interproximal oral hygiene methods in the reduction of clinical indices of inflammation. *Journal of Periodontology*, *89*(5), 558–570. https://doi.org/10.1002/JPER.17-0368

Kreif, N., Grieve, R., Diaz, I., & Harrison, D. (2015). Evaluation of the effect of a continuous treatment: A machine learning approach with an application to treatment for traumatic brain injury. *Health Economics*, *24*(9), 1213–1228. https://doi.org/10.1002/hec.3189

Kressin, N. R., Boehmer, U., Nunn, M. E., & Spiro, A., 3rd. (2003). Increased preventive practices lead to greater tooth retention. *Journal of Dental Research*, *82*(3), 223–227. https://doi.org/10.1177/154405910308200314

Lang, W. P., Ronis, D. L., & Farghaly, M. M. (1995). Preventive behaviors as correlates of periodontal health status. *Journal of Public Health Dentistry*, *55*(1), 10–17. https://doi.org/10.1111/j.1752-7325.1995.tb02324.x

Lee, J. H., Shin, Y. J., Lee, J. H., & Kim, H. D. (2018). Association of toothbrushing and proximal cleaning with periodontal health among Korean adults: Results from Korea National Health and Nutrition Examination Survey in year 2010 and 2012. *Journal of Clinical Periodontology*, *45*(3), 322–335. https://doi.org/10.1111/jcpe.12846

Manning, W. G., Basu, A., & Mullahy, J. (2005). Generalized modeling approaches to risk adjustment of skewed outcomes data. *Journal of Health Economics*, *24*(3), 465–488. https://doi.org/10.1016/j.jhealeco.2004.09.011

Marchesan, J. T., Byrd, K. M., Moss, K., Preisser, J. S., Morelli, T., Zandona, A. F., Jiao, Y., & Beck, J. (2020). Flossing is associated with improved oral health in older adults. *Journal of Dental Research*, *99*(9), 1047–1053. https://doi.org/10.1177/0022034520916151

Marchesan, J. T., Morelli, T., Moss, K., Preisser, J. S., Zandona, A. F., Offenbacher, S., & Beck, J. (2018). Interdental cleaning is associated with decreased oral disease prevalence. *Journal of Dental Research*, *97*(7), 773–778. https://doi.org/10.1177/0022034518759915

Page, R. C., & Eke, P. I. (2007). Case definitions for use in population-based surveillance of periodontitis. *Journal of Periodontology*, *78*(7 Suppl), 1387–1399. https://doi.org/10.1902/jop.2007.060264

Pitchika, V., Jordan, R., Micheelis, W., Welk, A., Kocher, T., & Holtfreter, B. (2021). Impact of powered toothbrush use and interdental cleaning on oral health. *Journal of Dental Research*, *100*(5), 487–495. https://doi.org/10.1177/0022034520973952

Pitchika, V., Jordan, R. A., Norderyd, O., Rolander, B., Welk, A., Volzke, H., Holtfreter, B., & Kocher, T. (2022). Factors influencing tooth loss in European populations. *Journal of Clinical Periodontology*, *49*(7), 642–653. https://doi.org/10.1111/jcpe.13642

Poklepovic, T., Worthington, H. V., Johnson, T. M., Sambunjak, D., Imai, P., Clarkson, J. E., & Tugwell, P. (2013). Interdental brushing for the prevention and control of periodontal diseases and dental caries in adults.

Cochrane Database of Systematic Reviews, *12*, CD009857. https://doi.org/10.1002/14651858.CD009857.pub2
R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/
Salzer, S., Slot, D. E., Van der Weijden, F. A., & Dorfer, C. E. (2015). Efficacy of inter-dental mechanical plaque control in managing gingivitis—A meta-review. *Journal of Clinical Periodontology*, *42*(Suppl 16), S92–S105. https://doi.org/10.1111/jcpe.12363
Sambunjak, D., Nickerson, J. W., Poklepovic Pericic, T., Johnson, T. M., Imai, P., Tugwell, P., & Worthington, H. V. (2019). WITHDRAWN: Flossing for the management of periodontal diseases and dental caries in adults. *Cochrane Database of Systematic Reviews*, *4*(4), CD008829. https://doi.org/10.1002/14651858.CD008829.pub3
Sambunjak, D., Nickerson, J. W., Poklepovic, T., Johnson, T. M., Imai, P., Tugwell, P., & Worthington, H. V. (2011). Flossing for the management of periodontal diseases and dental caries in adults. *Cochrane Database of Systematic Reviews*, *7*(12), Cd008829.
Schiffner, U., Staehle, I., & Dörfer, C. E. (2007). *Häusliche mechanische Zahn- und Mundpflege*.
Schutzhold, S., Kocher, T., Biffar, R., Hoffmann, T., Schmidt, C. O., Micheelis, W., Jordan, R., & Holtfreter, B. (2015). Changes in prevalence of periodontitis in two German population-based studies. *Journal of Clinical Periodontology*, *42*(2), 121–130. https://doi.org/10.1111/jcpe.12352
Slot, D. E., Dorfer, C. E., & Van der Weijden, G. A. (2008). The efficacy of interdental brushes on plaque and parameters of periodontal inflammation: A systematic review. *International Journal of Dental Hygiene*, *6*(4), 253–264. https://doi.org/10.1111/j.1601-5037.2008.00330.x
StataCorp. (2021). *Stata statistical software: Release 17*. StataCorp LLC.
VanderWeele, T. J. (2019). Principles of confounder selection. *European Journal of Epidemiology*, *34*(3), 211–219. https://doi.org/10.1007/s10654-019-00494-6
Volzke, H., Schossow, J., Schmidt, C. O., Jurgens, C., Richter, A., Werner, A., Werner, N., Radke, D., Teumer, A., Ittermann, T., Schauer, B., Henck, V., Friedrich, N., Hannemann, A., Winter, T., Nauck, M., Dörr, M., Bahls, M., Felix, S. B., … Kocher, T. (2022). Cohort profile update: The study of health in Pomerania (SHIP). *International Journal of Epidemiology*, *51*(6), e372–e383. https://doi.org/10.1093/ije/dyac034
von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gotzsche, P. C., Vandenbroucke, J. P., & Initiative, S. (2014). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: Guidelines for reporting observational studies. *International Journal of Surgery*, *12*(12), 1495–1499. https://doi.org/10.1016/j.ijsu.2014.07.013
Walsh, T., Worthington, H. V., Glenny, A. M., Marinho, V. C., & Jeroncic, A. (2019). Fluoride toothpastes of different concentrations for preventing dental caries. *Cochrane Database of Systematic Reviews*, *3*(3), CD007868. https://doi.org/10.1002/14651858.CD007868.pub3
Wolffe, G. N. (1976). An evaluation of proximal surface cleansing agents. *Journal of Clinical Periodontology*, *3*(3), 148–156. https://doi.org/10.1111/j.1600-051x.1976.tb01862.x
Worthington, H. V., MacDonald, L., Poklepovic Pericic, T., Sambunjak, D., Johnson, T. M., Imai, P., & Clarkson, J. E. (2019). Home use of interdental cleaning devices, in addition to toothbrushing, for preventing and controlling periodontal diseases and dental caries. *Cochrane Database of Systematic Reviews*, *4*(4), CD012018. https://doi.org/10.1002/14651858.CD012018.pub2

SUPPORTING INFORMATION

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

How to cite this article: Holtfreter, B., Conrad, E., Kocher, T., Baumeister, S.-E., Völzke, H., & Welk, A. (2024). Interdental cleaning aids are beneficial for oral health at 7-year follow-up: Results from the Study of Health in Pomerania (SHIP-TREND). *Journal of Clinical Periodontology*, *51*(3), 252–264. https://doi.org/10.1111/jcpe.13936