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“**The effect of interdental cleaning on progression of caries, periodontitis and tooth loss over 7 years - an analysis of the SHIP-TREND study**”

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1 Introduction

Dental diseases resulting in tooth loss have always been among the most common infectious diseases of mankind (Kassebaum et al., 2015). In the past they may have led to serious health problems and even death (Lee et al., 2019). The severity of a chronic inflammation in the body raises the risk of cardiovascular diseases and type 2 diabetes mellitus (Dregan et al., 2014). Today, thanks to the rapid medical development they are now usually manageable and can normally be limited to a local inflammatory process (Featherstone & Chaffee, 2018).

These diseases of the oral cavity are often related to lifestyle, especially the elevated consumption of sugar and tobacco abuse of a patient (Chapple et al., 2017). A person's health awareness is thus closely linked to the socio-economic factors such as education and financial income (Schmoeckel et al., 2015).

The substantial deterioration in oral health reported by the WHO in the period from 1980-2000, particularly in the case of tooth decay (Petersen, 2003), has clearly declined over the past two decades due to the widespread use of fluoridation measures (especially fluoridated toothpastes). Furthermore, the success in preventive dentistry was largely made possible by the group- and individual prophylaxis for children and adolescents in Germany, with the procedure of fissure sealing (Wright et al., 2016). These measurements benefited existential to the decrease of caries. Overall, it can be said that in Germany, from children to seniors, oral hygiene habits have improved today (Jordan et al., 2014).

1.1 Oral health

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, meaning the teeth, the gingiva, the periodontium, the mucous membranes, the tongue, the jaw joints and the salivary glands. It is defined as “the ability to chew and eat a wide range of foods, speak clearly, have a socially acceptable smile and a corresponding dentofacial profile, feel comfortable around the mouth, to be free from pain and to have a fresh breath” (Sheiham & Spencer, 1997). The chewing organ with its bony and muscular components is the start of the digestive tract and is used for food intake, chewing and digestion. At the same time, it is crucial for the formation of speech and for non-verbal communication using the teeth for facial expressions. The teeth also form part of the facial proportions and structure, which is particularly noticeable in the side profile of toothless patients where the face structure is sunken in and deformed. Social acceptance, self-confidence and attractiveness are closely related to a person's dental status. Furthermore, oral health can have a strong influence on general health, for example inflammatory heart valve diseases as well as endocarditis, which can develop due to a colonization with oral cavity bacteria (Carinci et al., 2018). Possible connections to arteriosclerosis and diabetes are also discussed (Jansson et al., 2006; Lalla et al., 2006).

The oral cavity is anatomically confined by the upper- and lower lip, the hard and soft palate as well as the pharynx. Normally a child has 20 primary teeth by the age of two and a half years. By the age of eighteen or older, adults mostly have 32 permanent teeth, if the wisdom teeth are predisposed, erupted and not removed. Newborns are born with a sterile oral cavity, which is firstly contaminated during birth by the bacteria of the mother.

The oral health is significantly influenced by the nature of the oral bacterial flora. A shift in the bacterial balance towards a predominance of certain pathogenic bacterial species, which are always present in the oral cavity favor the development of diseases (Marsh & Zaura, 2017). These diseases can be roughly categorized into three groups, which are caries (Chapter 1.2), gingivitis (Chapter 1.3), periodontal diseases (Chapter 1.4) leading finally to teeth loss (Chapter 1.5).

1.2 Caries

Caries is one of the most common multifactorial infectious diseases of the human teeth. Like previously mentioned, untreated cases lead to increased tooth decay and ultimately to tooth loss (Kassebaum et al., 2015). The tooth decay goes through different stages of severity as shown in Mathur and Dhillon´s Article (2018). While the surface of the tooth is naturally coated with a pellicle of protein, the acid, mainly produced by *Streptococcus mutans* and *Lactobacillus acidophilus*, starts eroding the superficial enamel and protein cover of the tooth (the pellicle) over time. However, due to a sufficient and adequate saliva production containing calcium and phosphate ions, the enamel surface is constantly physiologically remineralized. If the exposition time and frequency of sugar and starch in the oral cavity is increased the bacterial metabolism turns carbohydrates into acid (mainly lactic acid), which generates a low pH level within the biofilm being attached to the tooth. This may cause a surface demineralization and later softening of the enamel tissue in the initial carious stage (Marsh & Zaura, 2017). This loss of minerals in the enamel structure can be seen as white spots and is therefore called a *white spot lesion* (Mathur & Dhillon, 2018). Studies have shown that in this initial stage of caries, the tooth can be medically remineralized in a targeted manner using fluoride preparations. If this does not happen, the progression of caries destroys the enamel surface and penetrates the tooth deeper until it creates a cavity and reaches the dentin of the tooth. Since dentin is less mineralized than enamel, the decalcification spreads rapidly below the enamel-dentin junction in a cone shaped expansion with its base towards the enamel-dentin junction (Kidd & Fejerskov, 2004). In many cases, dentine caries can be linked to toothache, due to the many nerve endings located in the dentine.

Even teeth that have already been treated for caries and have fillings, secondary caries can reoccur due to poor oral hygiene or over contoured, unpolished, damaged filling or insufficient crown margins (Forss & Widstrom, 2004). Untreated tooth decay can lead to reversible or irreversible pulpitis, which may require root canal treatments or in severe cases tooth extraction. If no treatment is given, an inflammation in the surrounding tissue may occur, which ultimately results in tooth loss (Glockmann et al., 2011).

Etiology

The current definition of caries is based on the research by Willoughby D. Miller, who first described caries as a chemical parasitic process in 1882 (Miller, 1882). According to him, tooth decay is the destruction of dental hard tissue by low-molecular carbohydrates metabolized to organic acid by bacteria found in dental plaque. The development of caries depends on several interrelated factors. According to Keyes (1962) these include the susceptibility of the tooth to disease, plaque (microorganism film) and substrate such as sugar or starch (Keyes, 1962). In 1971, König added another relevant factor, which was time, meaning the duration of interaction between the tooth as a host, nutrition and bacteria in form of dental plaque (König, 1971).

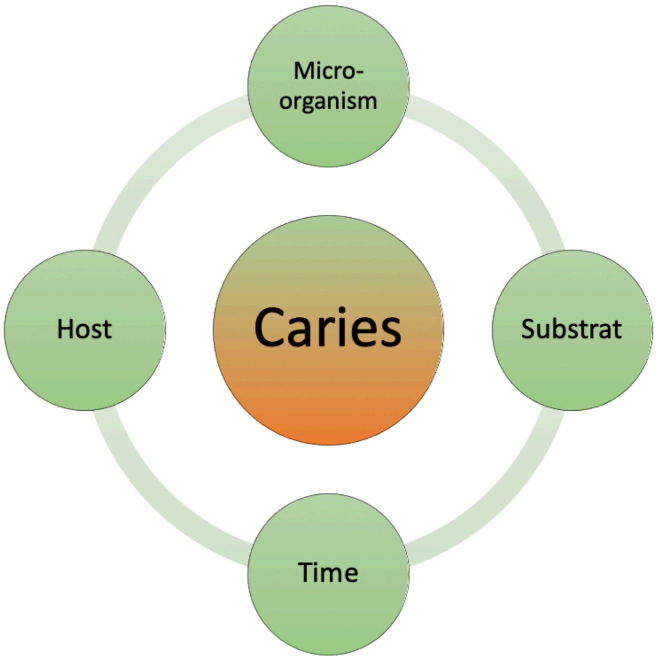

Figure (a): The four factors of caries development

Studies from Marsh et al. (2017) have shown that the oral microbiome hosts a great community of multispecies microorganisms organized and functioning in a dental biofilm (Marsh & Zaura, 2017).

The composition of the biofilm is influenced by the oral environment and the local conditions. If these change towards a dysbiotic relationship, the outcome is potentially damaging for the tooth in form of caries or periodontal diseases (Roberts & Darveau, 2015).

Normally, the processes of demineralization and remineralization of the dental hard tissue are in balance and the relationship between the microorganisms and the host are symbiotic. Only when the factors discussed above entail a shift towards a low pH level caused by the predominance of organic acids, carious lesions may develop due to demineralization. Repeated cycles of acid production result in the microscopic dissolution of calcified dental hard tissue and eventually into cavitation. Studies have shown that enamel demineralization occurs at a pH of 5.5 and below (Marsh & Martin, 2016). Specific microorganisms are associated with the initiation others with the progressions of dental plaque. Streptococci and/or actinomyces represent the early colonizers, which adhere to the tooth's surface (pellicle) directly and initiate the biofilm, while fusobacteria bridge the coaggregations to the late colonizers, who are linked to the progression of the plaque (Kolenbrander & London, 1993).

This damage of the tooth's structure is clinically characterized by whitish-opaque decalcification or discoloration mainly at caries predilection sites such as proximal contacts, exposed roots, fissures or pits (Kidd & Fejerskov, 2004). As the caries progresses, the affected tooth surface becomes softer before cavitation finally occurs due to the loss of the dental hard tissue. Radiologically, diffusely limited translucency can usually be seen in the area of the carious lesion of the tooth.

Besides the predilection sites, frequent snacking combined with excessive sugar consumption and a noticeable plaque build-up on the teeth, other caries risk factors are scientifically proven. These can be inherited in form of genetic variants (e.g. genetic mineralization disorders), due to illness in form of a sub-optimally controlled diabetes or locally environmental in form of hyposalivation or poor buffering capacity of the saliva for instance caused by smoking (Kutsch, 2014; Chapple et al., 2017). The physical aging processes, the *Sjörgen syndrome* (Inoue et al., 2006) and exposure to high radiation doses can also favor the arise of caries (Hellwig et al., 1999).

These factors may combine and favor each other differently in every patient and must always be observed and taken into account individually.

Epidemiology

A study on the global caries burden was published as part of the Global Burden of Disease (GBD) study in 2015 (Kassebaum et al., 2015). In this systematic review, the data from longitudinal studies, regardless of their design (retrospective, prospective or follow-up), as well as cross-sectional studies based on samples of national or sub-national populations from 1990-2010 were evaluated. The focus of the study was the presence of untreated caries (number of decayed teeth). Kassebaum et al. (2015) showed that untreated caries in deciduous teeth affected 9% of the global population and was listed as the 10th-most prevalent condition in children. Tooth decay in permanent teeth was the number one prevalent condition with 35% of the global population.

During the same period of time, the Fifth German Oral Health Study (DMS V) represented a completely different outcome of the caries burden in Germany (Jordan et al., 2014). The examined German residents were organized into four different age cohorts and again the DMF index was the tool for assessment. The study participants were children (12-year-olds), adults (35-44-year-olds), young old's (65-74-year-olds) and old old's (75-100-year-olds). Jordan et al. observed a decline of tooth decay in all age cohorts. Eight out of ten of the 12-year-old children (81%) were caries-free. In adults (35-44-year-olds) the number of teeth with caries experience decreased by 30% since 1997. In total the number of caries-free participants doubled between 1997 and 2014 during the study (Jordan et al., 2016).

One of the possible causes of a decreasing caries trend in all age groups is professional tooth cleaning, which has been one of the most essential pillars of caries prevention since 1977 (Axelsson & Lindhe, 1977) until today (Figuero et al., 2017). Besides that, fluoridation has been used successfully in children's dentistry for years and is recommended by the German Society for Dental and Oral Medicine (DGZMK) in a guideline for caries prophylaxis (Hellwig et al., 2002).In a meta-analysis by Griffin et al. (2007) the positive effectiveness of the domestic and professional application of fluorides, as well as the fluoridation of drinking water, became apparent as well, proven in adulthood (Griffin et al., 2007). A year later a decreasing caries trend could also be marked in patients using a fluoride containing toothpaste on a daily basis in the study of Hugoson et. al in 2008 (Hugoson & Koch, 2008).

Although a large extent of the declining caries prevalence had been attributed to fluoride supplementation, like it has been described in several studies before, the Swedish study by Mejàre et al. (1998) shows a different result for the approximal surfaces (Mejàre et al., 1998). The examined cohort of teenagers and adolescents underwent a fluoride-based remineralization treatment with an annual bite-wing radiographic inspection from the age of 11 to 22. Forty-three percent of all approximal surfaces had caries at the age of 21. The slow but continuous progression of approximal caries, in spite of the exposition to various forms of fluoride supplements over the years, suggested that for approximal surfaces the treatment simply retards the progression of caries and does not prevent it.

Clinical relevance

Fundamentally, oral diseases can be treated well in most cases using modern dentistry. If such diseases occur, despite extensive preventive measures, the type and severity of the clinical picture is of relevance for deciding which therapy concept should be applied. In general, the aim of treatment is to restore function and aesthetics, although the earlier a dentist is consulted if symptoms appear, the higher the chances of success in achieving this restoration.

The therapy of caries depends on the degree of destruction of the tooth (demineralization). In the initial stage of enamel caries, remineralization is possible through the targeted use of fluoride-containing products (Marthaler, 1990) as well as through the treatment with self-assembling peptides P_{11}-4 (SAP) (Welk et al., 2020). This current study aimed to evaluate the effect of SAP treating *white spot lesions* (WSL) in 23 patients. Welk et al. (2020) could show that the SAP is able to diffuse through the pores of the carious lesion into the subsurface and support the remineralization of the tooth in depth. The treatment reduced the WSL in size (mm^2) after 45 respectively 90 and 180 days and lead to a superior remineralization in the subsurface lesion compared to the control teeth.

Once this stadium has not been inhibited, the tooth surface is being cavitated and an invasive treatment is necessary, as the decay can no longer be targeted with non-invasive methods as described above. Various filling materials are available for replacing the demineralized removed tissue, exemplary shown in a study obtaining information on the restorative dental care of adults in Finland (Forss & Widstrom, 2004). Overall, composite was the most common material used in 79% of the restorations, amalgam was used in only 5%, compomers in 4% and glass ionomers in 7% of the cases in Forss' et al. (2004) patients. However, if the development of the carious lesion is not suitable for an adhesive technique, it is in need of a mechanical retention in form of a partial or full crown to restore the function of the tooth (Pitts et al., 2017).

Deep caries lesions may lead to pulp exposure as a result of a complete caries removal, therefore it has been scientifically proven in several publications, to remove the infected tissue stepwise to insure a lower risk of pulp complications (Sato et al., 2020). In the study of Sato et al. (2020) the caries depth was determined as a percentage of the distance between the outer edge of the enamel and the pulp base. The risk of undergoing a root canal treatment as a result of a deep caries lesion was very high with a size of 80% to 89%.

These medical procedures for the treatment of caries represent a great financial burden for the economy, with caries being the fourth-most expensive chronic disease to treat according to the WHO (Petersen, 2009). The major biological, social and financial burden on individuals and the health care system can be split into direct and indirect costs of the population. Direct costs contain the treatment itself, which have been estimated at 298 billion US$ a year. Indirect costs may result in adults' productivity loss due to absenteeism from work and children's limited school attendance, due to severe pain or mouth infection (Selwitz et al., 2007) caused by caries. These indirect costs where worldwide amounted to 144 billion US$ yearly (Listl et al., 2015).

1.3 Gingivitis

Gingivitis is characterized by an acute inflammation of the gingival tissue, caused by substances deduced from microbial plaque accumulating at or near the gingival sulcus (Page, 1986). The molecules in the progress of the pathogenic inflammation can be divided into two main groups: those deriving from the subgingival microbiota and those deriving from the host immune-inflammatory response (Preethanath et al., 2020). Preethanath et al. (2020) describes the histopathologic mechanism in his current publication on gingivitis as a biofilm causing injury to the periodontal tissue with an inflammatory host tissue reaction, including the infiltration by numerous defense cells, particularly neutrophils, macrophages, plasma cells and lymphocytes. These cells release destructive enzymes which themselves cause a destruction of the tissue, vasodilation, increased vascular permeability and hyperplastic gingival tissue (Preethanath et al., 2020). Clinically it is described as an erythematous and oedematose gingiva. The constituted inflammatory lesions go through different stages, which can be categorized into *the initial, the early, the established* and *the advanced stage*, each with characteristic features also described in Preethanath's publication.

Initially the low-grade picture of a lesion (after 2-4 days neglecting oral hygiene) is characterized by vasodilation and an increased vascular permeability resulting in an increased hydrostatic pressure in the local microcirculation, although this stage corresponds histologically still to clinically healthy gingival tissue. In the *early-stage* defense cells are infiltrating, the clinical signs of an erythematous and swollen appearance impose and therefore a deepening of the gingival sulcus, which increases the subgingival biofilm proliferation.

The degree of the established lesion depends on various factors, like the composition and quantity of the biofilm, the host susceptibility as well as the local and systemic risk factors. It is clinically equal to a chronic reversible gingivitis, with destructed collagen bundles and a formation of ulcerated pocket epithelium resulting in bleeding on probing. Furthermore, Preethanath et al. (2020) describes the advanced lesion, as the transitioning stage from gingivitis to periodontitis.

The gingivitis can be categorized and assessed according to its degree with the help of the Quigley-Hein-Index (QHI) (Quigley & Hein, 1962). The extent of the plaque is assessed starting from the gingival margin on the coronal tooth surface. To evaluate the QHI the facial and oral tooth surfaces are being assessed by staining the plaque and grading the degree of severity from 0-5 (0-no clinically plaque and 5-plaque expansion up to the coronal third of the tooth) and dividing the total sum by the number of tooth surfaces evaluated.

Etiology

As reviewed above, a close relation between the microorganisms of the deposit plaque and the gingival tissue is of great importance for the development of the gingivitis. Clinical trials have shown that the accumulation of dental biofilm leads to inflammation of the gingiva, like shown in the experimental study of Löe et al. (1965). Löe et al. examined twelve healthy participants with a mean age of twenty-three who abandoned any type of oral hygiene over a period of twenty-one days. Plaque formatted shortly after the absence of toothbrushing and other dental cleaning aids. The accumulation increased steadily resulting into inflammatory gingivitis after ten days. As soon as the bacterial plaque had been removed, the inflammation regressed. Thus, it can be concluded that the pathogen biofilm is an essential factor in the development of a gingivitis.

Brecx et al. (1988) also came to this conclusion in his long-term study over a period of six months, observing experimental gingivitis in men. He examined the chronic inflammation histopathological, which showed a slow shift towards some cell populations, for example an increase of plasma cells, PMN's (polymorphonuclear neutrophils) and lymphocytes (Brecx et al., 1988).

Other variables that favor the appearance of a gingival inflammation, besides deficient oral hygiene, are genetic predispositions, lifestyle factors including smoking, diabetes, nutrition and psychological stress (Chapple et al., 2015). Therefore, gingivitis is a partly preventable and treatable condition, which can be limited and controlled through lifestyle choices up to a certain point.

Epidemiology

To prevent and reduce plaque formation and gingival inflammations, inter-dental cleaning is strongly recommended, as well as further use of chemical agents for plaque control (Chapple et al., 2015). These are the public health recommendations of Chapple et al. (2015) for patients with gingivitis, in addition to a general recommendation to brush twice daily for at least two minutes with a fluoridated dentifrice. However, the greatest improvement was found by Hugoson et al. (2007), in patients who visited the dentist every second month and had an individual informal instruction on their personal oral hygiene recommendations (Hugoson et al., 2007).

Nevertheless, gingivitis is still present in the global burden of oral diseases, representatively evaluated in American adults shown in the following publication by Li et al (2010). The mean age of the 1,000 participants was 37.9 years, with 57.9% females and 42.1% males. It revealed that there was a significant correlation between the age and the Gingivitis Index (GI) (Löe, 1967), older participants had a higher score than younger groups. Statistical analysis of their data also showed that males GI was higher than the one of females. Overall, the general prevalence of adult gingivitis varies form 50-100% (Stamm, 1986), demonstrated by the 93.9% of the 1,000 subjects having an GI at 0.50 or higher and by the 55.7% subjects scoring at 1.0 or higher (Li et al., 2010).

Regardless, the trend of gingival inflammations does not seem to increase, as revealed in a Swedish study over 30 years by Hugoson et al. in 2008. He showed that the proportion of periodontally healthy patients increased from 8% in 1973 to 44% in 2003 and the proportion of patients suffering from gingivitis decreased dramatically over that period of time (Hugoson et al., 2008).

Clinical relevance

Although not all gingivitis progresses to the clinical picture of periodontitis, it is mostly believed that any periodontitis infection was preceded by gingivitis at some point (Löe

& Morrison, 1986; Page & Kornman, 1997). Based on this knowledge it is of extreme importance to treat and heal any signs of an initial gingiva inflammation.

A randomized, blinded and parallel group study evaluating three different programs on plaque and gingivitis control could show how to best reduce the clinical picture of gingivitis (Hugoson et al., 2007). In this study, plaque (PI) and gingival indices (GI) decreased in all programs. The greatest decrease in PI and GI was found in the group that had clinical check-ups every 2 months. In this group participants received repeated individual education about the disease from a dentist and underwent prophylactic care to control the plaque formation. Concerning the costs of the patient, group-based plaque prophylaxis programs taken place somewhere else than in a clinic turned out to be equally successful and could reduce the costs significantly (Hugoson et al., 2007).

1.4 Periodontitis

The pathogenesis of the early periodontitis includes the formation and maturation of a dental plaque, particularly in the supra-gingival area, which describes the clinical picture of the gingivitis (Heitz-Mayfield et al., 2003). As said before, the pathogenesis of the gingivitis does not necessarily lead to the clinical picture of a periodontitis but is mostly the initial stadium before progressing into a chronic periodontitis (Löe & Morrison, 1986; Page & Kornman, 1997). Further on, Heitz-Mayfield et al. (2003) describes the progress of the periodontal disease as an expansion of the bacterial biofilm until it reaches a chronic inflammatory process that initiates the destruction of the connective tissue attachment of the tooth. Beyond that, the authors explain that the apical expansion and the formation of a periodontal pocket ultimately leads to loss of the alveolar bone. The complexity of the severity of the disease must be considered and is closely related to the type of bone loss (vertical and/or horizontal), tooth mobility, furcation status, missing teeth and bite collapse (Tonetti et al., 2018).

The most vital consequence of the destruction of the alveolar bone is the loss of teeth, which has a negative impact on the formation of speech, the quality of nourishment and self-esteem (Chapple et al., 2015). The buccal surfaces of the posterior teeth and the interproximal areas of the molars are mostly affected (Heitz-Mayfield et al., 2003).

This characteristic clinical attachment loss (CAL) is normally detected by a circumferential assessment of the dentition with the use of a standardized periodontal probe, using the cemento-enamel junction (CEJ) as a reference point (Tonetti et al., 2018). There it is important to differentiate between gingivitis and an initial periodontitis, but the fluctuations between the states of these diseases are difficult to identify (Schätzle et al., 2009). Tonetti et al. (2018) has shed light into detecting periodontal disease states by reporting the principals at the 2017 World Workshop. According to their study a patient is a periodontitis case, if: (1) The interdental CAL is found at ≥2 non-adjacent teeth, or (2) the buccal or oral CAL ≥3 mm with pocketing >3 mm is found at ≥2 teeth and the detected CAL cannot be assigned to a non-periodontal cause (Tonetti et al., 2018). If a patient is detected as a periodontitis case, further classification is necessary in the context of a proper diagnose and an appropriate clinical treatment.

Participants from all over the world came together in the 2017 World Workshop to update the 1999 Classification of Periodontal Diseases and Conditions (Armitage, 1999) and develop a scheme for the new Classification of Periodontal and Peri-implant Diseases and Conditions (Caton et al., 2018). This classification offers an individual patient assessment that takes two dimensions into account, one is the complexity of managing the case and second one is the risk of progressing and/or being less responsive to the standard periodontal therapy (Tonetti et al., 2018).

Periodontitis stage		Stage I	Stage II	Stage III	Stage IV
Severity	**Interdental CAL at site of greatest loss**	1 to 2 mm	3 to 4 mm	≥5 mm	≥5 mm
	Radiographic bone loss	Coronal third (<15%)	Coronal third (15% to 33%)	Extending to mid-third of root and beyond	Extending to mid-third of root and beyond
	Tooth loss	No tooth loss due to periodontitis		Tooth loss due to periodontitis of ≤4 teeth	Tooth loss due to periodontitis of ≥5 teeth
Complexity	**Local**	Maximum probing depth ≤4 mm Mostly horizontal bone loss	Maximum probing depth ≤5 mm Mostly horizontal bone loss	In addition to stage II complexity: Probing depth ≥6 mm Vertical bone loss ≥3 mm Furcation involvement Class II or III Moderate ridge defect	In addition to stage III complexity: Need for complex rehabilitation due to: Masticatory dysfunction Secondary occlusal trauma (tooth mobility degree ≥2) Severe ridge defect Bite collapse, drifting, flaring Less than 20 remaining teeth (10 opposing pairs)
Extent and distribution	**Add to stage as descriptor**	For each stage, describe extent as localized (<30% of teeth involved), generalized, or molar/incisor pattern			

Figure (b): Periodontitis staging (Tonetti et al., 2018)

Periodontitis grade			Grade A: Slow rate of progression	Grade B: Moderate rate of progression	Grade C: Rapid rate of progression
Primary criteria	Direct evidence of progression	Longitudinal data (radiographic bone loss or CAL)	Evidence of no loss over 5 years	<2 mm over 5 years	≥2 mm over 5 years
	Indirect evidence of progression	% bone loss/age	<0.25	0.25 to 1.0	>1.0
		Case phenotype	Heavy biofilm deposits with low levels of destruction	Destruction commensurate with biofilm deposits	Destruction exceeds expectation given biofilm deposits; specific clinical patterns suggestive of periods of rapid progression and/or early onset disease (e.g., molar/incisor pattern; lack of expected response to standard bacterial control therapies)
Grade modifiers	Risk factors	Smoking	Non-smoker	Smoker <10 cigarettes/day	Smoker ≥10 cigarettes/day
		Diabetes	Normoglycemic/ no diagnosis of diabetes	HbA1c <7.0% in patients with diabetes	HbA1c ≥7.0% in patients with diabetes
Risk of systemic impact of periodontitis[a]	Inflammatory burden	High sensitivity CRP (hsCRP)	<1 mg/L	1 to 3 mg/L	>3 mg/L
Biomarkers	Indicators of CAL/bone loss	Saliva, gingival crevicular fluid, serum	?	?	?

Figure (c): Periodontitis grading (Tonetti et al., 2018)

Etiology

Increasing evidence from a variety of dental research in different fields has shown that there is a close correlation between oral deposits and the development and maintenance of periodontal diseases (Loe et al., 1965). Clinical experiments by Hine et al. in 1950 had already revealed that the accumulation of bacterial deposits in the subgingival area lead to a destructive host inflammatory immune response (Hine, 1950). Contributing to this pathological development are three major factors, which have already been in the causal spotlight in many publications, just like in the work of Schätzle et al. from 2009 examining the predictive factors of periodontal diseases. These include calculus, smoking and age which are significant predictors of the diseases progressing (Schätzle et al., 2009).

A more recent study from 2015 describes a further detailed analysis of the predicting factors of periodontal diseases in a cross-sectional survey in North-Eastern Germany with a total of 3.086 participants (Kowall et al., 2015). Thereupon, it can be said that periodontitis and edentulism were also closely linked to poorly regulated type 2 diabetes. These patients tended to be more often male, with a higher body mass index (BMI) and a low educational status resulting in higher CAL scores, a greater mean periodontal pocket depth and less remaining teeth, which defined as a periodontitis case (Kowall et al., 2015). Chapple et al. (2015) released a publication that same year pointing out more risk factors including nutrition, and psychological stress (Chapple et al., 2015). He also states that behavior changes in patient's lifestyle choices are necessary for a successful treatment, most importantly alternating high risk factors (e. g. smoking) and attending and sustaining an adequate standard of daily plaque removal. Careful attention should be given to the individual risk factors of a patient, since they are affecting severity and extent of the disease, as well as treatment response, improvement and/or rates of tooth loss (Tonetti et al., 2018).

Epidemiology

Epidemiologic data has been collected and analyzed in a systematic review and meta-regression by Kassebaum et al. (2014) between 1990-2010 on the global burden of severe periodontitis (SP). The outcome of the study stated that SP was the sixth-most prevalent condition globally with a prevalence of 11.2% between 1990-2010, with an incidence of 701 new cases per 100,000 people a year, in 2010 (Kassebaum et al., 2014a).

A more significant public health burden of periodontitis is represented in Germany where the prevalence of the disease is much higher (Holtfreter et al., 2009). Compared to other European countries, periodontitis ranges between a medium to a high prevalence in the German population (König et al., 2010). This could be related to the increasing prevalence of diabetes recorded over the past 10 years in German citizens (Atzpodien et al., 2009), known as one of the major risk factors of periodontitis if not well-controlled (Kowall et al., 2015). Nonetheless, an equally recent study by Schutzhold et al. (2015), which was based on the outcomes mentioned above, could reveal that the prevalence and extent of attachment loss has certainly improved in participants of the SHIP as well as in West German adults, generally (Schutzhold et al., 2015).

Overall, for the primary prevention of periodontitis, it is of great importance to prevent gingivitis. Chapple et al. (2015) reviewed the following four approaches of gingivitis prevention: (1) self-administered plaque control, (2) self-administered inter-dental plaque control, (3) adjunctive chemical plaque control and (4) anti-inflammatory agents (Chapple et al., 2015). Their outcome showed that professional plaque removal combined with reinforcement of oral hygiene decreased plaque scores and the corresponding gingival inflammation notably.

Another positive result was found by Chapple et al. (2015) in the use of re-chargeable power toothbrushes, which could promote a reduction in plaque levels and therefore inflammatory processes. If inter-dental brushes (IDB) fit through the interproximal area without traumatizing the gingiva, it is recommended and effective for plaque removal. Furthermore, they advise brushing one's teeth twice a day for at least two minutes (Chapple et al., 2015).

Trends of a slightly increasing prevalence with age, particularly between the third and fourth decade of life driven by a peak around the 38th year of life, has been reported in review "Global Burden of Severe Periodontitis in 1990-2010" by Kassebaum et al. (2014). These trends had been observed since 1990 and should be monitored closely now due to the growing world's population accompanied by an increasing life expectancy and a decrease in edentulism, which entails a predictable increasing burden of SP (Kassebaum et al., 2014a).

Clinical relevance

The goal of a periodontal therapy is to create a clinical condition that is aiming to reduce the microbial sub-gingival plaque amount due to retain as many teeth as possible and for as long as possible. Despite the biological differences between aggressive and chronic periodontitis, the treatment is mostly similar (Teughels & Dhondt, 2014).

The phases of the treatment have been explained by Teughels et al. (2014) in *Periodontology 2000*. He stated that the initial phase of active treatment includes mechanical debridement and is often supplemented with antimicrobial agents. Further on, he describes that regular scaling and root planning can significantly decrease clinical indices but often does not guarantee long-term stability for the patient.

If the microbial attack is kept low through the clinical treatment, as well as daily self-administered oral hygiene by the patient, periodontal stability will be reinstalled in the majority of cases (Axelsson & Lindhe, 1981). The most critical factor determining the outcome of the therapy is the patient's compliance and his standard of oral hygiene contributing to the treatment (Van der Weijden & Timmerman, 2002).

Success rates have been studied as a follow-up examination by Lundgren et al. (2001) 3 years after the periodontal treatment, including hygiene education, scaling and root planning as well as surgical procedures. 52.1% had been successfully cured according to the studies assessment criteria. 4.9% of the treated sites did not rehabilitate and needed further treatment time resulting in additional costs (Lundgren, 2001). Concerning the economic burden of periodontitis, it is suggested that non-surgical procedures are lower in costs than surgical interventions, this could be statistically shown by Braegger et al. in 2005 (Braegger, 2005).

Recent studies have discovered how essential treatment of chronic periodontitis is due to its associations with coronary artery disease, stroke and type II diabetes. The scientists could substantiate that the specific oral bacteria emerging from the periodontal pocket have the ability to gain access to the bloodstream and contribute to the overall inflammatory burden of the patient (Dregan et al., 2014; Pink et al., 2015).

1.5 Tooth loss

Tooth loss can be the outcome of a variety of causes, such as caries, periodontal diseases or trauma (Reich et al., 2011). It can also be seen as an indicator of one's individual history of dental diseases, treatment and the patient's attitude towards dental care, as well as his availability and accessibility of the medical services (Petersen et al., 2005; Baelum et al., 2007).

Not only single and/or multiple tooth loss but also the complete loss of dentition, is a global phenomenon, the so called edentulism (Lee & Saponaro, 2019). The World Health Organization, categorizes the edentulous patient as physically impaired, disabled and handicapped due to their lack of proper mastication and speech (Bouma et al., 1987). It is precisely this form of complete tooth loss that results in a serious condition, regardless of the reason causing the edentulism. In fact, this consequence occurs when the physiological masticatory forces no longer apply to the alveolar bone through the roots of the teeth (Devlin & Ferguson, 1991) and therefore the loss of mechanical stimulation expresses itself in form of a reduced bone mass (Wolff, 1892; Frost, 2003). Atrophic jaws have been observed due to ill-fitting dentures (Carlsson et al., 1969) as well as an result of disuse (Devlin & Ferguson, 1991). Patients with atrophic jawbones do not only suffer from alterations of the anatomic configuration of their jaw and loss of function but also from transformations of the facial shape and psychological problems (Atwood, 1971) like feelings of shame, insecurity and decreased attractiveness (Trulsson et al., 2002).

More common consequences of tooth loss are not only functional impairments like chewing and speech but also esthetics depending on the location (Gerritsen et al., 2010). Gerritsen et al. (2010) states that the highest impact on quality of life is being observed in anterior tooth loss. A tooth loss generates tooth gaps that promote tooth migration and/or tooth tilting. The tooth gaps and its resulting problems can also increase the risk of craniomandibular dysfunction (Mundt et al., 2005). Missing and unreplaced teeth are also related to a general higher change of all-cause mortality especially to an increased risk of cardiovascular mortality, according to a prospective analysis of SHIP with 1.803 subjects in 2013 (Schwahn et al., 2013).

The missing teeth can be managed with fixed, removable or complete dentures (John et al., 2007). John et al. (2007) consulted 119 prosthodontic patients and evaluated their self-reported oral health status before and one month after prosthetic treatment. At baseline the participants rated their status as poor (4.2%), moderate (37%) and good (54.6%), after treatment 21.9% reported a moderate, 61.3% a good and 16% a very good status. In general, participants with fixed or removable dentures reported in 33% and in 45% of the cases, respectively, a better oral health status. Whereas in the group of participants with complete dentures only 20% reported a positive change (John et al., 2007).

Etiology

One of the most common reasons for tooth loss are caries and periodontal diseases if not treated adequately (Gerritsen et al., 2010). According to the report of Glockmann et al. (2011), caries was the greatest reason causing tooth loss at 28.7% of the survey cases conducted in Germany in 2007, closely followed by periodontitis with 28.5% (Glockmann et al., 2011). He stated that teeth with severe destruction due to caries or chronically inflamed periodontal tissue resulted in tooth tilting and loosening and was in most cases not preservable, which led to the clinical extractions.

Another reason of tooth loss Glockmann et al. (2011) had taken into account which was seen in the peak of extractions around the age <18, was the high incidence of orthodontic treatment in children, receiving therapy including extractions. Until the age of 40 the main reason for tooth loss in adults was observed due to caries, subsequently periodontitis (Glockmann et al., 2011). Horn et al. (2007) gave evidence that tooth loss in patients correlated with their age and also showed that elderly patients visited the dentist infrequently, resulting in a lower oral hygiene (Horn et al., 2007).

Furthermore, a study by Mack et al. (2003) associated patients with complete and partial dentures (and therefore patients who suffered previous tooth loss), with their age, educational status, financial income and general health (smoking and alcohol abuse). The results showed that these variables were significant predictors of wearing dentures (Mack et al., 2003).

Epidemiology

According to the systematic review and meta-analysis of Kassebaum et al. (2010) in the Global Burden of Severe Tooth Loss, 2.3% populaces worldwide were edentate, which represents 158 million people at that time (Kassebaum et al., 2014b). In both sexes, age was one of the highest risks of severe tooth loss, showing a sudden increase of incidence around the seventh decade of life. Kassebaum et al. (2010) further reports that women generally demonstrate a higher prevalence and incidence of tooth loss, although this gap has reduced immensely over the last decades.

The most recent Fifth German Oral Health Study (DMS V, 2016) states that today every eighth younger senior (65- to 74-year-olds) is edentulous, compared to the survey of 1997 where it had been every forth young senior. Another statement of the DMS V was that younger seniors have an average of five more teeth of their own than in 1997 (Jordan et al., 2016).

The trend of a clear decrease, 45% over the last two decades, in the global burden of severe tooth loss between 1990 and 2010 is significant, even though the world's population tends to live longer and therefore is ageing immensely (Kassebaum et al., 2014b). It also has to be noted that loss of teeth nowadays might not be as common in society as it might have been in previous time periods and therefore the demand for prosthetic treatment increased in the future (Cronin et al., 2009).

To prevent tooth loss and increase the prospects of tooth retention long-term hygiene behaviors additionally to brushing, could confirm an association with a decreased tooth loss potential (Kressin et al., 2003). Kressin et al. (2003) could show that consistent flossing and regular prophylaxis could reduce the risk of tooth loss compared to participants without the supplementary hygiene habits after long-term assessments of preventive practices among 736 male subjects (Kressin et al., 2003).

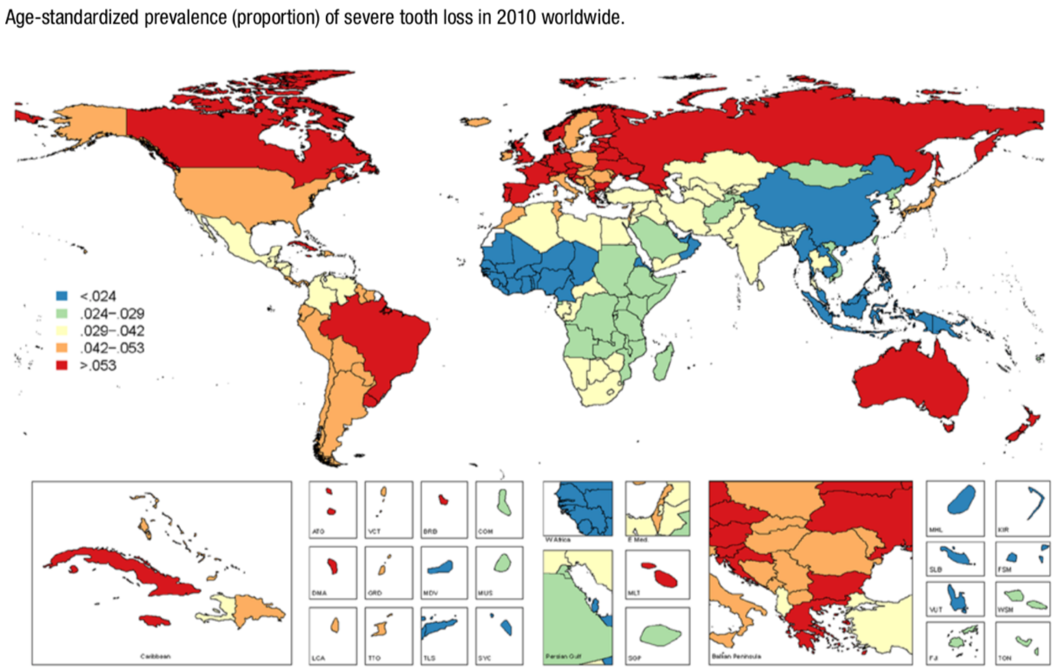

Figure (d): Prevalence of tooth loss (Kassebaum et al., 2014b)

Clinical relevance

The main duty of prosthetic or implant-supported treatment is to restore the function of the lost teeth (Sahin et al., 2002) and preserve the appearance of the patient (Fenlon & Sherriff, 2008). The patient's quality of life and function including mastication and speech depend largely on the extent and type of prosthetic restoration (John et al., 2007). Traditionally, the choice for restoring one or multiple teeth was between a fixed or removable prosthesis. Today, with the opportunity of dental implants, the options of tooth replacement vary from removable partial dentures to implant-supported fixed prostheses (Chee, 2005).

The choice of which treatment is suitable has to be carefully made by the patient and the dentist evaluating multiple factors, such as the number and location of missing teeth, the residual ridge form, the relation between the maxillary and mandibular, the bone availability, the facial support and the financial boundaries (Chee, 2005). Prosthetic patients with fixed dentures had the best overall oral situation as they described self-reportedly, of the general population portrayed in a survey by John et al. in 2007. However, this treatment is also associated with high costs and great effort. As a result, patients often choose removable dentures or bridgework. This type of tooth replacement is often the method of choice for few remaining teeth, insufficient bone to implant and lastly for financial reasons (Walter et al., 1998; Mack et al., 2003). Here, as well, a close relationship between the dental status and the socio-economic factors is observed (Walter et al., 1998).

Costs are a substantial factor in the planning and decision making of prosthetic restorations. Therefore, a study by Van der Wijk et al. (1998) compared the costs of dental implants with those of a conventional prosthetic treatment. The data had been collected over the course of the first treatment year in a randomized clinical trial with 240 participants. The outcome revealed that for the implant group additional costs arose, including the costs of the surgery itself, the material, the anesthesia and in some cases a hospital stay, as well as antibiotics and analgesics. The group receiving the standard procedure of a complete removable denture were seven times lower in costs than those receiving an overdenture supported by a trans-mandibular implant (Van der Wijk et al., 1998).

1.6 Interdental Aids

Successful oral hygiene has been a central factor for maintaining good oral health, which is associated with overall health and health-related good quality of life. Dental floss has been in use for many years supplementary to toothbrushing and particularly for cleaning the interdental spaces. However, over time, a great range of interdental aids have entered the market and offer society a wide variety of supplementary dental cleaning aid opportunities (Poklepovic et al., 2013).

Dental floss typically consists of nylon threads or folded PTFE-strands, structured in different forms and thicknesses. The floss often contains additives such as wax, fluoride and/or aromatics and should be wear-resistant and at the same time have an adequate gliding capacity. It is especially recommended for patients with very narrow interdental spaces, in which it should be inserted through the interdental space by sawing gently (Schiffner et al., 2007).

Interdental brushes consist of a thin wire core with cylindrical or cone-shaped nylon bristles arranged radially at an angle of 90 degrees to the longitudinal axis. Here, too, a large variety of sizes, widths and shapes is available nowadays. Interdental brushes are extremely effective in interdental spaces harboring concave surfaces of the tooth, which are inaccessible for conventional dental floss (Schiffner et al., 2007).

A study on the client's compliance for interdental care reported that subjects were more than twice as likely to use interdental brushes compared to floss. They were also willing to use the interdental brush on a daily basis and showed that the use was well accepted by society (Imai & Hatzimanolakis, 2010), whereas daily dental floss showed low adherence among patients (Asadoorian & Locker, 2006). A clinical research report analyzed the impact of interdental cleaning on general oral health over 17 years and could show that the use of interdental aids (IDA) increased along with an increase of oral health (Pitchika et al., 2020).

Another survey elaborated on interproximal caries and dental flossing and came to the conclusion that self-performed flossing in children and young adolescents followed for two years did not reduce the caries risk, although if carried out professionally every school day the risk could be reduced by 40% (Hujoel et al., 2006).

Interdental brushing could show a low-quality reduction in gingivitis, but could not elaborate enough evidence to claim a benefit for either interdental brushing or flossing, reducing plaque (Poklepovic et al., 2013). Kressin et al. (2003) carried out recommended preventive practices among 736 male participants and analyzed the effect on tooth retention. The authors could show that participants who reported flossing additionally to toothbrushing had approximately one more tooth compared with those who reported no baseline flossing (Kressin et al., 2003).

A study by Worthington et al. conducted several IDA and compared the effectiveness compared to each other, including dental floss, dental brushes, wood sticks, rubber sticks and oral irrigators (Worthington et al., 2019). The author came to the conclusion that IDA in addition to normal tooth brushing may reduce plaque and gingival inflammation more than tooth brushing alone, but stated that overall, the quality of evidence in his study was low to very-low.

Generally, there is a lack of long-term scientific high-quality evidence that verifies the use of IDA preventing caries, periodontitis and tooth loss. Nevertheless, daily dental floss has been recommended in the Dietary Guidelines of the US Department of Health and Human Services and of the US Department of Agriculture (2015) since 1979 and was left out without comment in 2015 (Pitchika et al., 2020). In August 2016, the

Associated Press (AP) released information that the "medical benefits of dental floss is unproven" (Donn, 2016). As a result, this press release liberated a rapid debate developed among the population and dentists whether interdentally cleaning had any benefit on oral health (Sälzer et al., 2016).

This lack of evidence-based data obstructs the revelation of any recommendations for flossing. Nevertheless, there was broad agreement that large-scale, long-term scientific studies on interdental care would be beneficial. Therefore, we aim to investigate possible effects of self-administered interdental cleaning aids and oral hygiene procedures in addition to regular tooth brushing on caries, periodontitis and tooth loss.

1.7 Aim

Literature on potentially beneficial effects of dental flossing in reducing plaque and gingival inflammation is limited and there is only inconsistent and weak evidence for an effect in addition to tooth brushing (Chapple et al., 2015). The aim of this study targets at gaining more detailed and long-term results of the effect of interdental aids on caries and periodontal diseases, thus tooth retention and to provide this information to prevent and cure these diseases in society. With this repeated cross-sectional data collection from representative subjects of northeast Germany, documented for a time period of 5 years, the possibility of a positive outcome of our investigations is theoretically attainable.

Targeting an accurate report about instructions on interdental aids, accessible for the broad population, the impact of this study could be helpful in contributing to further decreases of oral diseases and as well reduce economical burdens, in case of positive outcomes. Instructions should be given about the frequency, application, and timing of how to use IDA correctly without causing trauma or damage to the surrounding tissue.

Therefore, the goal of this study is furthermore to compensate the previous insufficient quality and bias afflicted literature, and to reduce the gap of previous research in interdental cleaning relevance.

2 Material and methods

2.1 Study of Health in Pomerania (SHIP-Trend)

The SHIP has two main objectives: firstly, to assess prevalence and incidence of common risk factors, subclinical disorders and clinical diseases; and secondly to investigate the complex associations among risk factors, subclinical disorders and clinical diseases in the northeast of Germany. The two independent cohorts SHIP and the follow-up study SHIP-Trend were selected from essentially the same area with minor deviations at the boundaries of the study areas (Volzke et al., 2011). SHIP-Trend is dedicated to the tendencies of the prevalence of common diseases in that area.

This dissertation is based on the data collected of the SHIP-Trend study (Study of Health in Pomerania-Trend). Which is the second SHIP study, it was carried out independently from the first study, but identical measuring instruments were used to establish a good comparability between the two studies. The population-based cohort study was carried out in northeast of Germany, specifically in the region of Western Pomerania in the state of Mecklenburg-Western Pomerania. The study region comprised the former districts of Stralsund-County, Greifswald-County, Anklam-County and the cities of Stralsund, Greifswald and Anklam shown in the Figure (e) below.

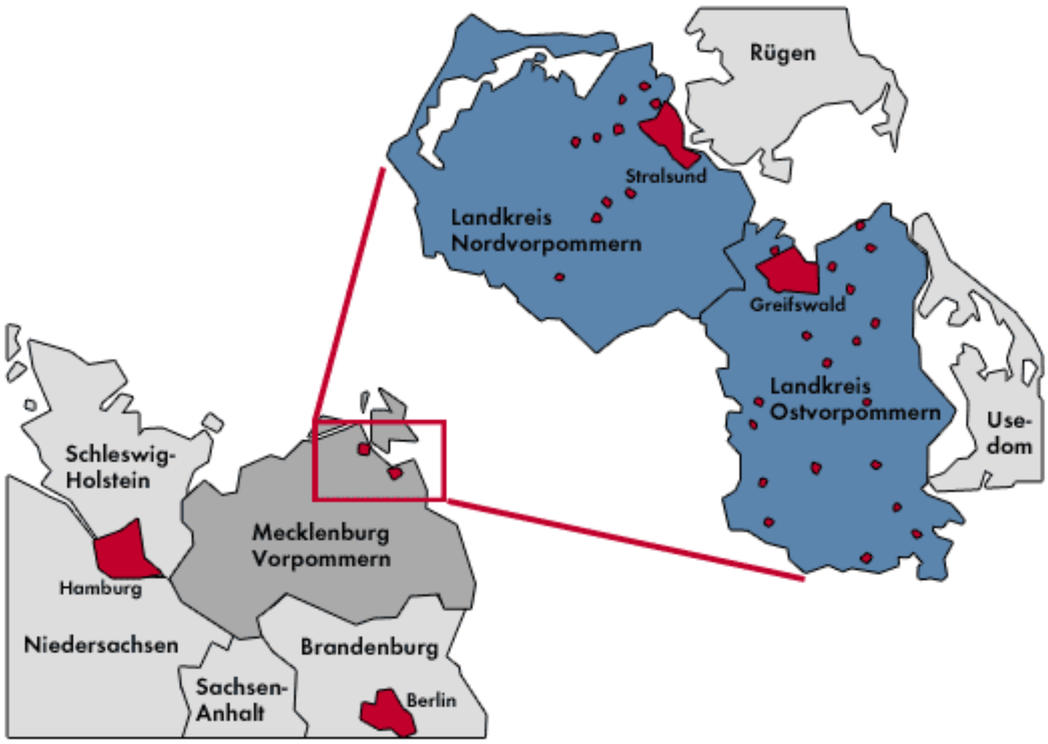

Figure (e): Study region of the Study of Health in Pomerania, modified according to the “Research Association Community Medicine, Ernst-Moritz-Arndt University of Greifswald”.

2.2 Study design and sample

SHIP-TREND is a population-based observational cross-sectional study conducted in Western Pomerania, a region in the north-east of Germany (Volzke et al., 2011). Examinations were conducted during the years 2008–2012. A follow-up of the study, called SHIP-Trend-1 ran from 2016–2019. Stratified random samples of 10,000 adults aged 20–79 years were drawn from regional population registries (Kowall et al., 2015). In order to motivate as many people as possible to take part in the study, the selected citizens were contacted twice per writing in the baseline study of SHIP-Trend-0, if possible, per telephone and, if necessary, even encouraged to participate in the study via home visit. Sample selection was facilitated by centralization of local population registries in the Federal State of Mecklenburg/West Pomerania. 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.

Because of several reasons (241 did not answer, 3367 refused participations, 549 did not keep the appointment and 249 agreed without an appointment), 4420 subjects were finally recruited in the study (response 50.1%). After 7 years, a first follow-up study was conducted (SHIP-TREND-1, 2014-2018) with 2507 participants.

SHIP-TREND was positively evaluated by the ethics committee of the University of Greifswald (SHIP-TREND-0: BB 39/08a issued on September 3rd 2009; SHIP-TREND-1: BB 174/15, issued December 12th 2015). All participants were informed about the study protocol and signed the informed consent and the privacy statement. Reporting was done in accordance with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines.

The following flowchart (Figure (f)) shows the process of participation in the follow-up study SHIP-Trend-1. Of the 4420 baseline participants 2507 had follow-up data. Seventy-eight participants of those were dentulous at baseline and were excluded, leaving 2429 participants. First, for analyses of periodontal variables the following participants were excluded. Eighteen participants did not have follow-up data for the number of missing teeth and 104 participants had missing data in at least one of the covariates, leaving 2307 participants for analyses with the number of missing teeth as the outcome. For analyses of periodontal variables, further exclusions were necessary due to missing measurements (primarily due to edentulism or crowns in case of CAL). Second, for analyses of caries variables the following participants were excluded. Sixty-six participants did not have follow-up data for the DMF-S (including the edentulous) and 83 participants had missing data in at least one of the covariates, leaving 2280 participants for analyses with the DMF-S (including the edentulous) as the outcome. For analyses of the DF-S and the DMF-S (excluding the edentulous), further exclusions were necessary due to exclusion of the edentulous mainly.

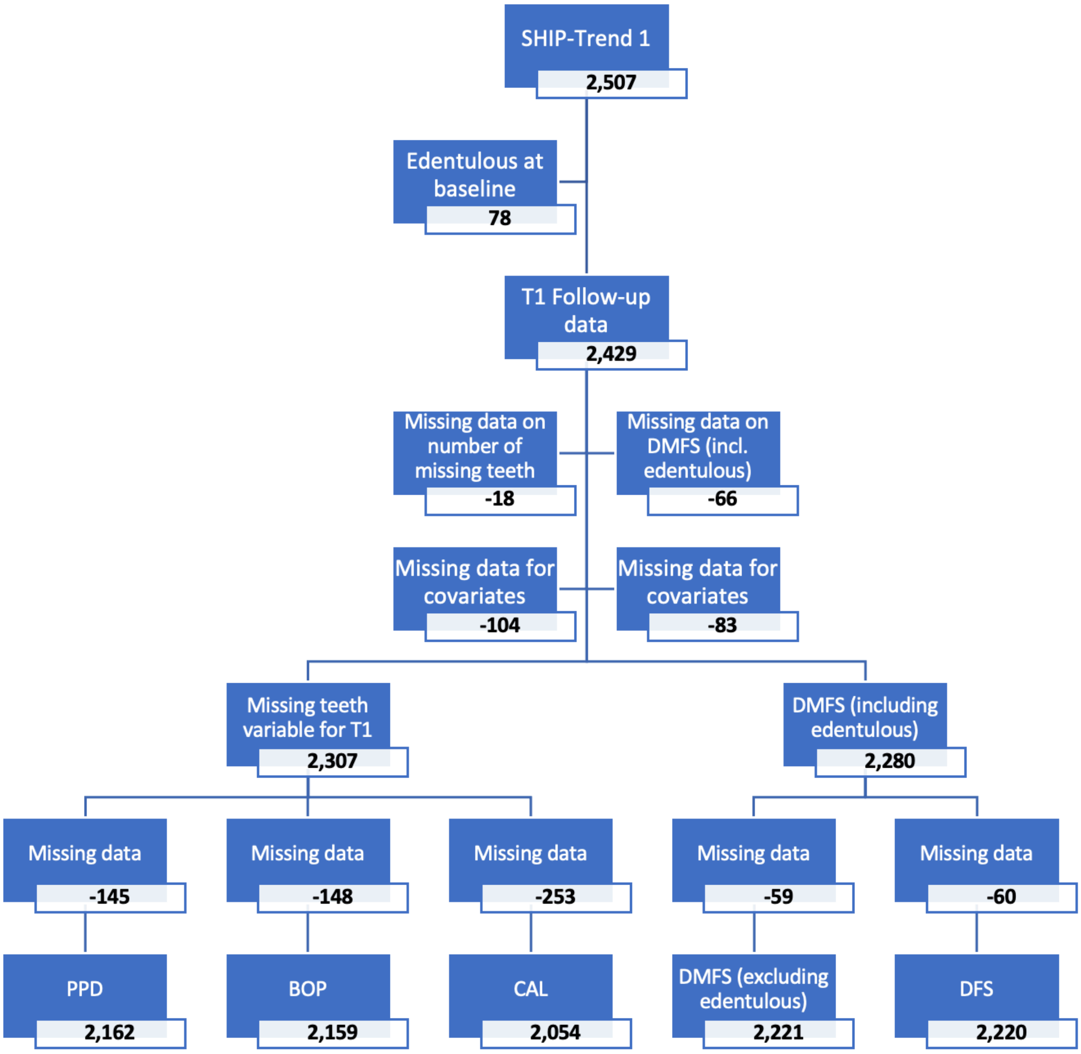

Figure (f): Flowchart of participants in SHIP-Trend-1 (follow-up)

2.3 Data collection

For the sake of completeness, all of the investigations conducted on the subjects who participated in the SHIP-Trend study are listed below. The variables relevant for this dissertation are listed separately.

Each test person was given a questionnaire that they completed independently and provided veridical information about their living conditions, job-related situation, social environment and their subjective state of health. In a standardized, computer-assisted conversation, general medical aspects of the participants were asked and registered. The medical examinations included an electrocardiogram, echocardiogram, ultrasound of various organs, neurological screenings, blood pressure measurements, and a blood and urine sample. Furthermore, smears were taken from the mucous membrane of the nasopharynx and the tongue, as well as a saliva sample. Five certified and coordinated dentists carried out the dental examination, during which the general medical, orthodontic, functional and periodontal findings were recorded. The condition of the oral mucosa and the dentures were also assessed, if there were prosthetic dentures existent. Additionally, questions about the subjective status of their own oral health were answered by the participants themselves. This included in particular the use of toothbrushes, interdental aids and the regularity of dentist visits and professional dental hygiene.

Caries examination

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 number of decayed or filled surfaces (DF-S, excluding those being edentulous at follow-up) was determined based on a maximum of 14 permanent teeth (excluding third molars) with (depending on the tooth type) 4 to 5 surfaces each, resulting in 64 surfaces being assessed in total. In addition, the DF-S was calculated restricting surfaces to interdental ones (distal and mesial).

Periodontal examination

Measurements of PD (probing depth) and CAL were conducted using a manual periodontal probe (PCPUNC 15, Hu-Friedy, Chicago, IL, USA) at distobuccal, midbuccal, mesiobuccal, and midlingual/midpalatinal sites according to the half-mouth method excluding third molars (left or right side randomly selected). Measurements were mathematically rounded to the next whole millimeter, PD was measured as the distance between free gingival margin (FGM) and pocket base. If the 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), the attachment level was not recorded.

On participant level, mean PD and mean CAL were calculated. All variables were also determined restricting sites to interdental ones (distobuccal and mesiobuccal sites). Also, participants were classified according to the Centers for Disease Control and Prevention/American Academy of Periodontology (CDC/AAP) case definition of periodontitis (Page & Eke, 2007). Bleeding on probing (BOP) and plaque were recorded at the identical four 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 bleeding sites and the percentage of sites with plaque were determined. Finally, the number of missing teeth was calculated (excluding third molars).

Calibration data

In SHIP-TREND-0, dental examinations were conducted by five calibrated examiners. In calibration exercises, all dentists repeatedly examined five persons not connected to the study. Intra-rater correlations for CAL measurements ranged between 0.67 and 0.89 and inter-rater correlation was 0.70. For PD measurements, the examiners yielded intra-rater correlations between 0.68 and 0.88 and an inter-rater correlation of 0.72. For coronal caries examinations, Cohen's kappa reliability coefficients were 0.83-1.00 (intra-examiner) and 0.72-1.00 (pairwise inter-examiner). For assessment of the tooth status, Cohen's kappa reliability coefficients were 0.93-0.99 (intra-examiner) and 0.94-0.98 (pairwise inter-examiner).

In SHIP-TREND-1, dental examinations were conducted by four calibrated examiners. In calibration exercises, all dentists repeatedly examined five persons not connected to the study. Intra-rater correlations for CAL measurements ranged between 0.90 and 0.96 and pairwise inter-rater correlations of 0.86-0.94. For PD measurements, the examiners yielded intra-rater correlations between 0.77 and 0.91 and pairwise inter-rater correlations of 0.63-0.85. For coronal caries examinations, Cohen's kappa reliability coefficients were 0.93-1.00 (intra-examiner) and 0.84-0.98 (pairwise inter-examiner). For assessment of the tooth status, Cohen's kappa reliability coefficients were 0.97-1.00 (intra-examiner) and 0.91-0.96 (pairwise inter-examiner).

Laboratory measurements

Fasting blood samples were drawn from the cubital vein in the supine position and aliquots were prepared for immediate analysis and for storage at −80 °C. HbA1c concentrations were determined by high-performance liquid chromatography (Bio-Rad Diamant, Munich, Germany).

Exposure variable and covariates

Based on the dental interview, usage of interdental aids was defined as self-reported daily use of dental floss, toothpicks, wooden tooth sticks, or interdental brushes. Furthermore, IDA usage was analyzed in more detail differentiating non-users, wooden stick users (toothpicks and wooden tooth sticks), floss users, and interdental brush users. Powered tooth brush usage was defined opposing powered (PTB) versus manual tooth brush usage (MTB). Participants using both were classified as PTB users. Based on the toothbrushing frequency, participants were categorized as irregular (<2 times/day) or regular brushers (≥2 times/day). Self-reported gum treatment ('periodontosis' treatment) during the last 5 years was recorded.

From the computer-assisted personal interview the following items were retrieved. School education was defined as <10, 10, >10 years. Smoking was categorized as never, former, and current smoking. Physical activity was defined as exercising for ≥1 h per week in summer or winter.

Standardized measurements of body height and weight were performed with calibrated scales and the body mass index (BMI) was calculated as weight divided by height (kg/m²). Known diabetes mellitus was defined as physician's diagnosis or antidiabetic medication intake (Anatomic Therapeutic Chemical classification system; code A10). The follow-up time was indicated in exact years.

2.4 Statistical analyses

Outcome variables were chosen to represent chronic periodontitis (mean PD of all, interdental and non-interdental sites, percentage of all, interdental and non-interdental sites with PD ≥4 mm, mean CAL of all, interdental, and non-interdental sites, CDC/AAP case definition of periodontitis), coronal caries (the DF-S of all, interdental, and non-interdental surfaces) and their major consequence (i.e., the number of missing teeth).

Means with standard deviations and/or medians with 25% and 75% quantiles were reported for continuous variables. Relative frequency distributions were computed for categorical variables.

We applied linear models using generalized least squares and ordinal logistic regression models. The latter ones are recommended for skewed continuous responses (Harrell, 2015). The relevant model assumptions were tested and the decision for linear or ordinal logistic models was made accordingly. For ordinal logistic models, various links were evaluated and the logit link was selected anywhere. We estimated effects of baseline IDA usage, follow-up time and their interaction on follow-up levels of dental variables. As we aimed to estimate total causal effects of the exposure on outcome variables, we did not adjust models for baseline outcome status, as the baseline outcome status was assumed to be a mediator of the effect of IDA usage on follow-up outcome status (Tennant et al., 2022), assuming long-term a priori effects of IDA usage on the baseline outcome status. Confounders were chosen according to prior clinical knowledge. Models were adjusted for baseline levels of age, sex, school education, smoking, known diabetes mellitus, HbA1c, BMI, dental visit within the last 12 months, tooth brushing frequency and powered tooth brush usage. Models on plaque, BOP, periodontitis variables, and the number of missing teeth were additionally adjusted for self-reported periodontal treatment within the last 5 years and physical activity. All continuous variables were modelled as restricted cubic splines with three knots to allow for non-linearity. Adjusted linear regression coefficients (Beta) and odds ratios (OR) with 95% confidence intervals (CIs) contrasting PTB users with MTB users were reported and graphically presented. Effect modification by age and sex was tested via multiplicative interaction terms with IDA usage and, if present ($p<0.10$ for interaction), stratified models were presented. As the fraction of missing values was about 50%, we imputed missing values (Groenwold et al., 2012). We did not impute missing teeth at follow-up and baseline interview items if participants refused examinations. We used the 'aregImpute' procedure provided in the rms package with 50 imputations (Harrell, 2021). A two-sided $P<0.05$ 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 package (Harrell, 2021).

3 Results

3.1 Baseline characteristics of study participants in total and stratified by interdental aid usage

Table 1 shows the baseline characteristics at SHIP-TREND-0 for all participants presented in the final model for the number of missing teeth, on the left side in total and in the two right columns stratified by interdental aids usage. The total number was 2,303 with an average age of 49.2 years and a percentage of 51.4% females and 48.6% males. 1,631 participants were IDA non-users, with a medium age of 48 years and a higher percentage of males with 52.7% (females 47.3%). The 672 IDA users with an average age of 52.2 years had a higher percentage of female participants (61.5%, males 38.5%).

In total, 12.3% of the 2,303 participants had less than 10 years school education, 55.5% underwent 10 years of education and the rest (32.1%) received over 10 years of schooling. IDA non-users showed the highest amount of >10 years education with 32.3% in comparisons to the IDA user group with 31.7%, and a lower <10-year education percentage with 11.9% than IDA users (13.4%). The smoking status was evaluated in all groups, displaying the best result of never smoker within the IDA users with 41.2% and the lowest score of current smokers with 18.8%. On the other hand, IDA non-users were predominantly never smokers (38.0%) and current smokers (24.6%). Ninety-two-point three percent of the IDA users reported to brush twice or more a day, whilst only 85.1% of the IDA non-users could confirm this statement, which led to a total percentage of 87.2% participants brushing more than twice a day. The variable tooth brush usage demonstrated a higher use of manual toothbrushes in IDA non-users with 72.3% than in IDA users (66.8%). Ten participants confirmed not to use a toothbrush at all (6 of the IDA non-users and 4 of the IDA users).

Dental visits within the last 12 months were confirmed by 91.8% over all, 90.5% in IDA non-users and with the highest score in IDA users with 95.1%. Gum treatment with in the last 5 years was confirmed by 20.4% over all, 17.5% in IDA non-users and again with the highest score in IDA users with 27.2%. Known diabetes mellitus was registered in 132 cases of the total, with 89 of those participants belonging to the IDA non-users and 43 to the IDA users. Hemoglobin A1c was reported to be 5.3% overall. The BMI was highest in IDA non-users (median 27.5 kg/m^2; quartiles 24.2 and 30.1 kg/m^2), whilst the average BMI in IDA users was 26.8 kg/m^2 with 25% and 75% quantiles being 24.0 and 30.0 kg/m^2. Seventy-eight percent of IDA users reported to be physically active, which was significantly higher than in the group of IDA non-users with only 70%.

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 aids usage.

	Total	IDA non-user	IDA user	P value *
N	2303	1631	672	-
Age, years	49.2±13.6	48.0±13.7	52.2±12.9	<0.001
	49 (39; 59)	47 (37; 58)	53 (43; 62)	
Male sex, yes	1,119 (48.6%)	860 (52.7%)	259 (38.5%)	<0.001
School education				
<10 years	284 (12.3%)	194 (11.9%)	90 (13.4%)	
10 years	1,279 (55.5%)	910 (55.8%)	369 (54.9%)	
>10 years	740 (32.1%)	527 (32.3%)	213 (31.7%)	0.610
Smoking status				
Never smoker	897 (38.9%)	620 (38.0%)	277 (41.2%)	
Former smoker	879 (38.2%)	610 (37.4%)	269 (40.0%)	
Current smoker	527 (22.9%)	401 (24.6%)	126 (18.8%)	0.010
Brushing ≥2 times/day, yes	2,008 (87.2%)	1,388 (85.1%)	620 (92.3%)	<0.001
Toothbrush usage				
Manual toothbrush	1,629 (70.7%)	1,180 (72.3%)	449 (66.8%)	
Powered toothbrush	664 (28.8%)	445 (27.3%)	219 (32.6%)	
None	10 (0.4%)	6 (0.4%)	4 (0.6%)	0.026
Dental visit within the last 12 months, yes	2,115 (91.8%)	1,476 (90.5%)	639 (95.1%)	<0.001
Gum treatment within last 5 years, yes	469 (20.4%)	286 (17.5%)	183 (27.2%)	<0.001
Known diabetes mellitus, yes	132 (5.7%)	89 (5.5%)	43 (6.4%)	0.377
Haemoglobin A1c, %	5.3±0.7	5.2±0.7	5.3±0.7	0.208
	5.2 (4.8; 5.6)	5.2 (4.8; 5.5)	5.2 (4.9; 5.6)	
Body Mass Index, kg/m^2	27.4±4.6	27.5±4.7	27.3±4.3	0.424
	27.0 (24.2; 30.0)	27.1 (24.2; 30.1)	26.8 (24.0; 30.0)	
Physical activity, yes	1,662 (72.2%)	1,141 (70.0%)	521 (77.5%)	<0.001

*Data are presented as mean ± standard deviation and median (25%; 75% quantiles). *Mann-Whitney U test or Chi squared test; Abbreviations: IDA, interdental aids.*

3.2 Baseline characteristics of study participants stratified by type of interdental aids

Participant characteristics at baseline (SHIP-TREND-0) were listed in Table 2 and examined separately depending on the IDA use, resulting in 4 groups: IDA non-users, wood stick users, dental floss users and interdental brush users. The youngest medium age was with 47 years arose in the IDA non-users and dental floss user group, which had a 10-year difference to the medium age of wooden stick users with 57 years. The highest number of female participants was found in dental floss users with 69.4%, on the contrary the highest number of male participants was registered in wood stick users with 53.1%.

More than 10 year of school education rose in the group of dental floss users (37.2%), which was higher compared to wood stick users (25.6%) and interdental brush users (30.3%). The portion of never smokers was highest among dental floss users (40.9%), and lowest in IDA non-users (38.0%). Consequently, the lowest portion of current smokers was found in dental floss users (21.1%), while the highest portion was found in IDA non-users (24.6%). Brushing regularly more than twice a day was reported in 94.8% of interdental brush users, in 93.8% of dental floss users and in 85.1% of IDA non-users (wood stick users, 85.6%). Dental floss users most often reported to use a PTB (34.7%), while PTB usage was least frequent in wood stick users (26.3%). None of the dental floss user participants reported to not use a dental brush at all. However, in the group of wood stick users 1.2% reported not to use a dental brush at all. Dental visits within the last 12 months were reported to be carried out by 98.5% of dental brush users, by 95.5% of floss users and only by 88.8% of wood stick users. Gum treatment within the last 5 years also showed a peak in dental brush users with 35.9% and the lowest score in IDA non-users with 17.5%. Known diabetes mellitus was found in 10.6% of wood stick users, which was the highest amount compared to other groups. Among dental floss users, only 2.1% had known diabetes mellitus. Hemoglobin A1c was comparably similar to each other, ranging from 5.4% (wood stick users/dental brush users) to 5.2% (dental floss users and non-IDA users). The BMI was lowest in floss users with 25.7 kg/m^2 and highest in wood stick users with 27.8 kg/m^2. Physical activity could only be confirmed by 71.3% in the group of wood stick users in compresence to 81% in dental floss users.

Table 2. Baseline characteristics (SHIP-TREND-0) for participants present in the final model for the number of missing teeth in total and stratified by interdental aids usage.

	IDA non-user	Wooden stick user	Floss user	Interdental brush user	P value #
N	1631	160	242	270	
Age, years	48.0±13.7	55.2±11.3	47.0±12.8	55.2±12.4	<0.001
	47 (37; 58)	57 (47; 64)	47 (38; 56)	56 (45; 65)	
Male sex, yes	860 (52.7%)	85 53.13	74 (30.6%)	100 (37.0%)	<0.001
School education					
<10 years	194 (11.9%)	26 (16.3%)	18 (7.4%)	46 (17.0%)	
10 years	910 (55.8%)	93 (58.1%)	134 (55.4%)	142 (52.6%)	
>10 years	527 (32.3%)	41 (25.6%)	90 (37.2%)	82 (30.3%)	0.010
Smoking status					
Never smoker	620 (38.0%)	61 (38.1%)	99 (40.9%)	117 (43.3%)	
Former smoker	610 (37.4%)	62 (38.8%)	92 (38.0%)	115 (42.6%)	
Current smoker	401 (24.6%)	37 (23.1%)	51 (21.1%)	38 (14.1%)	0.019
Brushing ≥2 times/day, yes	1,388 (85.1%)	137 (85.6%)	227 (93.8%)	256 (94.8%)	<0.001
Toothbrush usage					
Manual toothbrush	1,180 (72.3%)	116 (72.5%)	158 (65.3%)	175 (64.8%)	
Powered toothbrush	445 (27.3%)	42 (26.3%)	84 (34.7%)	93 (34.5%)	
None	6 (0.4%)	2 (1.2%)	0 (0%)	2 (0.7%)	0.021
Dental visit within the last 12 months, yes	1,476 (90.5%)	142 (88.8%)	231 (95.5%)	266 (98.5%)	<0.001
Gum treatment within last 5 years, yes	286 (17.5%)	33 (20.6%)	53 (21.9%)	97 (35.9%)	<0.001
Known diabetes mellitus, yes	89 (5.5%)		5 (2.1%)	21 (7.8%)	0.001
Haemoglobin A1c, %	5.2±0.7	5.4±0.8	5.2±0.7	5.4±0.8	0.0069
	5.2 (4.8; 5.5)	5.3 (4.9; 5.6)	5.1 (4.8; 5.5)	5.3 (4.9; 5.6)	
Body Mass Index, kg/m^2	27.5±4.7	28.7±4.5	26.4±4.2	27.2±4.2	<0.001
	27.1 (24.2; 30.1)	27.8 (25.8; 31.6)	25.7 (23.4; 28.8%)	26.9 (24.0; 29.7)	
Physical activity, yes	1,141 (70.0%)	114 (71.3%)	196 (81.0%)	211 (78.2%)	<0.001

*Data are presented as mean ± standard deviation and median (25%; 75% quantiles). *Kruskal Wallis test or Chi squared test; Abbreviations: IDA, interdental aids.*

3.3 Baseline and follow-up dental data stratified by interdental aids usage

In Table 3, baseline (SHIP-TREND-0) and follow-up (SHIP-TREND-1) distributions of periodontal variables including the CDC/AAP case definition, caries variables and the number of missing teeth is shown. In the right part of Table 3, participants were stratified by baseline interdental aid usage and variable distributions were tabulated accordingly. Plaque was significantly lower at baseline than at follow-up in all groups. Lowest baseline scores were achieved in IDA users with only 8.3%. At follow-up all groups had comparable plaque score of 16.7%. BOP was lower at follow-up examinations than at baseline, with the lowest score being 12.5% in IDA users and the highest being 15.0% in IDA non-users. Mean PD as well as interdental and non-interdental PD significantly improved between baseline and follow-up in all groups similarly, in total being 2.36 mm at baseline and 2.27 mm at follow-up examinations for mean PD, 2.73 mm (baseline) PD compared to 2.53 mm (follow-up) at interdental sites and 2.00 mm (baseline) PD compared to 1.96 mm (follow-up) at non-interdental sites. Furthermore, the percentage of all sites with a PD of ≥4 mm was specified as well as for interdental sites and non-interdental sites. The percentage of sites with PD ≥4 mm dropped significantly between baseline and follow-up, with IDA non-users starting with a total of 5.4% at baseline to 3.8% at follow-up, compared to IDA users with 5.0% at baseline and 4.2% at follow-up. Mean CAL was stable in total and rose in IDA non-users from 1.79 mm (baseline) to 1.83 mm (follow-up) compared to IDA users were the variable dropped from 2.17 mm (baseline) to 2.02 mm (follow-up). Mean interdental and non-interdental CAL showed the same tendencies.

According to the CDC/AAP case definition the percentage of participants with severe periodontitis dropped in all groups, with 13.7% (baseline) to only 8.7% (follow-up) in IDA non-users and 14.6% (baseline) to 12.1% (follow-up) in IDA users. The number of decayed and filled surfaces (DF-S and interdental DF-S) showed no significant differences between IDA non-users and IDA users, ranging from 19 to 17 (DF-S) and 7 to 8 (interdental DF-S) between baseline and follow-up. The number of missing teeth also ranged between 3 and 4 at baseline and between 4 and 5 at follow-up in all groups.

Table 3. Baseline (SHIP-TREND-0) and follow-up (SHIP-TREND-1) dental data in total and stratified by baseline interdental aids (IDA) usage.

		Total		IDA non-user		IDA user		P value*
		N	N (%) or Median (Q25; Q75)	N	N (%) or Median (Q25; Q75)	N	N (%) or Median (Q25; Q75)	
Plaque, %	Baseline	2197	10.0 (0; 30.0)	1556	12.5 (0; 33.3)	641	8.3 (0; 25)	<0.001
	Follow-up		16.7 (5.0; 37.5)		16.7 (5.0; 37.5)		16.7 (4.2; 30.0)	0.0039
BOP, %	Baseline	2159	16.7 (4.2; 33.3)	1525	16.7 (5.0; 37.5)	634	15.0 (4.2; 29.2)	0.0098
	Follow-up		12.5 (4.2; 25.0)		15.0 (4.2; 29.2)		12.5 (4.2; 25.0)	0.0098
Mean PD, mm	Baseline	2162	2.36 (2.13; 2.71)	1529	2.38 (2.13; 2.73)	633	2.33 (2.11; 2.65)	0.1370
	Follow-up		2.27 (2.07; 2.58)		2.29 (2.09; 2.58)		2.25 (2.04; 2.57)	0.0585
Mean interdental PD, mm	Baseline	2162	2.73 (2.43; 3.15)	1529	2.75 (2.45; 3.18)	633	2.69 (2.39; 3.11)	0.0150
	Follow-up		2.58 (2.32; 2.95)		2.61 (2.35; 2.96)		2.54 (2.28; 2.90)	0.0038
Mean non-interdental PD, mm	Baseline	2162	2.00 (1.79; 2.30)	1529	2.00 (1.79; 2.31)	633	2.00 (1.79; 2.27)	0.9831
	Follow-up		1.96 (1.78; 2.20)		1.96 (1.78; 2.20)		1.96 (1.77; 2.21)	0.7970
Percentage of sites with PD ≥4 mm, %	Baseline	2162	5.4 (0; 17.3)	1529	5.4 (0; 17.5)	633	5 (0; 15.6)	0.7460
	Follow-up		3.9 (0; 13.6)		3.8 (0; 14.3)		4.2 (0; 12.5)	0.6405
Percentage of interdental sites with PD ≥4 mm, %	Baseline	2162	9.1 (0; 28.6)	1529	9.1 (0; 29.2)	633	8.3 (0; 25)	0.4353
	Follow-up		7.1 (0; 21.4)		7.1 (0; 21.4)		7.1 (0; 20)	0.8151
Percentage of non-interdental sites with PD ≥4 mm, %	Baseline	2162	0 (0; 5)	1529	0 (0; 5)	633	0 (0; 5.6)	0.4787
	Follow-up		0 (0; 5)		0 (0; 4.5)		0 (0; 7.1)	0.2055
Mean CAL, mm	Baseline	2054	1.89 (1.21; 2.87)	1445	1.79 (1.14; 2.75)	609	2.17 (1.38; 3.13)	<0.001
	Follow-up		1.89 (1.43; 2.73)		1.83 (1.41; 2.60)		2.02 (1.48; 3.04)	<0.001
Mean interdental CAL, mm	Baseline	2053	2.00 (1.19; 3.05)	1444	1.83 (1.13; 2.95)	609	2.20 (1.39; 3.19)	<0.001
	Follow-up		1.92 (1.50; 2.75)		1.88 (1.50; 2.65)		2.04 (1.50; 3.04)	0.0163
Mean non-interdental CAL, mm	Baseline	2053	1.83 (1.15; 2.75)	1444	1.70 (1.08; 2.63)	609	2.14 (1.42; 3.00)	<0.001
	Follow-up		1.86 (1.35; 2.70)		1.79 (1.31; 2.56)		2.08 (1.43; 3.00)	<0.001
CDC/AAP case definition	Baseline	2015		1419		596		
No/mild periodontitis			1,053 (52.3%)		785 (55.3%)		268 (45.0%)	
Moderate periodontitis			681 (33.8%)		440 (31.0%)		241 (40.4%)	
Severe periodontitis			281 (13.9%)		194 (13.7%)		87 (14.6%)	<0.001
CDC/AAP case definition	Follow-up	2015		1419		596		
No/mild periodontitis			1,168 (58.0%)		861 (60.7%)		307 (51.5%)	
Moderate periodontitis			651 (32.3%)		434 (30.6%)		217 (36.4%)	
Severe periodontitis			196 (9.7%)		124 (8.7%)		72 (12.1%)	<0.001
DF-S	Baseline	2220	17 (10; 25)	1574	17 (9; 24)	646	19 (12; 27)	<0.001
	Follow-up		18 (10; 26)		17 (9; 25)		19 (12; 27)	<0.001
Interdental DF-S	Baseline	2220	8 (4; 11)	1574	7 (3; 11)	646	8 (5; 12)	<0.001
	Follow-up		8 (4; 12)		8 (4; 11)		8 (5; 12)	<0.001
Non-interdental DF-S	Baseline	2319	10 (6; 14)	1574	9 (6; 13)	646	10 (7; 14)	<0.001
	Follow-up		10 (6; 14)		10 (6; 14)		11 (7; 15)	0.0019
Number of missing teeth	Baseline	2303	3 (1; 7)	1631	3 (1; 7)	672	4 (1; 7)	0.0057
	Follow-up		4 (1; 9)		4 (1; 9)		5 (2; 9)	0.0021

*Data are presented as median (25%; 75% quantiles). *Mann-Whitney U test or Chi squared test; Abbreviations: IDA, interdental aids; PD, probing depth; CAL, clinical attachment level; BOP, bleeding on probing; CDC, Centers for Disease Control and*

Prevention; AAP, American Academy of Periodontology; DF-S, number of decayed or filled surfaces.

3.4 Baseline and follow-up dental data stratified by type of interdental aids

Table 4 shows the distributions of baseline and follow-up data for periodontitis, caries variables and the number of missing teeth, which were evaluated stratified by three different interdental aids (wooden sticks, dental floss, dental brushes). Overall, dental floss users had the lowest scores for periodontal variables compared to the other groups. Plaque was significantly lower at baseline in all groups than at follow-up, dental floss users had the lowest score overall with 4.2% at baseline, compared to 12.5% in IDA non-users and wood stick users (dental brush users 8.3%). The follow-up scores showed the same evaluation pattern, but overall, with higher scores.

BOP was lower at follow-up than at baseline examinations in all four groups. Dental floss users started with 12.5% (baseline), dental brush users and IDA non-users with 16.7% (baseline) and wood stick users with 20.8% (baseline). Follow-up plaque scores were 8.3% in dental floss users, 12.5% in dental brush users, 15.0% in IDA non-users and 16.7% in wood stick users. Mean PD, as well as mean interdental PD and mean non-interdental PD improved between baseline and follow-up in all groups with the same pattern. At both times lowest values were achieved by the dental floss user group, with mean PD of 1.8 mm based on non-interdental sites. The percentage of sites with PD ≥4 mm was in every group higher at baseline and dropped with follow-up time. The highest percentage at baseline was found in wood stick users with 9.6% and the lowest value in dental floss users with 2.1%. At follow up the highest value was again found in wood stick users (7.1%) and the lowest in dental floss users (2.1%). Restricting sites to interdental ones gave similar results. Mean CAL reduced in all groups, with a higher value at follow-up in IDA non-users. The same development was observed for mean interdental and mean non-interdental CAL.

According to the CDC/AAP case definition of all groups, dental floss users had the lowest percentage of participants with moderate periodontitis at baseline with 29.2% as well as the lowest percentage for severe periodontitis with only 6.7%. Of dental brush users 50.4% had moderate periodontitis at baseline and 17.0% severe periodontitis cases, while at follow-up only 43.9% (moderate periodontitis) and 15.2% (severe periodontitis) were registered. The highest percentage of severe periodontitis cases at baseline was found in wood stick users with 23.1%, the moderate periodontitis score was 42.0% in this group. At follow-up times wood stick users were categorised into 47.5% moderate cases and 14.0% severe cases. DF-S showed no remarkable differences in between the examined groups, dental floss users had the highest score with 20 (at baseline) and 21 (at follow-up), compared to IDA non-users with 17 (at baseline and follow-up). Interdental and non-interdental DF-S showed similar patterns. The number of missing teeth ranged between 2.5 (dental floss users at baseline) and 6 (dental brush users at follow-up).

Table 4. Baseline (SHIP-TREND-0) and follow-up (SHIP-TREND-1) dental data stratified by baseline interdental aids usage.

		IDA non-user		Wooden stick		Dental floss user		Dental brush user		P value*
		N	N (%) or Median (Q25%; Q75%)	N	N (%) or Median (Q25%; Q75%)	N	N (%) or Median (Q25%; Q75%)	N	N (%) or Median (Q25%; Q75%)	
Plaque, %	Baseline	1556	12.5 (0; 33.3)	153	12.5 (4.2; 29.2)	238	4.2 (0; 16.7)	250	8.3 (0; 29.2)	<0.001
	Follow-up		16.7 (5.0; 37.5)		25.0 (12.5; 50.0)		8.3 (4.2; 20.8)		16.7 (4.2; 31.3)	<0.001
BOP, %	Baseline	1525	16.7 (5.0; 37.5)	151	20.8 (8.3; 33.3)	235	12.5 (4.2; 25.0)	248	16.7 (5; 30)	<0.001
	Follow-up		15.0 (4.2; 29.2)		16.7 (8.3; 33.3)		8.3 (4.2; 16.7)		12.5 (5; 25)	<0.001
Mean PD, mm	Baseline	1529	2.38 (2.13; 2.73)	151	2.48 (2.23; 2.94)	235	2.23 (2.04; 2.48)	247	2.42 (2.12; 2.71)	<0.001
	Follow-up		2.29 (2.09; 2.58)		2.35 (2.11; 2.73)		2.18 (1.96; 2.39)		2.25 (2.05; 2.62)	<0.001
Mean interdental PD, mm	Baseline	1529	2.75 (2.45; 3.18)	151	2.86 (2.57; 3.39)	235	2.57 (2.32; 2.83)	247	2.71 (2.39; 3.18)	<0.001
	Follow-up		2.61 (2.35; 2.96)		2.68 (2.39; 3.09)		2.46 (2.25; 2.75)		2.56 (2.25; 2.96)	<0.001
Mean non-interdental PD, mm	Baseline	1529	2.00 (1.79; 2.31)	151	2.13 (1.90; 2.50)	235	1.88 (1.71; 2.09)	247	2.08 (1.86; 2.29)	<0.001
	Follow-up		1.96 (1.78; 2.20)		2.04 (1.83; 2.30)		1.88 (1.71; 2.04)		2.00 (1.81; 2.32)	<0.001
Percentage of sites with PD ≥4 mm, %	Baseline	1529	5.4 (0; 17.5)	151	9.6 (2.3; 22.9)	235	2.1 (0; 7.7)	247	6.3 (1.9; 17.9)	<0.001
	Follow-up		3.8 (0; 14.3)		7.1 (1.9; 19.2)		2.1 (0; 7.7)		5.4 (0; 15.4)	<0.001
Percentage of interdental sites with PD ≥4 mm, %	Baseline	1529	9.1 (0; 29.2)	151	15.0 (4.2; 35.7)	235	3.8 (0; 12.5)	247	11.5 (3.8; 25.0)	<0.001
	Follow-up		7.1 (0; 21.4)		10.7 (0; 27.3)		3.8 (0; 11.1)		8.3 (0; 21.4)	<0.001
Percentage of non-interdental sites with PD ≥4 mm, %	Baseline	1529	0 (0; 5)	151	0 (0; 10.7)	235	0 (0; 3.6)	247	0 (0; 7.7)	<0.001
	Follow-up		0 (0; 4.5)		0 (0; 10.0)		0 (0; 3.6)		0 (0; 8.3)	<0.001
Mean CAL, mm	Baseline	1445	1.79 (1.14; 2.75)	147	2.59 (1.75; 3.50)	227	1.75 (1.13; 2.53)	235	2.42 (1.65; 3.48)	<0.001
	Follow-up		1.83 (1.41; 2.60)		2.44 (1.75; 3.38)		1.70 (1.29; 2.22)		2.40 (1.60; 3.39)	<0.001
Mean interdental CAL, mm	Baseline	1444	1.83 (1.13; 2.95)	147	2.63 (1.75; 3.67)	227	1.80 (1.05; 2.73)	235	2.38 (1.55; 3.56)	<0.001
	Follow-up		1.88 (1.50; 2.65)		2.46 (1.79; 3.35)		1.64 (1.29; 2.33)		2.27 (1.63; 3.41)	<0.001

(Table 4 continues on next page)

(Continuation of Table 4)

Mean non-interdental CAL, mm	Baseline	1444	1.70 (1.08; 2.63)	147	2.50 (1.81; 3.50)	227	1.64 (1.13; 2.45)	235	2.38 (1.60; 3.33)	<0.001
	Follow-up		1.79 (1.31; 2.56)		2.40 (1.75; 3.40)		1.73 (1.19; 2.27)		2.44 (1.54; 3.35)	<0.001
CDC/AAP case definition	Baseline	1419		143		223		230		
No/mild periodontitis			785 (55.3%)		50 (35.0%)		143 (64.1%)		75 (32.6%)	
Moderate periodontitis			440 (31.0%)		60 (42.0%)		65 (29.2%)		116 (50.4%)	
Severe periodontitis			194 (13.7%)		33 (23.1%)		15 (6.7%)		39 (17.0%)	<0.001
CDC/AAP case definition	Follow-up	1419		143		223		230		
No/mild periodontitis			861 (60.7%)		55 (38.5%)		158 (70.9%)		94 (40.9%)	
Moderate periodontitis			434 (30.6%)		68 (47.5%)		48 (21.5%)		101 (43.9%)	
Severe periodontitis			124 (8.7%)		20 (14.0%)		17 (7.6%)		35 (15.2%)	<0.001
DF-S	Baseline	1574	17 (9; 24)	153	17 (11; 25)	239	20 (11; 27)	254	19 (12; 27)	<0.001
	Follow-up		17 (9; 25)		19 (10; 26)		21 (12; 27)		19 (12; 27)	<0.001
Interdental DF-S	Baseline	1574	7 (3; 11)	153	8 (4; 12)	239	8 (4; 13)	254	9 (5; 12)	<0.001
	Follow-up		8 (4; 11)		8 (4; 12)		9 (5; 13)		8 (5; 12)	<0.001
Non-interdental DF-S	Baseline	1574	9 (6; 13)	153	10 (6; 14)	239	11 (7; 14)	254	10 (7; 15)	<0.001
	Follow-up		10 (6; 14)		10 (6; 14)		11 (7; 15)		10 (6; 15)	0.0019
Number of missing teeth	Baseline	1631	3 (1; 7)	160	4 (2; 9)	242	2.5 (1; 5)	270	5 (2; 9)	<0.001
	Follow-up		4 (1; 9)		5 (2.5; 11)		3 (1; 6)		6 (2; 11)	<0.001

*Data are presented as median (25%; 75% quantiles). *Kruskal Wallis test or Chi squared test; Abbreviations: IDA, interdental aids; PD, probing depth; CAL, clinical attachment level; BOP, bleeding on probing; CDC, Centers for Disease Control and Prevention; AAP, American Academy of Periodontology; DF-S, number of decayed or filled surfaces.*

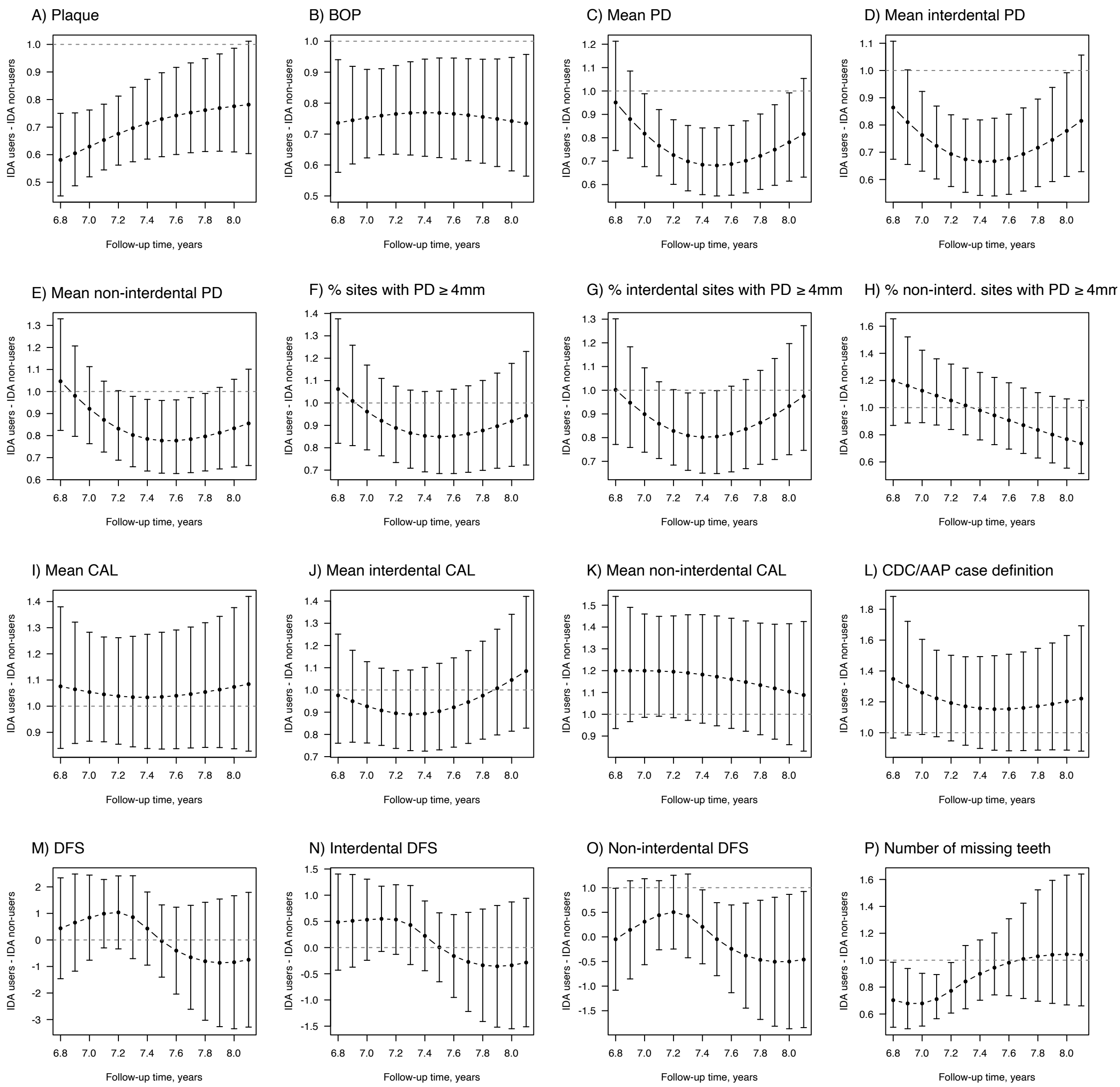

Figure 1. Adjusted proportional odds ratios from ordinal logistic models (A-L, P; with logit link) and beta coefficients from linear models using generalized least squares (M-O) contrasting interdental aids (IDA) users with IDA non-users. Estimates are tabulated in Supplementary Table 1.

3.5 Effects contrasting interdental cleaning aid users with IDA non-users

Overall, the ordinal logistic models showed stable effects favoring IDA usage over IDA non-usage, especially for dental floss usage followed by interdental brushes (Figures 1, 2). These beneficial effects of interdental aids usage on plaque, BOP, periodontitis variables (PD, CAL), caries (DF-S) and the number of missing teeth were relatively constant in all of the following analyses.

In Figure 1 we can see a significant effect of IDA usage for plaque scores and BOP, with odds ratios ranging between 0.58 (6.8 years) and 0.78 (8.0 years) for plaque scores and between 0.74 (6.8 follow-up time, years) and 0.73 (8.1 follow-up time, years) for BOP. There was also a clear beneficial effect for IDA usage on mean PD and mean interdental PD, with significantly reduced odds ratios for IDA users for follow-up times between the 7.0- and 8.0-year mark (mean PD 0.82-0.78; mean interdental PD 0.76-0.78). Favorable effects of IDA usage regarding mean PD of non-interdental sites were only observed between the 7.3- and the 7.8-year mark (OR 0.80-0.80). For the percentage of sites (also if restricting to interdental or non-interdental sites) with PD ≥4 mm interdental aids usage showed no consistent beneficial effects. The interdental aids usage showed no beneficial effects on mean CAL, also when sites were restricted to interdental or non-interdental ones. Also, no beneficial effects on the CDC/AAP case definition were identified.

For the DF-S and the interdental DF-S effects of IDA usage were non-significant. The non-interdental DF-S varied widely with beta coefficient ranging between -0.257 and -0.747. For the number of missing teeth beneficial effects of IDA usage with odds ratios of 0.70 to 0.77 were only observed for restricted follow-up times between 6.8 and 7.2 years.

3.6 Effects contrasting wooden stick users, floss users, interdental brush users with IDA non-users

In Figures 2 to 5 we can see odds ratios from ordinal logistic models contrasting wooden stick users, floss users and interdental brush users with IDA non-users. For plaque, BOP and most of the periodontal variables (mean PD, percentage of sites with PD ≥4 mm, mean CAL, CDC/AAP case definition) dental floss usage showed almost only pronounced effects. Interdental brushes resulted into the second favorable profile of IDA usage, with significant effects for plaque, BOP and mean interdental PD (only for 7.1-year to 7.6-years and an OR of 0.76-0.72). For other variables dental brushes could not show a consistent positive effect. Compared to IDA non-users, wood stick users did not show beneficial effects on any of the dental variable's outcome. Furthermore, none of the interdental aids showed a significant beneficial effect on the caries variables (DF-S, interdental DF-S and non-interdental DF-S) nor on the number of missing teeth.

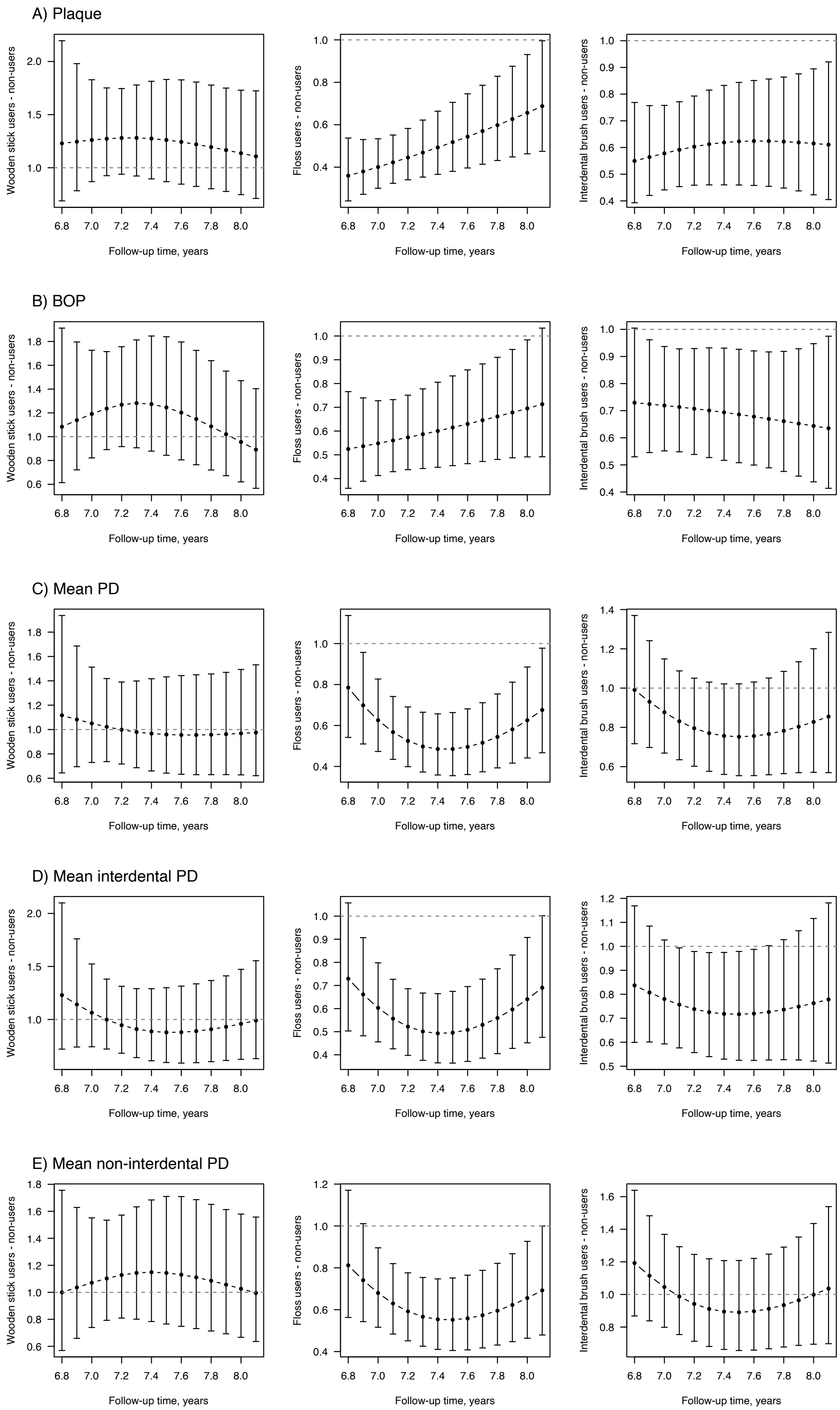

Figure 2. Adjusted proportional odds ratios from ordinal logistic models (with logit link) contrasting wooden stick users (left), floss users (middle) or interdental brush users (right) with non-users. Estimates are tabulated in Supplementary Table 2.

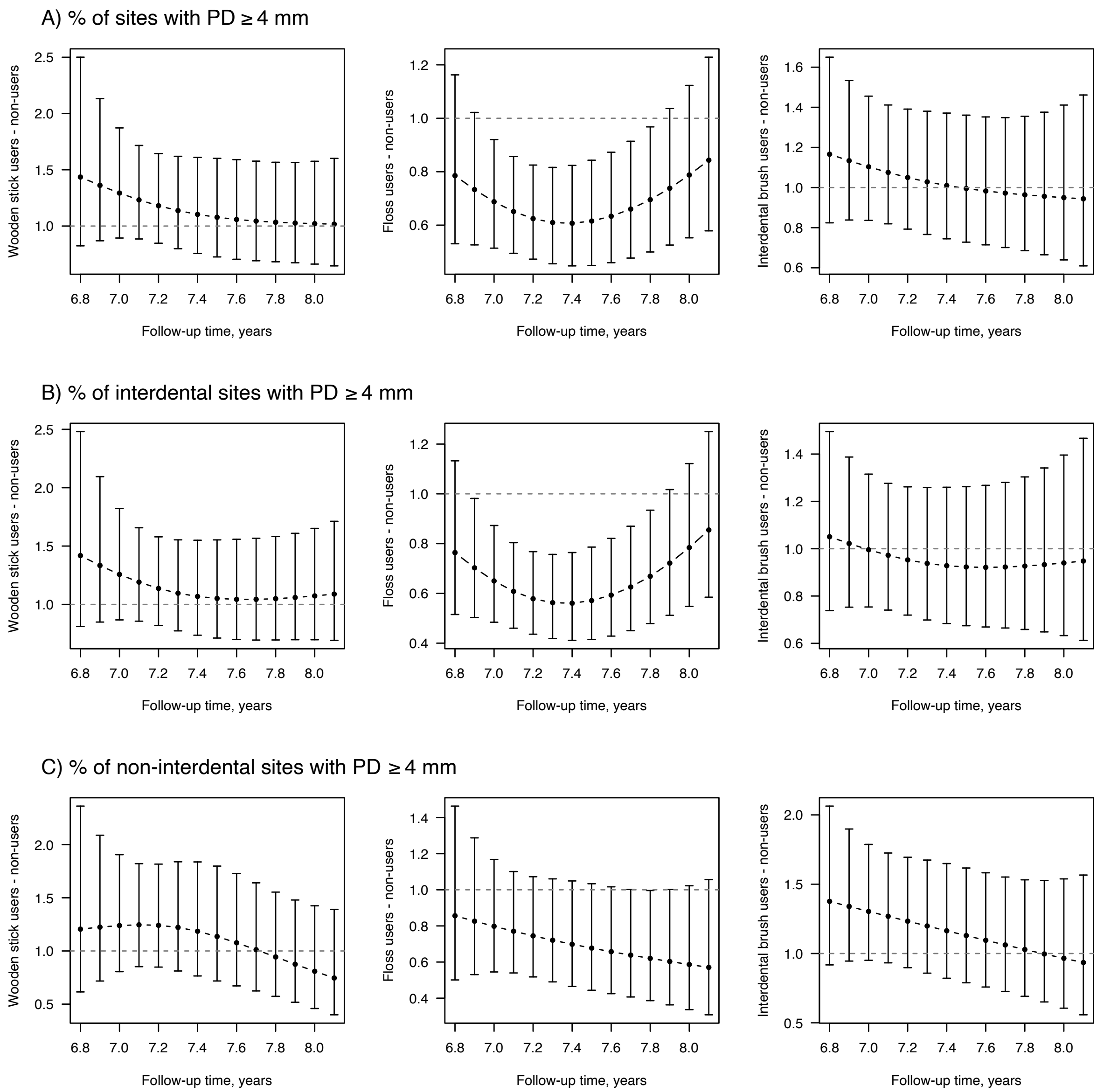

Figure 3. Adjusted proportional odds ratios from ordinal logistic models (with logit link) contrasting wooden stick users (left), floss users (middle) or interdental brush users (right) with non-users. Estimates are tabulated in Supplementary Tables 2.

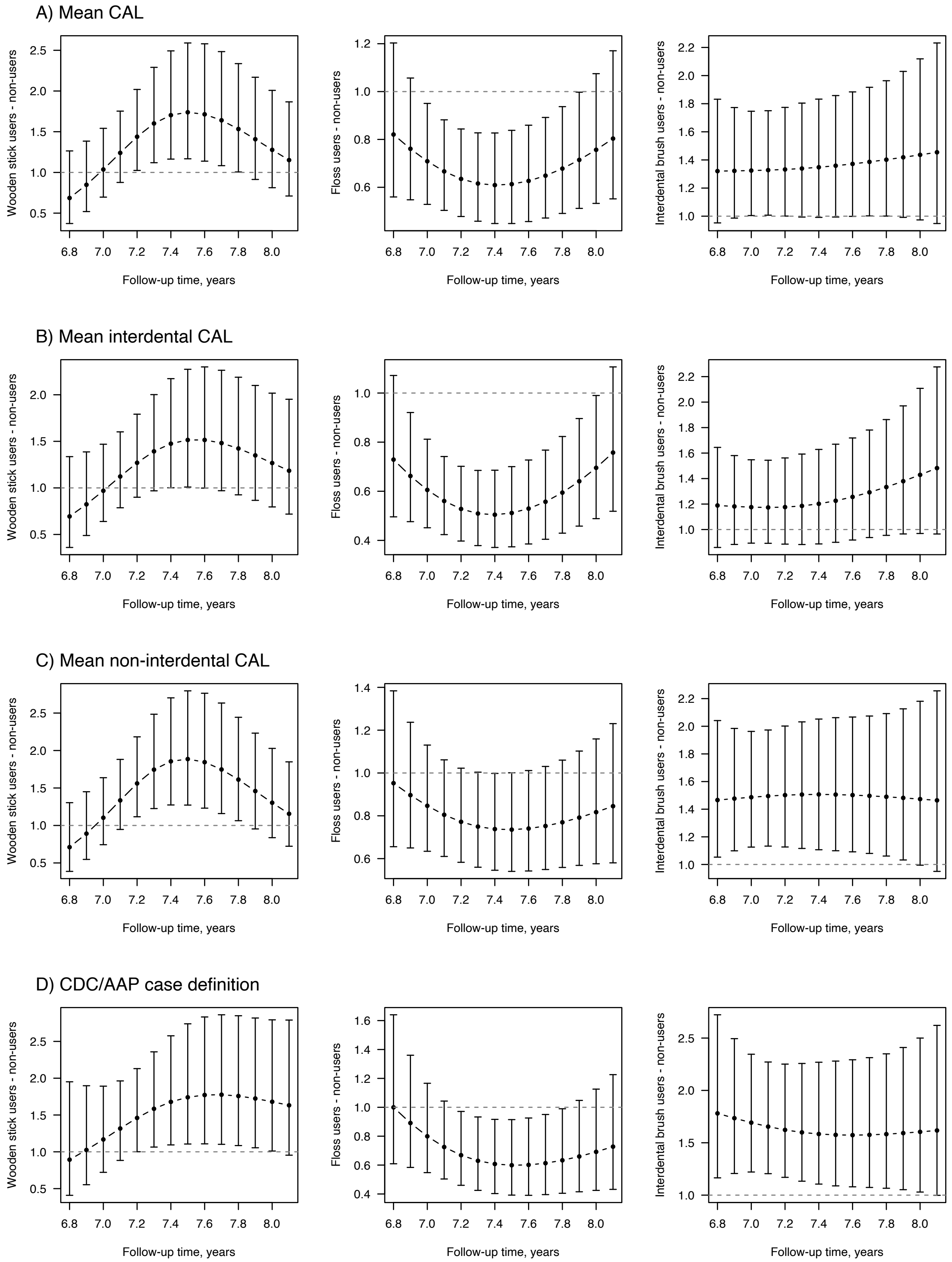

Figure 4. Adjusted proportional odds ratios from ordinal logistic models (with logit link) contrasting wooden stick users (left), floss users (middle) or interdental brush users (right) with non-users. Estimates are tabulated in Supplementary Tables 3.

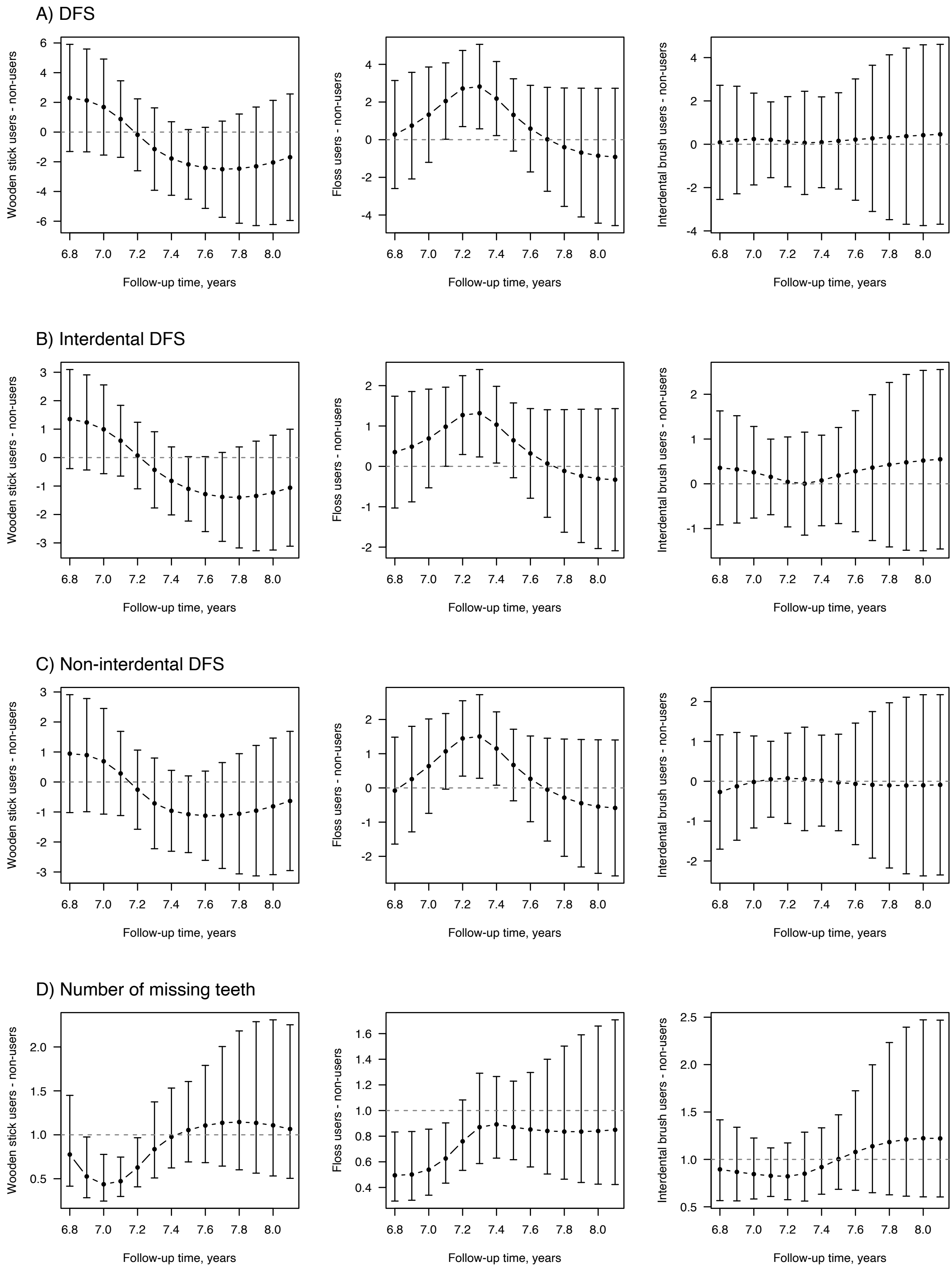

Figure 5. Adjusted beta coefficients from linear models using generalized least squares (A-C) and adjusted proportional odds ratios from ordinal logistic models (D; with logit link) and contrasting wooden stick users (left), floss users (middle) or interdental brush users (right) with non-users. Estimates are tabulated in Supplementary Table 3.

3.7 Sensitivity analyses using imputed data

In Figure 6 odds ratios contrasting IDA users with IDA non-users using imputed data are presented. In line with previous results, beneficial effects of IDA usage were seen for plaque, BOP, mean PD, mean interdental PD, mean non-interdental PD, as well as for mean interdental CAL and the percentage of interdental sites with PD ≥4 mm. For the other variables (percentage of sites with PD ≥4 mm, percentage of non-interdental sites with PD ≥4 mm, mean CAL, mean non-interdental CAL, CDC/AAP case definition, DF-S and interdental and non-interdental DF-S and number of missing teeth) no significant effects of IDA usage versus IDA non-usage were observed.

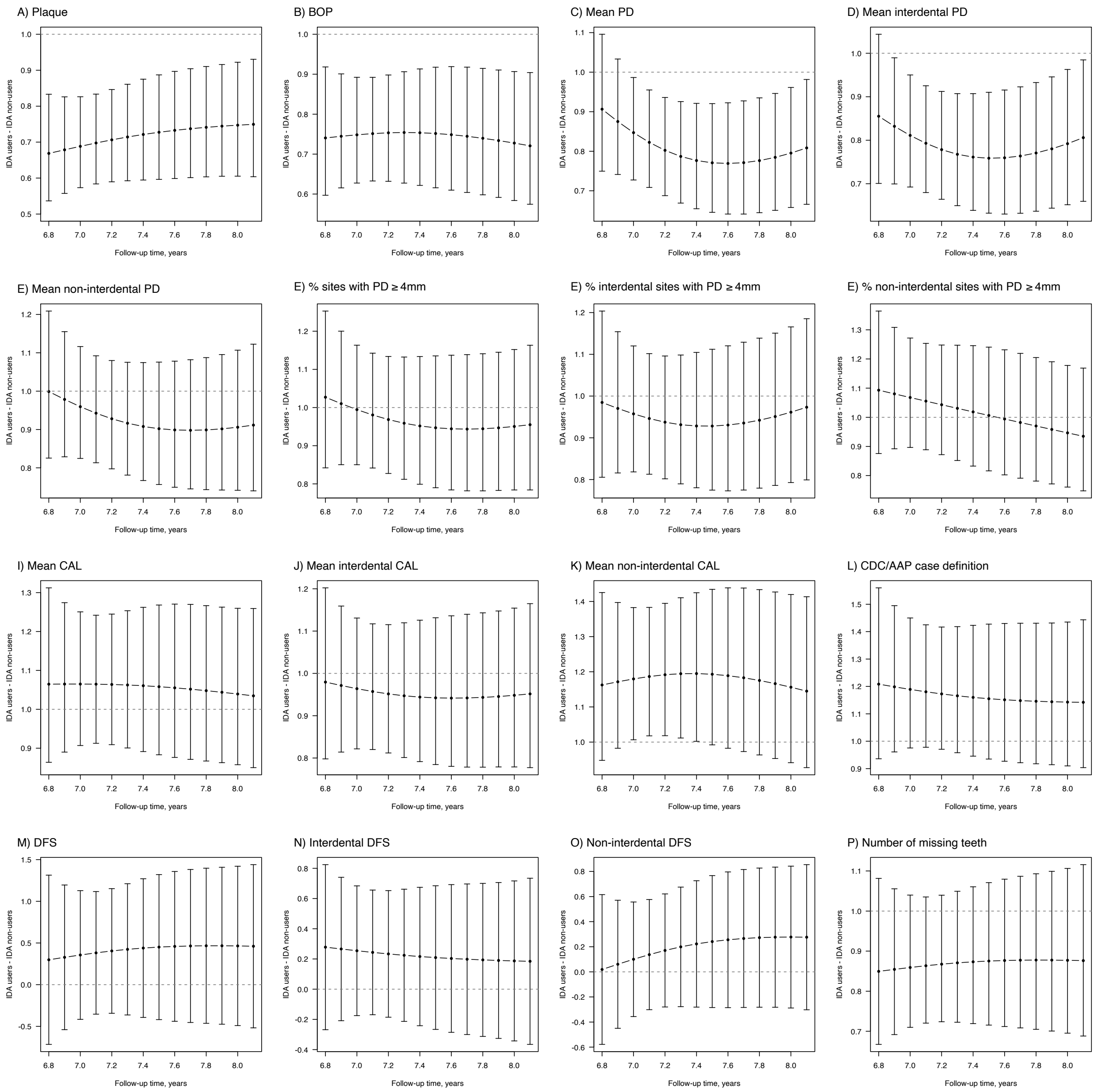

Figure 6. Adjusted proportional odds ratios from ordinal logistic models (A-K, P; with logit link), odds ratios from logistic models (L), and beta coefficients from linear models using generalized least squares (M-O) contrasting interdental aids (IDA) users with IDA non-users using imputed data. Estimates are tabulated in Supplementary Table 4.

4 Discussion

4.1 Main results

In this study, interdental aids usage was associated with reduced 7-year follow-up levels of periodontitis related variables, while effects on caries variables (DF-S) and the number of missing teeth were non-significant. Among interdental cleaning aids, dental floss was most effective in reducing follow-up levels of periodontitis variables, followed by interdental brushes. The effect of these IDA on follow-up levels of mean PD, BOP and plaque were seen in noticeably reduced values through dental floss and interdental brushes, although those did not show a beneficial effect on CAL variables. Odds of having higher mean PD levels were halved (Odds Ratio 0.49; 95% confidence interval (CI) 0.35;0.66) comparing dental floss users with non-users. Respective ORs were 0.61 (95%CI 0.45;0.83) for mean CAL, 0.52 (95%CI 0.36;0.77) for BOP and 0.36 (95%CI 0.24;0.54) for plaque. Similarly, ORs for interdental brush users were 0.75 (95%CI 0.55;1.02) for mean PD, 0.64 (95%CI 0.41;0.97) for BOP and 0.55 (95%CI 0.39;0.77) for plaque, compared to non-users. For wooden sticks non-significant associations were found, which does not allow any statement to be made regarding possible effects on oral health. Caries variables (DF-S) and the number of missing teeth were non-significantly associated with interdental aids usage.

4.2 Possible elaboration of results

As we know, the caries demineralization process is closely linked to plaque/biofilm and is often found on approximal surfaces of the teeth. This fact would amplify that plaque-control through IDA should also reflect in measured long-term caries variables. However, there were no significant reductions in DMF-T indices due to IDA usage in our study, neither in the ones mentioned before. This could suggest that basic interdental aids such as floss, brushes and sticks do not remove plaque and bacteria sufficiently to a microscopic level, which would be needed to prevent the demineralization process of caries. The macroscopic pathogenic plaque and tartar formation, which induces symptoms of gingivitis and combined with co-factors also periodontitis was removed and therefore had a positive outcome. For caries prevention treatment with fluorides is of way greater importance, as well as the avoidance of the combination and presence of the four main caries risk factors (see Figure 1).

Another issue appeared in CAL and PD variables: mean PD was significantly reduced by IDA usage, especially through the use of dental floss and dental brushes. For CAL no significant reduction could be found in this study. This particularity has its origin in the recession of the periodontium and marginal gingiva, which leads to exposed roots. On this occasion CAL is high (measuring from the enamel-cement-junction to the bottom of the sulcus/pocket), but PD measurements can be low (measuring from the marginal gingiva to the bottom of the gingival sulcus/pocket). PD can decrease through careful and continuous dental cleaning with a decline of the acute inflammation, whereby CAL cannot be repaired non-invasively.

4.3 Comparison to related studies

As already mentioned earlier in the introductory chapter (1.7), there is only limited literature on potential beneficial effects of interdental cleaning aids regarding oral health (Chapple et al., 2015). There were profound disagreements and diverging results regarding the effect of interdental cleaning aids in previous literature dealing with the use of IDA as an advantage for oral selfcare preventing caries, gingivitis, periodontitis and tooth loss.

In this study, IDA usage, specifically dental floss and dental brushes, noticeably reduced follow-up levels of plaque (gingivitis) and periodontal variables (BOP, PD and partially CAL). A renowned recent Cochrane Collaboration review came to a similar conclusion, that flossing plus tooth brushing showed a positive benefit compared to tooth brushing alone in reducing periodontitis (Sambunjak et al., 2011). The effectiveness of flossing was examined in twelve studies that met the inclusion criteria of Sambunjak et al. and was searched and collected in different databases in October 2011. The follow-up times were one, three and six months and measured with the Loe-Silness gingivitis index (range 0-3 points). The results showed a reduction of 0.13 at 1 month, 0.20 at 3 months and 0.09 at 6 months. But the review also found insufficient evidence in reducing plaque and no information on further tooth decay variables, due to short follow-up trials. Those measurements were practicable in our long-term SHIP-

Trend study but did also not show any beneficial effects of IDA on caries nor the number of missing teeth.

Vernon et al. defended dental floss after recent meta-analyses and other reviews that had reported inconclusive evidence on dental floss promoting gingival and periodontal health (Vernon et al., 2017). Vernon et al. claimed that on one hand high-quality evidence has yet not been determined, however, if IDA cannot be proven to be unhelpful or unnecessary on the other. This assumption can now be supported by our study, were the effectiveness in reducing clinical gingivitis and periodontitis parameters through the use of dental floss has been proven. One of the most recent articles with the title "Impact of Powered Toothbrush Use and Interdental Cleaning on Oral Health" by Pitchika et al. (2020) is one of few observational studies that serves long-term data and results on the effectiveness of PTB and IDA on caries, periodontitis, and tooth loss over the course of 17 years (Pitchika et al., 2020). The study included data from three independent cross-sectional surveys of the German Oral Health Studies (DMS) and used measures of PD, number of caries-free surfaces and number of teeth as variables. In contrast to short-term clinical studies, Pitchika et al. reported that both PTB and IDA usage contributed to increased numbers of caries-free surfaces and numbers of teeth. This was continuously found over the course of time between DMS III, IV and V. The fact that IDA usage has a positive effect regarding caries and tooth loss could not be confirmed by the results of our study.

In a more recent review and meta-analysis several interdental cleaning aids (floss, brushes, wood sticks, rubber sticks and oral irrigators) were evaluated for their effects on various gingivitis and plaque indices (Worthington et al., 2019). The authors came to the conclusion that interdental brushes may be more effective than dental floss in reducing gingivitis and/or plaque. In contrast to that study, Berchier et al. (2008) concluded that dental floss in combination with tooth brushing provided no additional benefit at all for clinical parameters of periodontal diseases and plaque reduction compared with tooth brushing alone (Berchier et al., 2008).

Our results were in contrast to Worthington et al. statements, where dental floss showed better effects on plaque and BOP parameters and contradicting Berchier et al. results. This might be explained by the fact that clinical studies evaluated short-term effects of IDA usage and that most of the participants had a low level of gingival inflammation at baseline. Worthington et al. also pointed out that further trials should report on the participant's periodontal status according to the new periodontal disease classification, and last long enough to have an observational view on interdental caries and periodontitis parameters, which were both met in our SHIP-TREND study.

4.4 Prevention and clinical relevance

To prevent oral diseases like caries, gingivitis, and periodontitis, a regular and proper prevention program has to be encouraged and carried out daily. This includes primarily tooth brushing and IDA usage at home and secondly a yearly checkup (for high-risk patients half-yearly) with a professional dental cleaning. A trend towards noticeably greater use of IDA can be seen over the last few decades. This is illustrated for example in the DMS V between the years 1997-2014, where a significant increase in the use of dental floss and interdental brushes was noted (Jordan et al., 2016). This trend is a pioneer in daily dental hygiene and should be encouraged and promoted further on.

We can also conclude from our study that the practical handling of IDA should be included into daily practice life and home usage for preventing periodontal diseases especially. Therefore, it is of great importance that the use and correct handling is being instructed and carried out properly in order to achieve the positive effect and do no harm to gingival gums and sulcus. This also implies that the complexity of the disease should also be communicated in a simpler manner to the wide public in order to understand the dimensions of this disease and to support treatment more from home.

These instructions must be given out by dental practitioners to the patients directly, especially for the use of interdental brushes. Personal instructions should include the frequency, the right timing and correct inserting and handling of IDA, as well as a consultation on which IDA (if brushes also which size) should be used (Carrouel et al., 2016). These individual instructions should be considered when investigating the use and effect of more detailed IDA concerning studies in the future, to include the unmitigated complexity of the topic. Furthermore, the new gingivitis and periodontitis classification introduced in 2018 (Tonetti et al., 2018) should be evaluated to have a more standardized overarching technique that facilitates the understanding of the longitudinal disease process even if changing practitioners investigate the status.

4.5 Strengths and limitations of the study

The study had several strengths. Firstly, this is one of the very few large-scaled long-term cohort studies evaluating effects of IDA usage on various oral disease parameters, ranging from caries to periodontitis and tooth loss. Secondly, a representative cross-section of the population of the examined region was obtained in SHIP-TREND. In all examinations, the practitioners were well calibrated, which led to consistent quality of measurements in the collection process, good data quality and significant results. In addition, the investigations were not limited to just one medical or dental specialty.

Nevertheless, this study showed that the follow-up time of approximately 7.5 years was too short for certain endpoints that have a progression like in the process of caries formation and tooth loss. Potential developments in these parameters could therefore only be determined to a small extent. Regarding the limitations of the study, selection bias could have been an issue in the follow-up process, where healthier subjects with a higher compliance were more likely to show up and continue the participation of the study. However, missing data were imputed and results using imputed data basically confirmed previous results.

Also, caries and periodontitis measurements were conducted based on a half-mouth protocol, thereby underestimating disease severity to a certain extent (Alawaji et al., 2022). However, for mean PD/CAL the level of bias associated with half-mouth recordings is nevertheless small (Kingman et al., 2008). But, in general, there is a shift in effect estimates towards the null effect (Akinkugbe et al., 2015). Thus, effects might have been underestimated rather than overestimated.

4.6 Conclusion and outlook

In conclusion, the study results provide further evidence in favor of recommending IDA usage combined with daily toothbrushing. This implicates the clinical importance of home usage of IDA with correct handling on a regular basis. Oral health can be increased throughout continuous and correctly performed plaque control at home. These findings are of great importance for everyday clinical practice.

The use of IDA has been increasing over the last years and oral health behavior has been included better into daily life routines (Jordan et al., 2016). A study by Hamilton et al. concerning the intentions of flossing behavior in young adults shows that self-efficacy, planning and self-regulatory mechanisms have to be installed in order to make an intension like flossing turn into a daily behavior (Hamilton et al., 2017). In outlook, oral health behaviorism and knowledge is one of the main factors for a lifelong healthy oral cavity and should be introduced as early as possible into a daily routine of a child's dental care. This solid ground would give future studies concerning IDA usage a distinctly better pre-condition for research and further progression of this topic.

5 Summary

The effect of interdental cleaning on progression of caries, periodontitis and tooth loss is a highly discussed topic in dental research since these conditions are among the most common infectious diseases of mankind. Caries is a multifactorial disease defined by a demineralization process of the dental hard tissue, caused by bacteria, which, if untreated ultimately results in tooth decay and tooth loss. A study published in 2015 confirmed that untreated caries in permanent teeth is still the most prevalent condition worldwide. Gingivitis, an acute inflammation of the gingival tissue, caused by substances deduced from the microbial plaque can develop into the clinical picture of an acute periodontitis. Severe periodontitis is still the sixth-most prevalent condition globally with a prevalence of 11.2% between 1990-2010. Progression of periodontitis leads to bone loss which as well ultimately results in tooth loss, if left untreated. In our study we want to examine the use of IDA in relation to caries and periodontal diseases, thus tooth retention to gain more detailed and long-term results about the effect of IDA and therefore prevent, counteract and understand these oral diseases better.

Using data from SHIP-TREND, a population-based observational cohort study conducted in Western Pomerania (Germany), we examined effects of daily usage of interdental cleaning aids on follow-up (SHIP-TREND-1) values of oral outcomes comprising caries (DF-S, interdental DF-S, non-interdental DF-S), gingivitis (plaque, BOP), chronic periodontitis (mean PD, mean interdental PD, mean non-interdental PD, mean CAL, mean interdental CAL, mean non-interdental CAL, CDC/APP case definition) and tooth loss (number of missing teeth) using comprehensively adjusted linear and ordinal logistic regression models. In total, data from over 2,000 participants with a follow-up time of approximately seven years were utilized. Based on interviews, participants were asked about their habit and the regularity of using interdental aids as a cleaning aid at home. Furthermore, the type of IDA was then analyzed and differentiated into groups of IDA non-users, wooden stick users, floss users and interdental brush users.

Regular interdental aids usage was associated with reduced levels of periodontitis severity (mean PD and mean CAL) and gingivitis variables (plaque and BOP). The beneficial effect was more pronounced in participants using dental floss or interdental brushes regularly. After seven years of follow-up, odds of having higher mean PD

levels were halved (Odds Ratio 0.49; 95% confidence interval (CI) 0.35;0.66) comparing dental floss users with non-users. Respective ORs were 0.61 (95%CI 0.45;0.83) for mean CAL, 0.52 (95%CI 0.36;0.77) for BOP and 0.36 (95%CI 0.24;0.54) for plaque. Similarly, ORs for interdental brush users were 0.75 (95%CI 0.55;1.02) for mean PD, 0.64 (95%CI 0.41;0.97) for BOP and 0.55 (95%CI 0.39;0.77) for plaque, compared to non-users. For wooden sticks non-significant associations were found, which does not allow any statement to be made regarding possible effects on oral health. Caries variables (DF-S) and the number of missing teeth were non-significantly associated with interdental aids usage.

In conclusion, results suggest that interdental cleaning aids usage may contribute to healthier gums and reduced inflammation, if combined with daily toothbrushing and regular dental checkups. Specifically, dental flossing and interdental brushing might notably reduce gingival inflammation and therefore prevent chronic periodontitis. These findings contribute to a more distinct picture of how IDA might help to prevent oral diseases and must be properly integrated into our daily oral hygiene program.

6 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. *J Clin Periodontol, 42*(7), 609-621. doi:10.1111/jcpe.12425

Alawaji, Y. N., Mostafa, N., Carvalho, R. M., Alshammari, A., & Aleksejuniene, J. (2022). Accuracy and precision of using partial-mouth recordings to study the prevalence, extent and risk associations of untreated periodontitis. *Saudi Dent J, 34*(2), 142-149.

Armitage, G. C. (1999). Development of a classification system for periodontal diseases and conditions. *Ann Periodontol, 4*(1), 1-6.

Asadoorian, J., & Locker, D. (2006). The impact of quality assurance programming: a comparison of two canadian dental hygienist programs. *J Dent Educ, 70*(9), 965-971.

Atwood, D. A. (1971). Reduction of residual ridges: a major oral disease entity. *Journal of Prosthetic Dentistry, 26*(3), 266-279.

Atzpodien, K., Bergmann, E., Bertz, J., Busch, M., Eis, D., Ellert, U., Fuchs, J., Gaber, E., Gutsche, J., Haberland, J., Hagen, C., & Hapke, U. (2009). 20 Jahre nach dem Fall der Mauer: Wie hat sich die Gesundheit in Deutschland entwickelt? *Robert Koch-Institut*, 302.

Axelsson, P., & Lindhe, J. (1977). The effect of a plaque control program on gingivitis and dental caries in schoolchildren. *J Dent Res, 56 Spec No*, C142-148.

Axelsson, P., & Lindhe, J. (1981). The significance of maintenance care in the treatment of periodontal disease. *J Clin Periodontol, 8*(4), 281-294.

Baelum, V., van Palenstein Helderman, W., Hugoson, A., Yee, R., & Fejerskov, O. (2007). A global perspective on changes in the burden of caries and periodontitis: implications for dentistry. *J Oral Rehabil, 34*(12), 872-906; discussion 940.

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. *Int J Dent Hyg, 6*(4), 265-279.

Bouma, J., Uitenbroek, D., Westert, G., Schaub, R. M., & van de Poel, F. (1987). Pathways to full mouth extraction. *Community Dent Oral Epidemiol, 15*(6), 301-305.

Braegger, U. (2005). Cost-benefit, cost-effectiveness and cost-utility analyses of periodontitis prevention. *J Clin Periodontol, 32 Suppl 6*, 301-313.

Brecx, M. C., Fröhlicher, I., Gehr, P., & Lang, N. P. (1988). Stereological observations on long-term experimental gingivitis in man. *J Clin Periodontol, 15*(10), 621-627.

Carinci, F., Martinelli, M., Contaldo, M., Santoro, R., Pezzetti, F., Lauritano, D., Candotto, V., Mucchi, D., Palmieri, A., Tagliabue, A., & Tettamanti, L. (2018). Focus on periodontal disease and development of endocarditis. *J Biol Regul Homeost Agents, 32*(2 Suppl. 1), 143-147.

Carlsson, G. E., Ragnarson, N., & Astrand, P. (1969). Changes in height of the alveolar process in edentulous segments. II. A longitudinal clinical and radiographic study over 5 years of full upper denture patients with residual lower anteriors. *Sven Tandlak Tidskr, 62*(3), 125-136.

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.

Caton, J. G., Armitage, G., Berglundh, T., Chapple, I. L. C., Jepsen, S., Kornman, K. S., Mealey, B. L., Papapanou, P. N., Sanz, M., & Tonetti, M. S. (2018). A new classification scheme for periodontal and peri-implant diseases and conditions - Introduction and key changes from the 1999 classification. *J Periodontol, 89 Suppl 1*, S1-s8.

Chapple, I. L., Bouchard, P., Cagetti, M. G., Campus, G., Carra, M. C., Cocco, F., Nibali, L., Hujoel, P., Laine, M. L., Lingstrom, P., Manton, D. J., Montero, E., Pitts, N., Range, H., Schlueter, N., Teughels, W., Twetman, S., Van Loveren, C., Van der Weijden, F., Vieira, A. R., & Schulte, A. G. (2017). Interaction of lifestyle, behaviour or systemic diseases with dental caries and

periodontal diseases: consensus report of group 2 of the joint EFP/ORCA workshop on the boundaries between caries and periodontal diseases. *J Clin Periodontol, 44 Suppl 18*, S39-S51.
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., Eren Kuru, B., Arweiler, N., Teughels, W., Aimetti, M., Molina, A., Montero, E., & Graziani, F. (2015). Primary prevention of periodontitis: managing gingivitis. *J Clin Periodontol, 42 Suppl 16*, S71-76.
Chee, W. W. (2005). Treatment planning: implant-supported partial overdentures. *J Calif Dent Assoc, 33*(4), 313-316.
Cronin, M., Meaney, S., Jepson, N. J., & Allen, P. F. (2009). A qualitative study of trends in patient preferences for the management of the partially dentate state. *Gerodontology, 26*(2), 137-142.
Devlin, H., & Ferguson, M. W. (1991). Alveolar ridge resorption and mandibular atrophy. A review of the role of local and systemic factors. *Br Dent J, 170*(3), 101-104.
Donn, J. (2016). Medical benefits of dental floss unproven. *AP News*.
Dregan, A., Charlton, J., Chowienczyk, P., & Gulliford, M. C. (2014). Chronic inflammatory disorders and risk of type 2 diabetes mellitus, coronary heart disease, and stroke: a population-based cohort study. *Circulation, 130*(10), 837-844.
Featherstone, J. D. B., & Chaffee, B. W. (2018). The Evidence for Caries Management by Risk Assessment (CAMBRA(R)). *Adv Dent Res, 29*(1), 9-14.
Fenlon, M. R., & Sherriff, M. (2008). An investigation of factors influencing patients' satisfaction with new complete dentures using structural equation modelling. *J Dent, 36*(6), 427-434.
Figuero, E., Nóbrega, D. F., García-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. *J Clin Periodontol, 44 Suppl 18*, S116-s134.
Forss, H., & Widstrom, E. (2004). Reasons for restorative therapy and the longevity of restorations in adults. *Acta Odontol Scand, 62*(2), 82-86.
Frost, H. M. (2003). Bone's mechanostat: a 2003 update. *Anat Rec A Discov Mol Cell Evol Biol, 275*(2), 1081-1101.
Gerritsen, A. E., Allen, P. F., Witter, D. J., Bronkhorst, E. M., & Creugers, N. H. (2010). Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. *Health Qual Life Outcomes, 8*, 126.
Glockmann, E., Panzner, K.-D., Huhn, P., Sigusch, B., & Glockmann, K. (2011). “Reasons for tooth loss in Germany” Documentation of a nationwide survey (2007). In *Köln: Institute of German Dentists (IDZ)* (Vol. 2).
Griffin, S. O., Regnier, E., Griffin, P. M., & Huntley, V. (2007). Effectiveness of fluoride in preventing caries in adults. *J Dent Res, 86*(5), 410-415.
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. *Am J Epidemiol, 175*(3), 210-217.
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. *Int J Behav Med, 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.). London: Springer.
Harrell, F. E. J. (2021). rms: Regression Modeling Strategies. Retrieved from https://CRAN.R-project.org/package=rms
Heitz-Mayfield, L. J., Schätzle, M., Löe, H., Bürgin, W., Anerud, A., Boysen, H., & Lang, N. P. (2003). Clinical course of chronic periodontitis. II. Incidence, characteristics and time of occurrence of the initial periodontal lesion. *J Clin Periodontol, 30*(10), 902-908.
Hellwig, Gülzow, & Hetzer. (2002). Empfehlungen zur Kariesprophylaxe mit Fluoriden. *DGZMK, 2.1*.

Hellwig, Klimek, & Attin. (1999). *Einführung in die Zahnerhaltung - Ätiologie, Histologie und Epidemiologie der Karies und anderer Zahnhartsubstanzdefekte*. München-Jena Urban&Fischer.
Hine, M. K. (1950). The use of the toothbrush in the treatment of periodontitis. *J Am Dent Assoc, 41*(2), 158-168.
Holtfreter, B., Schwahn, C., Biffar, R., & Kocher, T. (2009). Epidemiology of periodontal diseases in the Study of Health in Pomerania. *J Clin Periodontol, 36*(2), 114-123.
Horn, J., Pistorius, J., Willershausen, B., & Kraft, J. (2007). WISSENSCHAFT-Tagungsbeitrage (Jahrestagung der DGZMK)-Faktoren des Zahnverlustes bei Patienten mit herausnehmbarem Zahnersatz. *Deutsche Zahnärztliche Zeitschrift, 62*(6), 403-407.
Hugoson, A., & Koch, G. (2008). Thirty year trends in the prevalence and distribution of dental caries in Swedish adults (1973-2003). *Swed Dent J, 32*(2), 57-67.
Hugoson, A., Lundgren, D., Asklöw, B., & Borgklint, G. (2007). Effect of three different dental health preventive programmes on young adult individuals: a randomized, blinded, parallel group, controlled evaluation of oral hygiene behaviour on plaque and gingivitis. *J Clin Periodontol, 34*(5), 407-415.
Hugoson, A., Sjödin, B., & Norderyd, O. (2008). Trends over 30 years, 1973–2003, in the prevalence and severity of periodontal disease. *Journal of Clinical periodontology, 35*(5), 405-414.
Hujoel, P. P., Cunha-Cruz, J., Banting, D. W., & Loesche, W. J. (2006). Dental flossing and interproximal caries: a systematic review. *J Dent Res, 85*(4), 298-305.
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).
Inoue, H., Ono, K., Masuda, W., Morimoto, Y., Tanaka, T., Yokota, M., & Inenaga, K. (2006). Gender difference in unstimulated whole saliva flow rate and salivary gland sizes. *Arch Oral Biol, 51*(12), 1055-1060.
Jansson, H., Lindholm, E., Lindh, C., Groop, L., & Bratthall, G. (2006). Type 2 diabetes and risk for periodontal disease: a role for dental health awareness. *J Clin Periodontol, 33*(6), 408-414.
John, M., Reissmann, D., & Allen, F. (2007). The short-term effect of prosthodontic treatment on delf reported oral health status: the use of a singel item questionaire. *Int J Prostodont 20*(5), 507 - 513.
Jordan, A. R., Micheelis, W., Cholmakow-Bodechtel, C., Füßl-Grünig, E., Geyer, S., Hertrampf, K., Hoffmann, T., Holtfreter, B., Kocher, T., Nitschke, I., Noffz, S., Scharf, L., Schiffner, U., Schützhold, S., Stark, H., & Zimmer, S. (2016). Fünfte Deutsche Mundgesundheitsstudie (DMS V) *Deutscher Zahnärzte Verlag Köln, 1. Auflage*.
Jordan, R. A., Bodechtel, C., Hertrampf, K., Hoffmann, T., Kocher, T., Nitschke, I., Schiffner, U., Stark, H., Zimmer, S., Micheelis, W., & Group, D. V. S. I. (2014). The Fifth German Oral Health Study (Funfte Deutsche Mundgesundheitsstudie, DMS V) - rationale, design, and methods. *BMC Oral Health, 14*, 161.
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. *J Dent Res, 94*(5), 650-658.
Kassebaum, N. J., Bernabé, E., Dahiya, M., Bhandari, B., Murray, C. J., & Marcenes, W. (2014a). Global burden of severe periodontitis in 1990-2010: a systematic review and meta-regression. *J Dent Res, 93*(11), 1045-1053.
Kassebaum, N. J., Bernabé, E., Dahiya, M., Bhandari, B., Murray, C. J., & Marcenes, W. (2014b). Global Burden of Severe Tooth Loss: A Systematic Review and Meta-analysis. *J Dent Res, 93*(7 Suppl), 20s-28s.
Keyes, P. H. (1962). Recent advances in dental caries research. *Int Dent J 1962*(12), 443–464.
Kidd, E. A., & Fejerskov, O. (2004). What constitutes dental caries? Histopathology of carious enamel and dentin related to the action of cariogenic biofilms. *J Dent Res, 83 Spec No C*, C35-38.

Kingman, A., Susin, C., & Albandar, J. M. (2008). Effect of partial recording protocols on severity estimates of periodontal disease. *J Clin Periodontol, 35*(8), 659-667. doi:10.1111/j.1600-051X.2008.01243.x

Kolenbrander, P. E., & London, J. (1993). Adhere today, here tomorrow: oral bacterial adherence. *J Bacteriol, 175*(11), 3247-3252.

König, J., Holtfreter, B., & Kocher, T. (2010). Periodontal health in Europe: future trends based on treatment needs and the provision of periodontal services--position paper 1. *Eur J Dent Educ, 14 Suppl 1*, 4-24.

König, K. (1971). Karies und Kariesprophylaxe. *München: Wilhelm GoldmannVerlag GmbH*.

Kowall, B., Holtfreter, B., Volzke, H., Schipf, S., Mundt, T., Rathmann, W., & Kocher, T. (2015). Pre-diabetes and well-controlled diabetes are not associated with periodontal disease: the SHIP Trend Study. *J Clin Periodontol, 42*(5), 422-430.

Kressin, N. R., Boehmer, U., Nunn, M. E., & Spiro, A., 3rd. (2003). Increased preventive practices lead to greater tooth retention. *J Dent Res, 82*(3), 223-227.

Kutsch, V. K. (2014). Dental caries: an updated medical model of risk assessment. *J Prosthet Dent, 111*(4), 280-285.

Lalla, E., Cheng, B., Lal, S., Tucker, S., Greenberg, E., Goland, R., & Lamster, I. B. (2006). Periodontal changes in children and adolescents with diabetes: a case-control study. *Diabetes Care, 29*(2), 295-299.

Lee, D. J., & Saponaro, P. C. (2019). Management of Edentulous Patients. *Dent Clin North Am, 63*(2), 249-261.

Lee, H. J., Choi, E. K., Park, J. B., Han, K. D., & Oh, S. (2019). Tooth Loss Predicts Myocardial Infarction, Heart Failure, Stroke, and Death. *J Dent Res, 98*(2), 164-170.

Li, Y., Lee, S., Hujoel, P., Su, M., Zhang, W., Kim, J., Zhang, Y. P., & De Vizio, W. (2010). Prevalence and severity of gingivitis in American adults. *American journal of dentistry, 23*(1), 9.

Listl, S., Galloway, J., Mossey, P. A., & Marcenes, W. (2015). Global Economic Impact of Dental Diseases. *J Dent Res, 94*(10), 1355-1361.

Löe, H. (1967). The Gingival Index, the Plaque Index and the Retention Index Systems. *J Periodontol, 38*(6), Suppl:610-616.

Löe, H., & Morrison, E. (1986). Periodontal health and disease in young people: screening for priority care. *Int Dent J, 36*(3), 162-167.

Loe, H., Theilade, E., & Jensen, S. B. (1965). EXPERIMENTAL GINGIVITIS IN MAN. *J Periodontol, 36*, 177-187.

Lundgren, D. (2001). Success rates in periodontal treatment as related to choice of evaluation criteria. Presentation of an evaluation criteria staircase for cost-benefit use. *J Clin Periodontol, 28*(1), 23-30.

Mack, F., Mundt, T., Budtz-Jorgensen, E., Mojon, P., Schwahn, C., Bernhardt, O., Gesch, D., John, U., & Biffar, R. (2003). Prosthodontic status among old adults in Pomerania, related to income, education level, and general health (results of the Study of Health in Pomerania, SHIP). *Int J Prosthodont, 16*(3), 313-318.

Marsh, P., & Martin, M. (2016). *Marsh and Martin's oral microbiology* (6. ed.). Edinburgh; New York: Elsevier.

Marsh, P. D., & Zaura, E. (2017). Dental biofilm: ecological interactions in health and disease. *J Clin Periodontol, 44 Suppl 18*, S12-S22.

Marthaler, T. M. (1990). Cariostatic efficacy of the combined use of fluorides. *J Dent Res, 69 Spec No*, 797-800; discussion 820-793.

Mathur, V. P., & Dhillon, J. K. (2018). Dental Caries: A Disease Which Needs Attention. *Indian J Pediatr, 85*(3), 202-206.

Mejàre, I., Källestål, C., Stenlund, H., & Johansson, H. (1998). Caries development from 11 to 22 years of age: a prospective radiographic study. Prevalence and distribution. *Caries Res, 32*(1), 10-16.

Miller, W. D. (1882). Einfluss der Mikroorganismen auf die Karies der menschlichen Zähne. *Arch f exper Path u Pharmakol 1882*.

Mundt, T., Mack, F., & Schwahn, C. (2005). Gender differences in associations between occlusal support and signs of temporomandibular disorders: results of population-based Study of Health in Pomerania (SHIP 0). *Int J Prostodont 18*, 232 to 239.
Page, R. C. (1986). Gingivits. *Journal of Clinical periodontology, 13*(5).
Page, R. C., & Eke, P. I. (2007). Case definitions for use in population-based surveillance of periodontitis. *J Periodontol, 78*(7 Suppl), 1387-1399.
Page, R. C., & Kornman, K. S. (1997). The pathogenesis of human periodontitis: an introduction. *Periodontol 2000, 14*, 9-11.
Petersen, P. E. (2003). The World Oral Health Report 2003: continuous improvement of oral health in the 21st century--the approach of the WHO Global Oral Health Programme. *Community Dent Oral Epidemiol, 31 Suppl 1*, 3-23.
Petersen, P. E. (2009). Global policy for improvement of oral health in the 21st century--implications to oral health research of World Health Assembly 2007, World Health Organization. *Community Dent Oral Epidemiol, 37*(1), 1-8.
Petersen, P. E., Bourgeois, D., Ogawa, H., Estupinan-Day, S., & Ndiaye, C. (2005). The global burden of oral diseases and risks to oral health. *Bull World Health Organ, 83*(9), 661-669.
Pink, C., Kocher, T., Meisel, P., Dörr, M., Markus, M. R., Jablonowski, L., Grotevendt, A., Nauck, M., & Holtfreter, B. (2015). Longitudinal effects of systemic inflammation markers on periodontitis. *J Clin Periodontol, 42*(11), 988-997.
Pitchika, V., Jordan, R., Micheelis, W., Welk, A., Kocher, T., & Holtfreter, B. (2020). Impact of Powered Toothbrush Use and Interdental Cleaning on Oral Health. *J Dent Res*, 22034520973952.
Pitts, N. B., Zero, D. T., Marsh, P. D., Ekstrand, K., Weintraub, J. A., Ramos-Gomez, F., Tagami, J., Twetman, S., Tsakos, G., & Ismail, A. (2017). Dental caries. *Nat Rev Dis Primers, 3*, 17030.
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 Syst Rev*(12), Cd009857.
Preethanath, R. S., Ibraheem, W. I., & Anil, A. (2020). Pathogenesis of gingivitis. *Oral Diseases*.
Quigley, G. A., & Hein, J. W. (1962). Comparative cleansing efficiency of manual and power brushing. *J Am Dent Assoc, 65*, 26-29.
R Core Team. (2021). R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/
Reich, K. M., Huber, C. D., Lippnig, W. R., Ulm, C., Watzek, G., & Tangl, S. (2011). Atrophy of the residual alveolar ridge following tooth loss in an historical population. *Oral Dis, 17*(1), 33-44.
Roberts, F. A., & Darveau, R. P. (2015). Microbial protection and virulence in periodontal tissue as a function of polymicrobial communities: symbiosis and dysbiosis. *Periodontol 2000, 69*(1), 18-27.
Sahin, S., Cehreli, M. C., & Yalçin, E. (2002). The influence of functional forces on the biomechanics of implant-supported prostheses--a review. *J Dent, 30*(7-8), 271-282.
Sälzer, S., Graetz, C., Plaumann, A., Heinevetter, N., Grender, J., Klukowska, M., Schneider, C. A., Springer, C., Van der Weijden, F. A., & Dörfer, C. E. (2016). Effect of a Multidirectional Power Toothbrush and a Manual Toothbrush in Individuals Susceptible to Gingival Recession: A 12-Month Randomized Controlled Clinical Study. *J Periodontol, 87*(5), 548-556.
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 Syst Rev*(12), Cd008829.
Sato, T., Matsuyama, Y., Fujiwara, T., & Tagami, J. (2020). Pulp survival after composite resin restoration of caries lesions in adults. *J Oral Sci, 63*(1), 27-30.
Schätzle, M., Faddy, M. J., Cullinan, M. P., Seymour, G. J., Lang, N. P., Bürgin, W., Anerud, A., Boysen, H., & Löe, H. (2009). The clinical course of chronic periodontitis: V. Predictive factors in periodontal disease. *J Clin Periodontol, 36*(5), 365-371.
Schiffner, U., Staehle, I., & Dörfer, C. E. (2007). Häusliche mechanische Zahn- und Mundpflege. *DGZMK 1*.

Schmoeckel, J., Santamaría, R. M., & Splieth, C. H. (2015). Long-term caries development in schoolchildren and the role of educational status. *Quintessence Int, 46*(5), 409-415.
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. *J Clin Periodontol, 42*(2), 121-130.
Schwahn, C., Polzer, I., Haring, R., Dörr, M., Wallaschofski, H., Kocher, T., Mundt, T., Holtfreter, B., Samietz, S., Völzke, H., & Biffar, R. (2013). Missing, unreplaced teeth and risk of all-cause and cardiovascular mortality. *Int J Cardiol, 167*(4), 1430-1437.
Selwitz, R. H., Ismail, A. I., & Pitts, N. B. (2007). Dental caries. *Lancet, 369*(9555), 51-59.
Sheiham, A., & Spencer, J. (1997). Health needs assessment Community Oral Health Oxford (10). 39 to 54
Stamm, J. W. (1986). Epidemiology of gingivitis. *J Clin Periodontol, 13*(5), 360-366.
Tennant, P. W. G., Arnold, K. F., Ellison, G. T. H., & Gilthorpe, M. S. (2022). Analyses of 'change scores' do not estimate causal effects in observational data. *Int J Epidemiol, 51*(5), 1604-1615.
Teughels, W., & Dhondt, R. (2014). Treatment of aggressive periodontitis. *Periodontology 2000*(1).
Tonetti, M. S., Greenwell, H., & Kornman, K. S. (2018). Staging and grading of periodontitis: Framework and proposal of a new classification and case definition. *J Periodontol, 89 Suppl 1*, S159-s172.
Trulsson, U., Engstrand, P., Berggren, U., Nannmark, U., & Brånemark, P. I. (2002). Edentulousness and oral rehabilitation: experiences from the patients' perspective. *Eur J Oral Sci, 110*(6), 417-424.
Van der Weijden, G. A., & Timmerman, M. F. (2002). A systematic review on the clinical efficacy of subgingival debridement in the treatment of chronic periodontitis. *J Clin Periodontol, 29 Suppl 3*, 55-71; discussion 90-51.
Van der Wijk, P., Bouma, J., Van Waas, M. A., Van Oort, R. P., & Rutten, F. F. (1998). The cost of dental implants as compared to that of conventional strategies. *International Journal of Oral and Maxillofacial Implants, 13*, 546-553.
Vernon, L. T., Da Silva, A. P. B., & Seacat, J. D. (2017). In Defense of Flossing: Part II-Can We Agree It's Premature to Claim Flossing Is Ineffective to Help Prevent Periodontal Diseases? *J Evid Based Dent Pract, 17*(3), 149-158.
Volzke, H., Alte, D., Schmidt, C. O., Radke, D., Lorbeer, R., Friedrich, N., Aumann, N., Lau, K., Piontek, M., Born, G., Havemann, C., Ittermann, T., Schipf, S., Haring, R., Baumeister, S. E., Wallaschofski, H., Nauck, M., Frick, S., Arnold, A., Junger, M., Mayerle, J., Kraft, M., Lerch, M. M., Dorr, M., Reffelmann, T., Empen, K., Felix, S. B., Obst, A., Koch, B., Glaser, S., Ewert, R., Fietze, I., Penzel, T., Doren, M., Rathmann, W., Haerting, J., Hannemann, M., Ropcke, J., Schminke, U., Jurgens, C., Tost, F., Rettig, R., Kors, J. A., Ungerer, S., Hegenscheid, K., Kuhn, J. P., Kuhn, J., Hosten, N., Puls, R., Henke, J., Gloger, O., Teumer, A., Homuth, G., Volker, U., Schwahn, C., Holtfreter, B., Polzer, I., Kohlmann, T., Grabe, H. J., Rosskopf, D., Kroemer, H. K., Kocher, T., Biffar, R., John, U., & Hoffmann, W. (2011). Cohort profile: the study of health in Pomerania. *Int J Epidemiol, 40*(2), 294-307.
Walter, M., Rieger, C., & Wolf, B. (1998). Bevölkerungsrepräsentative Studie zum zahnärztlich-prothetischen Versorgungsgrad und Behandlungsbedarf.
Welk, A., Ratzmann, A., Reich, M., Krey, K. F., & Schwahn, C. (2020). Effect of self-assembling peptide P(11)-4 on orthodontic treatment-induced carious lesions. *Sci Rep, 10*(1), 6819.
Wolff, J. (1892). The Law of Bone Remodeling. *Springer Verlag Berlin*
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 Syst Rev, 4*(4), Cd012018.
Wright, J. T., Tampi, M. P., Graham, L., Estrich, C., Crall, J. J., Fontana, M., Gillette, E. J., Novy, B. B., Dhar, V., Donly, K., Hewlett, E. R., Quinonez, R. B., Chaffin, J., Crespin, M., Iafolla, T., Siegal, M. D., & Carrasco-Labra, A. (2016). Sealants for Preventing and Arresting Pit-and-fissure Occlusal Caries in Primary and Permanent Molars. *Pediatr Dent, 38*(4), 282-308.

7 Supplementary Table

Supplementary Table 1. Adjusted proportional odds ratios from ordinal logistic models (with logit link) and beta coefficients from linear models using generalized least squares contrasting interdental aids (IDA) users with IDA non-users. In all models the follow-up outcome status was regressed on the baseline IDA status and follow-up time (including an interaction between both).

	Plaque (N=2197)	BOP (N=2159)	Mean PD (N=2162)	Mean interdental PD (N=2162)	Mean non-interdental PD (N=2162)	Percentage of sites with PD ≥4 mm (N=2162)	Percentage of interdental sites with PD ≥4 mm (N=2162)	Percentage of non-interdental sites with PD ≥4 mm (N=2162)
Follow-up time, years	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
6.8	0.58 (0.45; 0.75)	0.74 (0.58; 0.94)	0.95 (0.75; 1.21)	0.86 (0.67; 1.11)	1.05 (0.82; 1.33)	1.06 (0.82; 1.38)	1.00 (0.77; 1.30)	1.20 (0.87; 1.65)
6.9	0.61 (0.49; 0.75)	0.74 (0.60; 0.92)	0.88 (0.71; 1.09)	0.81 (0.66; 1.00)	0.98 (0.80; 1.21)	1.01 (0.81; 1.26)	0.95 (0.76; 1.18)	1.16 (0.89; 1.52)
7.0	0.63 (0.52; 0.76)	0.75 (0.62; 0.91)	0.82 (0.68; 0.99)	0.76 (0.63; 0.92)	0.92 (0.76; 1.11)	0.96 (0.79; 1.17)	0.90 (0.74; 1.09)	1.12 (0.89; 1.42)
7.1	0.65 (0.54; 0.78)	0.76 (0.63; 0.91)	0.77 (0.64; 0.92)	0.72 (0.60; 0.87)	0.87 (0.73; 1.05)	0.92 (0.76; 1.11)	0.86 (0.71; 1.04)	1.09 (0.87; 1.36)
7.2	0.68 (0.56; 0.81)	0.76 (0.63; 0.92)	0.73 (0.60; 0.88)	0.69 (0.57; 0.84)	0.83 (0.69; 1.00)	0.89 (0.73; 1.07)	0.83 (0.68; 1.00)	1.05 (0.84; 1.32)
7.3	0.70 (0.57; 0.84)	0.77 (0.63; 0.93)	0.70 (0.57; 0.85)	0.67 (0.55; 0.82)	0.80 (0.66; 0.98)	0.87 (0.71; 1.06)	0.81 (0.66; 0.99)	1.02 (0.80; 1.29)
7.4	0.71 (0.58; 0.87)	0.77 (0.63; 0.94)	0.68 (0.56; 0.84)	0.67 (0.54; 0.82)	0.79 (0.64; 0.96)	0.85 (0.69; 1.05)	0.80 (0.65; 0.99)	0.98 (0.76; 1.26)
7.5	0.73 (0.59; 0.90)	0.77 (0.62; 0.95)	0.68 (0.55; 0.84)	0.67 (0.54; 0.82)	0.78 (0.63; 0.96)	0.85 (0.68; 1.05)	0.80 (0.65; 1.00)	0.94 (0.73; 1.22)
7.6	0.74 (0.60; 0.92)	0.77 (0.62; 0.95)	0.69 (0.55; 0.85)	0.68 (0.55; 0.84)	0.78 (0.63; 0.96)	0.85 (0.68; 1.06)	0.82 (0.66; 1.02)	0.91 (0.69; 1.18)
7.7	0.75 (0.61; 0.93)	0.76 (0.61; 0.94)	0.70 (0.56; 0.87)	0.69 (0.56; 0.86)	0.78 (0.63; 0.97)	0.86 (0.69; 1.08)	0.84 (0.67; 1.05)	0.87 (0.66; 1.14)
7.8	0.76 (0.61; 0.95)	0.76 (0.61; 0.94)	0.72 (0.58; 0.90)	0.72 (0.57; 0.90)	0.80 (0.64; 0.99)	0.88 (0.70; 1.10)	0.86 (0.69; 1.08)	0.84 (0.63; 1.11)
7.9	0.77 (0.61; 0.97)	0.75 (0.60; 0.94)	0.75 (0.60; 0.94)	0.75 (0.59; 0.94)	0.81 (0.65; 1.02)	0.90 (0.71; 1.13)	0.90 (0.71; 1.13)	0.80 (0.59; 1.08)
8.0	0.78 (0.61; 0.99)	0.74 (0.58; 0.95)	0.78 (0.61; 0.99)	0.78 (0.61; 0.99)	0.83 (0.66; 1.06)	0.92 (0.72; 1.18)	0.93 (0.73; 1.20)	0.77 (0.55; 1.06)
8.1	0.78 (0.60; 1.01)	0.73 (0.56; 0.96)	0.82 (0.63; 1.05)	0.82 (0.63; 1.06)	0.86 (0.66; 1.10)	0.94 (0.72; 1.23)	0.97 (0.75; 1.27)	0.74 (0.51; 1.05)
	Mean CAL (N=2054)	Mean interdental CAL (N=2054)	Mean non-interdental CAL (N=2054)	CDC/AAP classification (N=2015)	DFS (N=2220)	Interdental DFS (N=2220)	Non-interdental DFS (N=2220)	Number of missing teeth (N=2303)
Follow-up time, years	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Odds ratio (95% CI)
6.8	1.08 (0.84; 1.38)	0.98 (0.76; 1.25)	1.20 (0.93; 1.54)	1.35 (0.97; 1.88)	0.438 (-1.462; 2.339)	0.486 (-0.432; 1.404)	-0.257 (-1.309; 0.795)	0.70 (0.50; 0.98)
6.9	1.06 (0.86; 1.32)	0.95 (0.76; 1.18)	1.20 (0.97; 1.49)	1.30 (0.98; 1.72)	0.653 (-1.177; 2.484)	0.510 (-0.374; 1.394)	-0.006 (-1.023; 1.011)	0.68 (0.49; 0.94)
7.0	1.05 (0.87; 1.28)	0.93 (0.76; 1.13)	1.20 (0.99; 1.46)	1.26 (0.99; 1.60)	0.840 (-0.763; 2.444)	0.532 (-0.243; 1.306)	0.245 (-0.653; 1.143)	0.68 (0.51; 0.90)
7.1	1.05 (0.86; 1.26)	0.91 (0.75; 1.10)	1.20 (0.99; 1.45)	1.22 (0.97; 1.53)	0.988 (-0.301; 2.278)	0.548 (-0.074; 1.171)	0.496 (-0.228; 1.219)	0.71 (0.57; 0.89)
7.2	1.04 (0.85; 1.26)	0.90 (0.74; 1.09)	1.20 (0.98; 1.45)	1.19 (0.95; 1.50)	1.037 (-0.338; 2.413)	0.535 (-0.130; 1.199)	0.687 (-0.070; 1.445)	0.77 (0.61; 0.98)
7.3	1.03 (0.84; 1.27)	0.89 (0.73; 1.09)	1.19 (0.97; 1.46)	1.17 (0.92; 1.49)	0.857 (-0.704; 2.419)	0.430 (-0.324; 1.184)	0.679 (-0.194; 1.553)	0.84 (0.64; 1.11)
7.4	1.03 (0.84; 1.27)	0.89 (0.72; 1.10)	1.18 (0.96; 1.46)	1.16 (0.90; 1.49)	0.429 (-0.949; 1.807)	0.224 (-0.442; 0.889)	0.421 (-0.365; 1.206)	0.90 (0.70; 1.15)

7.5	1.04 (0.84; 1.28)	0.90 (0.73; 1.12)	1.17 (0.95; 1.45)	1.15 (0.89; 1.50)	-0.041 (-1.402; 1.321)	0.005 (-0.652; 0.663)	0.079 (-0.677; 0.835)	0.94 (0.74; 1.20)
7.6	1.04 (0.84; 1.29)	0.92 (0.74; 1.14)	1.16 (0.94; 1.44)	1.15 (0.88; 1.51)	-0.403 (-2.040; 1.234)	-0.161 (-0.952; 0.629)	-0.207 (-1.096; 0.683)	0.98 (0.74; 1.31)
7.7	1.05 (0.84; 1.30)	0.95 (0.76; 1.18)	1.15 (0.92; 1.43)	1.16 (0.88; 1.52)	-0.654 (-2.613; 1.304)	-0.274 (-1.220; 0.672)	-0.426 (-1.487; 0.636)	1.01 (0.72; 1.42)
7.8	1.05 (0.84; 1.32)	0.97 (0.78; 1.22)	1.13 (0.91; 1.42)	1.17 (0.89; 1.55)	-0.804 (-3.027; 1.418)	-0.338 (-1.411; 0.735)	-0.583 (-1.791; 0.624)	1.03 (0.70; 1.52)
7.9	1.06 (0.84; 1.34)	1.01 (0.80; 1.27)	1.12 (0.89; 1.41)	1.19 (0.89; 1.58)	-0.863 (-3.268; 1.542)	-0.358 (-1.519; 0.803)	-0.686 (-1.999; 0.627)	1.04 (0.68; 1.59)
8.0	1.07 (0.84; 1.38)	1.04 (0.81; 1.34)	1.10 (0.86; 1.42)	1.20 (0.89; 1.63)	-0.840 (-3.346; 1.665)	-0.339 (-1.549; 0.871)	-0.738 (-2.113; 0.636)	1.04 (0.67; 1.63)
8.1	1.08 (0.83; 1.42)	1.08 (0.83; 1.42)	1.09 (0.83; 1.43)	1.22 (0.88; 1.69)	-0.746 (-3.285; 1.792)	-0.286 (-1.512; 0.940)	-0.747 (-2.145; 0.652)	1.04 (0.66; 1.64)

All models were adjusted for baseline covariates, such as age, sex, education, smoking, BMI, known diabetes mellitus, HbA1c values, toothbrushing frequency, dental visits in the last 12 months, and powered tooth brush usage. Models with periodontal variables or the number of missing teeth were additionally adjusted for physical activity and gum treatment within the last 5 years. Abbreviations: PD, probing depth; CAL, clinical attachment level; BOP, bleeding on probing; DF-S, number of decayed or filled surfaces; CI, confidence interval.

Supplementary Table 2. Adjusted proportional odds ratios from ordinal logistic models (with logit link) contrasting wooden stick users, floss users, or interdental brush users with non-users. In all models the follow-up outcome status was regressed on the baseline IDA status and follow-up time (including an interaction between both).

	Plaque (N=2197)	BOP (N=2159)	Mean PD (N=2162)	Mean interdental PD (N=2162)	Mean non-interdental PD (N=2162)	Percentage of sites with PD ≥4 mm (N=2162)	Percentage of interdental sites with PD ≥4 mm (N=2162)	Percentage of non-interdental sites with PD ≥4 mm (N=2162)
Follow-up time, years	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
Wooden stick users vs. non-users								
6.8	1.23 (0.69; 2.20)	1.08 (0.61; 1.91)	1.12 (0.64; 1.94)	1.23 (0.72; 2.10)	1.00 (0.57; 1.76)	1.44 (0.82; 2.50)	1.42 (0.81; 2.48)	1.21 (0.61; 2.36)
6.9	1.25 (0.78; 1.98)	1.14 (0.72; 1.80)	1.08 (0.69; 1.69)	1.14 (0.74; 1.76)	1.04 (0.66; 1.63)	1.36 (0.87; 2.13)	1.33 (0.85; 2.09)	1.22 (0.72; 2.09)
7.0	1.26 (0.87; 1.83)	1.19 (0.82; 1.73)	1.05 (0.73; 1.51)	1.06 (0.74; 1.52)	1.07 (0.74; 1.55)	1.29 (0.89; 1.87)	1.26 (0.87; 1.82)	1.24 (0.81; 1.91)
7.1	1.27 (0.93; 1.75)	1.24 (0.89; 1.72)	1.02 (0.74; 1.42)	1.00 (0.72; 1.38)	1.10 (0.79; 1.53)	1.23 (0.89; 1.72)	1.19 (0.86; 1.66)	1.25 (0.85; 1.82)
7.2	1.28 (0.94; 1.75)	1.27 (0.92; 1.76)	1.00 (0.72; 1.39)	0.95 (0.68; 1.31)	1.13 (0.81; 1.57)	1.18 (0.85; 1.64)	1.14 (0.82; 1.58)	1.24 (0.85; 1.82)
7.3	1.28 (0.92; 1.78)	1.28 (0.91; 1.81)	0.98 (0.69; 1.40)	0.91 (0.64; 1.29)	1.14 (0.80; 1.63)	1.14 (0.80; 1.62)	1.10 (0.77; 1.55)	1.22 (0.81; 1.84)
7.4	1.27 (0.90; 1.81)	1.27 (0.88; 1.85)	0.97 (0.66; 1.42)	0.89 (0.61; 1.29)	1.15 (0.78; 1.68)	1.10 (0.76; 1.61)	1.07 (0.74; 1.55)	1.19 (0.76; 1.84)
7.5	1.26 (0.87; 1.83)	1.25 (0.84; 1.84)	0.96 (0.64; 1.43)	0.88 (0.59; 1.30)	1.14 (0.77; 1.71)	1.08 (0.73; 1.60)	1.05 (0.71; 1.55)	1.14 (0.72; 1.80)
7.6	1.24 (0.85; 1.83)	1.20 (0.81; 1.80)	0.96 (0.63; 1.44)	0.88 (0.59; 1.31)	1.13 (0.75; 1.71)	1.06 (0.70; 1.59)	1.04 (0.70; 1.56)	1.08 (0.67; 1.73)
7.7	1.22 (0.82; 1.81)	1.15 (0.76; 1.73)	0.96 (0.63; 1.45)	0.89 (0.59; 1.34)	1.11 (0.73; 1.69)	1.04 (0.69; 1.58)	1.04 (0.69; 1.57)	1.01 (0.62; 1.64)
7.8	1.19 (0.80; 1.78)	1.09 (0.72; 1.64)	0.96 (0.63; 1.46)	0.91 (0.60; 1.37)	1.09 (0.71; 1.65)	1.03 (0.68; 1.57)	1.05 (0.70; 1.58)	0.94 (0.57; 1.55)
7.9	1.17 (0.78; 1.75)	1.02 (0.67; 1.55)	0.96 (0.63; 1.47)	0.93 (0.61; 1.41)	1.06 (0.69; 1.61)	1.03 (0.67; 1.56)	1.06 (0.70; 1.61)	0.88 (0.52; 1.48)
8.0	1.14 (0.75; 1.73)	0.96 (0.62; 1.47)	0.97 (0.63; 1.49)	0.96 (0.62; 1.47)	1.03 (0.67; 1.58)	1.02 (0.66; 1.58)	1.07 (0.70; 1.65)	0.81 (0.46; 1.42)
8.1	1.11 (0.71; 1.72)	0.89 (0.57; 1.40)	0.98 (0.62; 1.53)	0.99 (0.63; 1.55)	1.00 (0.64; 1.56)	1.02 (0.65; 1.60)	1.09 (0.69; 1.71)	0.75 (0.40; 1.39)
Floss users vs. non-users								
6.8	0.36 (0.24; 0.54)	0.52 (0.36; 0.77)	0.78 (0.54; 1.14)	0.73 (0.50; 1.06)	0.81 (0.56; 1.17)	0.79 (0.53; 1.16)	0.76 (0.52; 1.13)	0.86 (0.50; 1.46)
6.9	0.38 (0.27; 0.53)	0.54 (0.39; 0.74)	0.70 (0.51; 0.96)	0.66 (0.48; 0.91)	0.74 (0.54; 1.01)	0.73 (0.53; 1.02)	0.70 (0.50; 0.98)	0.83 (0.53; 1.29)
7.0	0.40 (0.30; 0.53)	0.55 (0.41; 0.73)	0.63 (0.47; 0.83)	0.60 (0.46; 0.80)	0.68 (0.52; 0.90)	0.69 (0.51; 0.92)	0.65 (0.48; 0.87)	0.80 (0.55; 1.17)
7.1	0.42 (0.32; 0.55)	0.56 (0.43; 0.73)	0.57 (0.43; 0.74)	0.56 (0.43; 0.73)	0.63 (0.48; 0.82)	0.65 (0.49; 0.86)	0.61 (0.46; 0.80)	0.77 (0.54; 1.10)
7.2	0.45 (0.34; 0.58)	0.57 (0.44; 0.75)	0.52 (0.40; 0.69)	0.52 (0.40; 0.69)	0.59 (0.45; 0.78)	0.62 (0.47; 0.82)	0.58 (0.44; 0.77)	0.75 (0.52; 1.07)
7.3	0.47 (0.35; 0.62)	0.59 (0.44; 0.78)	0.50 (0.37; 0.66)	0.50 (0.38; 0.67)	0.57 (0.43; 0.75)	0.61 (0.46; 0.82)	0.56 (0.42; 0.76)	0.72 (0.49; 1.06)
7.4	0.49 (0.37; 0.66)	0.60 (0.45; 0.81)	0.49 (0.36; 0.66)	0.49 (0.37; 0.66)	0.55 (0.41; 0.75)	0.61 (0.45; 0.82)	0.56 (0.41; 0.76)	0.70 (0.47; 1.05)
7.5	0.52 (0.38; 0.71)	0.61 (0.45; 0.83)	0.49 (0.35; 0.66)	0.50 (0.36; 0.67)	0.55 (0.41; 0.75)	0.62 (0.45; 0.84)	0.57 (0.41; 0.79)	0.68 (0.44; 1.03)
7.6	0.54 (0.40; 0.75)	0.63 (0.46; 0.86)	0.50 (0.36; 0.68)	0.51 (0.37; 0.70)	0.56 (0.41; 0.76)	0.63 (0.46; 0.87)	0.59 (0.43; 0.82)	0.66 (0.43; 1.02)
7.7	0.57 (0.41; 0.79)	0.65 (0.47; 0.88)	0.52 (0.37; 0.71)	0.53 (0.39; 0.73)	0.57 (0.42; 0.79)	0.66 (0.48; 0.91)	0.63 (0.45; 0.87)	0.64 (0.41; 1.00)
7.8	0.60 (0.43; 0.83)	0.66 (0.48; 0.91)	0.54 (0.39; 0.75)	0.56 (0.41; 0.77)	0.60 (0.43; 0.82)	0.70 (0.50; 0.97)	0.67 (0.48; 0.93)	0.62 (0.39; 1.00)
7.9	0.63 (0.45; 0.88)	0.68 (0.49; 0.94)	0.58 (0.42; 0.81)	0.60 (0.43; 0.83)	0.62 (0.45; 0.87)	0.74 (0.53; 1.04)	0.72 (0.51; 1.02)	0.60 (0.36; 1.00)
8.0	0.66 (0.46; 0.93)	0.70 (0.49; 0.98)	0.63 (0.44; 0.89)	0.64 (0.45; 0.91)	0.66 (0.46; 0.93)	0.79 (0.55; 1.12)	0.78 (0.55; 1.12)	0.59 (0.34; 1.02)
8.1	0.69 (0.47; 1.00)	0.71 (0.49; 1.03)	0.68 (0.47; 0.98)	0.69 (0.48; 1.00)	0.69 (0.48; 1.00)	0.84 (0.58; 1.23)	0.85 (0.58; 1.25)	0.57 (0.31; 1.06)
Interdental brush users vs. non-users								
6.8	0.55 (0.39; 0.77)	0.73 (0.53; 1.00)	0.99 (0.72; 1.37)	0.84 (0.60; 1.17)	1.19 (0.87; 1.64)	1.17 (0.82; 1.65)	1.05 (0.74; 1.49)	1.38 (0.92; 2.06)

6.9	0.56 (0.42; 0.76)	0.72 (0.55; 0.96)	0.93 (0.70; 1.24)	0.81 (0.60; 1.08)	1.11 (0.84; 1.48)	1.13 (0.84; 1.53)	1.02 (0.75; 1.39)	1.34 (0.95; 1.90)
7.0	0.58 (0.44; 0.76)	0.72 (0.55; 0.94)	0.88 (0.67; 1.15)	0.78 (0.59; 1.03)	1.05 (0.80; 1.37)	1.10 (0.84; 1.46)	1.00 (0.75; 1.32)	1.30 (0.95; 1.79)
7.1	0.59 (0.45; 0.77)	0.71 (0.55; 0.93)	0.83 (0.64; 1.09)	0.76 (0.58; 0.99)	0.99 (0.75; 1.29)	1.08 (0.82; 1.41)	0.97 (0.74; 1.28)	1.27 (0.93; 1.72)
7.2	0.60 (0.46; 0.79)	0.71 (0.54; 0.93)	0.80 (0.60; 1.05)	0.74 (0.56; 0.98)	0.94 (0.71; 1.25)	1.05 (0.79; 1.39)	0.95 (0.72; 1.26)	1.23 (0.90; 1.69)
7.3	0.61 (0.46; 0.82)	0.70 (0.53; 0.93)	0.77 (0.58; 1.03)	0.73 (0.54; 0.97)	0.91 (0.68; 1.22)	1.03 (0.77; 1.38)	0.94 (0.70; 1.26)	1.20 (0.86; 1.67)
7.4	0.62 (0.46; 0.83)	0.69 (0.52; 0.93)	0.76 (0.56; 1.02)	0.72 (0.53; 0.97)	0.89 (0.66; 1.21)	1.01 (0.74; 1.37)	0.93 (0.68; 1.26)	1.16 (0.82; 1.65)
7.5	0.62 (0.46; 0.84)	0.69 (0.51; 0.93)	0.75 (0.55; 1.02)	0.72 (0.52; 0.98)	0.89 (0.66; 1.21)	1.00 (0.73; 1.36)	0.92 (0.67; 1.26)	1.13 (0.79; 1.62)
7.6	0.62 (0.46; 0.85)	0.68 (0.50; 0.92)	0.76 (0.55; 1.03)	0.72 (0.52; 0.99)	0.90 (0.66; 1.22)	0.98 (0.71; 1.35)	0.92 (0.67; 1.27)	1.10 (0.76; 1.58)
7.7	0.62 (0.45; 0.86)	0.67 (0.49; 0.92)	0.77 (0.56; 1.05)	0.73 (0.53; 1.00)	0.91 (0.67; 1.25)	0.97 (0.70; 1.35)	0.92 (0.66; 1.28)	1.06 (0.73; 1.55)
7.8	0.62 (0.45; 0.86)	0.66 (0.48; 0.92)	0.78 (0.56; 1.08)	0.74 (0.53; 1.03)	0.93 (0.68; 1.29)	0.96 (0.69; 1.36)	0.93 (0.66; 1.30)	1.03 (0.69; 1.53)
7.9	0.62 (0.44; 0.88)	0.65 (0.46; 0.93)	0.80 (0.57; 1.13)	0.75 (0.53; 1.07)	0.96 (0.69; 1.35)	0.96 (0.66; 1.38)	0.93 (0.65; 1.34)	1.00 (0.65; 1.53)
8.0	0.62 (0.42; 0.89)	0.64 (0.44; 0.95)	0.83 (0.57 1.20)	0.76 (0.52; 1.12)	1.00 (0.69; 1.43)	0.95 (0.64; 1.41)	0.94 (0.63; 1.40)	0.97 (0.61; 1.54)
8.1	0.61 (0.41; 0.92)	0.64 (0.41; 0.97)	0.86 (0.57; 1.28)	0.78 (0.51; 1.18)	1.04 (0.70; 1.54)	0.94 (0.61; 1.46)	0.95 (0.61; 1.47)	0.93 (0.56; 1.57)

All models were adjusted for baseline covariates, such as age, sex, education, smoking, BMI, known diabetes mellitus, HbA1c values, toothbrushing frequency, dental visits in the last 12 months, and powered tooth brush usage. Models with periodontal variables or the number of missing teeth were additionally adjusted for physical activity and gum treatment within the last 5 years. Abbreviations: PD, probing depth; CAL, clinical attachment level; BOP, bleeding on probing; DF-S, number of decayed or filled surfaces; CI, confidence interval.

Supplementary Table 3. Adjusted proportional odds ratios from ordinal logistic models (with logit link) and beta coefficients from linear models using generalized least squares contrasting wooden stick users, floss users, or interdental brush users with non-users. In all models the follow-up outcome status was regressed on the baseline IDA status and follow-up time (including an interaction between both).

	Mean CAL (N=2054)	Mean interdental CAL (N=2054)	Mean non-interdental CAL (N=2054)	CDC/AAP classification (N=2015)	DFS (N=2220)	Interdental DFS (N=2220)	Non-interdental DFS (N=2220)	Number of missing teeth (N=2303)
Follow-up time, years	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Odds ratio (95% CI)
Wooden stick users vs. non-users								
6.8	0.69 (0.37; 1.26)	0.69 (0.36; 1.34)	0.71 (0.39; 1.30)	0.89 (0.41; 1.95)	2.299 (-1.308; 5.906)	1.354 (-0.387; 3.096)	0.924 (-1.066; 2.915)	0.78 (0.42; 1.45)
6.9	0.85 (0.52; 1.38)	0.82 (0.49; 1.39)	0.89 (0.55; 1.45)	1.02 (0.55; 1.90)	2.131 (-1.331; 5.593)	1.236 (-0.436; 2.907)	1.133 (-0.804; 3.070)	0.53 (0.28; 0.98)
7.0	1.04 (0.70; 1.54)	0.97 (0.64; 1.47)	1.10 (0.74; 1.64)	1.17 (0.72; 1.89)	1.684 (-1.548; 4.916)	0.994 (-0.566; 2.555)	1.077 (-0.726; 2.880)	0.44 (0.25; 0.78)
7.1	1.24 (0.88; 1.75)	1.12 (0.79; 1.60)	1.33 (0.95; 1.88)	1.32 (0.88; 1.96)	0.877 (-1.698; 3.453)	0.593 (-0.650; 1.837)	0.677 (-0.760; 2.115)	0.47 (0.30; 0.75)
7.2	1.44 (1.02; 2.02)	1.27 (0.90; 1.79)	1.56 (1.12; 2.18)	1.46 (1.00; 2.13)	-0.184 (-2.606; 2.237)	0.072 (-1.097; 1.241)	0.037 (-1.302; 1.377)	0.63 (0.41; 0.97)
7.3	1.60 (1.12; 2.29)	1.39 (0.97; 2.00)	1.74 (1.23; 2.48)	1.58 (1.06; 2.36)	-1.144 (-3.919; 1.631)	-0.431 (-1.770; 0.909)	-0.475 (-2.028; 1.077)	0.84 (0.51; 1.37)
7.4	1.70 (1.16; 2.49)	1.48 (1.00; 2.17)	1.86 (1.27; 2.70)	1.68 (1.09; 2.58)	-1.780 (-4.256; 0.695)	-0.820 (-2.015; 0.376)	-0.641 (-2.055; 0.774)	0.98 (0.62; 1.53)
7.5	1.74 (1.17; 2.59)	1.51 (1.01; 2.27)	1.89 (1.27; 2.80)	1.74 (1.11; 2.74)	-2.175 (-4.521; 0.170)	-1.100 (-2.232; 0.033)	-0.627 (-1.948; 0.694)	1.05 (0.69; 1.61)
7.6	1.71 (1.14; 2.58)	1.51 (1.00; 2.30)	1.84 (1.23; 2.76)	1.77 (1.11; 2.83)	-2.409 (-5.138; 0.321)	-1.284 (-2.602; 0.034)	-0.591 (-2.099; 0.917)	1.11 (0.68; 1.79)
7.7	1.64 (1.08; 2.48)	1.48 (0.97; 2.26)	1.75 (1.16; 2.63)	1.78 (1.10; 2.86)	-2.500 (-5.738; 0.739)	-1.382 (-2.946; 0.181)	-0.551 (-2.332; 1.230)	1.14 (0.64; 2.00)
7.8	1.53 (1.01; 2.34)	1.42 (0.93; 2.19)	1.61 (1.06; 2.44)	1.76 (1.08; 2.85)	-2.461 (-6.137; 1.216)	-1.401 (-3.176; 0.374)	-0.506 (-2.532; 1.519)	1.15 (0.60; 2.18)
7.9	1.41 (0.91; 2.17)	1.35 (0.87; 2.10)	1.46 (0.95; 2.23)	1.72 (1.05; 2.82)	-2.305 (-6.296; 1.686)	-1.348 (-3.275; 0.579)	-0.458 (-2.664; 1.749)	1.14 (0.56; 2.29)
8.0	1.28 (0.81; 2.01)	1.27 (0.80; 2.02)	1.30 (0.84; 2.03)	1.68 (1.01; 2.79)	-2.044 (-6.223; 2.134)	-1.232 (-3.249; 0.786)	-0.406 (-2.724; 1.912)	1.11 (0.53; 2.31)
8.1	1.15 (0.71; 1.87)	1.18 (0.72; 1.95)	1.16 (0.72; 1.85)	0.89 (0.41; 1.95)	-1.693 (-5.951; 2.566)	-1.059 (-3.116; 0.997)	-0.351 (-2.717; 2.015)	1.07 (0.50; 2.25)
Floss users vs. non-users								
6.8	0.82 (0.56; 1.20)	0.73 (0.50; 1.07)	0.95 (0.66; 1.38)	1.00 (0.61; 1.64)	0.274 (-2.594; 3.142)	0.353 (-1.031; 1.738)	-0.068 (-1.679 1.543)	0.49 (0.29; 0.83)
6.9	0.76 (0.55; 1.06)	0.66 (0.48; 0.92)	0.90 (0.65; 1.24)	0.89 (0.58; 1.36)	0.745 (-2.085; 3.575)	0.487 (-0.879; 1.854)	0.250 (-1.342 1.842)	0.50 (0.30; 0.84)
7.0	0.71 (0.53; 0.95)	0.61 (0.45; 0.81)	0.85 (0.63; 1.13)	0.80 (0.55; 1.17)	1.328 (-1.204; 3.859)	0.691 (-0.531; 1.913)	0.613 (-0.817 2.043)	0.54 (0.34; 0.85)
7.1	0.67 (0.50; 0.88)	0.56 (0.42; 0.74)	0.80 (0.61; 1.06)	0.72 (0.50; 1.04)	2.051 (0.022; 4.079)	0.982 (0.002; 1.961)	1.032 (-0.115 2.179)	0.63 (0.43; 0.90)
7.2	0.63 (0.48; 0.84)	0.53 (0.40; 0.70)	0.77 (0.58; 1.02)	0.67 (0.46; 0.97)	2.716 (0.695; 4.738)	1.270 (0.294; 2.246)	1.416 (0.292 2.540)	0.76 (0.53; 1.08)
7.3	0.62 (0.46; 0.83)	0.51 (0.38; 0.68)	0.75 (0.56; 1.00)	0.63 (0.43; 0.93)	2.820 (0.577; 5.062)	1.316 (0.234; 2.399)	1.519 (0.255 2.783)	0.87 (0.59; 1.29)
7.4	0.61 (0.45; 0.83)	0.50 (0.37; 0.69)	0.74 (0.55; 1.00)	0.61 (0.40; 0.92)	2.183 (0.216; 4.150)	1.032 (0.083; 1.982)	1.238 (0.112 2.365)	0.89 (0.63; 1.27)
7.5	0.61 (0.45; 0.84)	0.51 (0.37; 0.70)	0.74 (0.54; 1.00)	0.60 (0.39; 0.91)	1.314 (-0.605; 3.233)	0.645 (-0.282; 1.571)	0.820 (-0.259 1.900)	0.87 (0.62; 1.23)
7.6	0.63 (0.46; 0.86)	0.53 (0.39; 0.73)	0.74 (0.54; 1.01)	0.60 (0.39; 0.93)	0.586 (-1.713; 2.886)	0.321 (-0.789; 1.431)	0.471 (-0.807 1.748)	0.85 (0.56; 1.30)
7.7	0.65 (0.47; 0.89)	0.56 (0.40; 0.77)	0.75 (0.55; 1.03)	0.61 (0.40; 0.95)	0.020 (-2.738; 2.779)	0.071 (-1.261; 1.403)	0.206 (-1.329 1.741)	0.84 (0.50; 1.40)
7.8	0.68 (0.49; 0.94)	0.59 (0.43; 0.82)	0.77 (0.56; 1.06)	0.63 (0.40; 0.99)	-0.398 (-3.543; 2.746)	-0.113 (-1.631; 1.405)	0.020 (-1.740 1.780)	0.84 (0.46; 1.50)
7.9	0.71 (0.51; 1.00)	0.64 (0.46; 0.90)	0.79 (0.57; 1.10)	0.66 (0.42; 1.05)	-0.684 (-4.103; 2.735)	-0.237 (-1.887; 1.414)	-0.096 (-2.022 1.830)	0.84 (0.44; 1.59)
8.0	0.76 (0.53; 1.07)	0.70 (0.49; 0.99)	0.82 (0.58; 1.16)	0.69 (0.42; 1.13)	-0.852 (-4.432; 2.729)	-0.307 (-2.036; 1.422)	-0.148 (-2.178 1.883)	0.84 (0.43; 1.66)
8.1	0.80 (0.55; 1.17)	0.76 (0.52; 1.11)	0.84 (0.58; 1.23)	0.73 (0.43; 1.23)	-0.915 (-4.561; 2.731)	-0.330 (-2.090; 1.431)	-0.143 (-2.224 1.938)	0.85 (0.42; 1.71)
Interdental brush users vs. non-users								
6.8	1.32 (0.95; 1.83)	1.19 (0.86; 1.64)	1.47 (1.05; 2.04)	1.78 (1.16; 2.72)	0.087 (-2.547; 2.722)	0.356 (-0.916; 1.628)	-0.845 (-2.275; 0.585)	0.89 (0.57; 1.42)

6.9	1.32 (0.99; 1.77)	1.18 (0.88; 1.58)	1.48 (1.10; 1.98)	1.73 (1.21; 2.49)	0.195 (-2.287; 2.677)	0.322 (-0.876; 1.521)	-0.578 (-1.935; 0.779)	0.87 (0.56; 1.34)
7.0	1.32 (1.00; 1.75)	1.18 (0.89; 1.55)	1.49 (1.13; 1.96)	1.69 (1.22; 2.35)	0.240 (-1.879; 2.359)	0.258 (-0.765; 1.281)	-0.251 (-1.425; 0.922)	0.84 (0.58; 1.23)
7.1	1.33 (1.01; 1.75)	1.17 (0.89; 1.54)	1.50 (1.13; 1.97)	1.65 (1.20; 2.27)	0.205 (-1.544; 1.954)	0.154 (-0.690; 0.999)	0.153 (-0.821; 1.127)	0.83 (0.61; 1.12)
7.2	1.33 (1.00; 1.77)	1.18 (0.89; 1.56)	1.50 (1.13; 2.00)	1.62 (1.17; 2.25)	0.116 (-1.964; 2.197)	0.042 (-0.963; 1.046)	0.532 (-0.604; 1.668)	0.82 (0.58; 1.17)
7.3	1.34 (0.99; 1.80)	1.19 (0.88; 1.59)	1.51 (1.12; 2.03)	1.60 (1.13; 2.26)	0.063 (-2.319; 2.446)	0.004 (-1.147; 1.154)	0.611 (-0.717; 1.939)	0.85 (0.56; 1.29)
7.4	1.35 (0.99; 1.83)	1.20 (0.89; 1.63)	1.51 (1.11; 2.05)	1.58 (1.11; 2.27)	0.091 (-2.004; 2.186)	0.074 (-0.937; 1.086)	0.270 (-0.919; 1.459)	0.92 (0.63; 1.33)
7.5	1.36 (0.99; 1.86)	1.23 (0.90; 1.67)	1.51 (1.10; 2.06)	1.58 (1.09; 2.28)	0.154 (-2.069; 2.377)	0.184 (-0.889; 1.257)	-0.225 (-1.420; 0.970)	1.00 (0.68; 1.47)
7.6	1.37 (1.00; 1.88)	1.26 (0.92; 1.72)	1.50 (1.09; 2.07)	1.57 (1.08; 2.29)	0.215 (-2.584; 3.015)	0.281 (-1.071; 1.633)	-0.650 (-2.103; 0.804)	1.08 (0.67; 1.72)
7.7	1.39 (1.00; 1.92)	1.29 (0.94; 1.78)	1.50 (1.08; 2.07)	1.58 (1.07; 2.31)	0.272 (-3.103; 3.646)	0.361 (-1.268; 1.991)	-0.986 (-2.727; 0.755)	1.14 (0.65; 2.00)
7.8	1.40 (1.00; 1.96)	1.33 (0.95; 1.86)	1.49 (1.06; 2.09)	1.58 (1.07; 2.35)	0.324 (-3.481; 4.129)	0.427 (-1.410; 2.264)	-1.242 (-3.211; 0.727)	1.18 (0.63; 2.23)
7.9	1.42 (0.99; 2.03)	1.38 (0.97; 1.97)	1.48 (1.03; 2.13)	1.59 (1.05; 2.41)	0.372 (-3.694; 4.439)	0.479 (-1.485; 2.442)	-1.424 (-3.540; 0.691)	1.21 (0.61; 2.40)
8.0	1.44 (0.97; 2.12)	1.43 (0.97; 2.11)	1.47 (0.99; 2.18)	1.60 (1.03; 2.50)	0.417 (-3.755; 4.590)	0.519 (-1.496; 2.533)	-1.541 (-3.723; 0.642)	1.22 (0.61; 2.47)
8.1	1.45 (0.95; 2.23)	1.48 (0.97; 2.28)	1.46 (0.95; 2.26)	1.62 (1.00; 2.62)	0.459 (-3.692; 4.611)	0.548 (-1.456; 2.553)	-1.598 (-3.781; 0.585)	1.22 (0.60; 2.47)

All models were adjusted for baseline covariates, such as age, sex, education, smoking, BMI, known diabetes mellitus, HbA1c values, toothbrushing frequency, dental visits in the last 12 months, and powered tooth brush usage. Models with periodontal variables or the number of missing teeth were additionally adjusted for physical activity and gum treatment within the last 5 years. Abbreviations: PD, probing depth; CAL, clinical attachment level; BOP, bleeding on probing; DF-S, number of decayed or filled surfaces; CI, confidence interval.

Supplementary Table 4. Adjusted proportional odds ratios from ordinal logistic models (with logit link), odds ratios from logistic models, and beta coefficients from linear models using generalized least squares, respectively, contrasting wooden stick users, floss users, or interdental brush users with non-users. In all models the follow-up outcome status was regressed on the baseline IDA status and follow-up time (including an interaction between both) using imputed data.

	Plaque (N=4080)	BOP (N=4080)	Mean PD (N=4080)	Mean interdental PD (N=4080)	Mean non-interdental PD (N=4080)	Percentage of sites with PD ≥4 mm (N=4080)	Percentage of interdental sites with PD ≥4 mm (N=4080)	Percentage of non-interdental sites with PD ≥4 mm (N=4080)
Follow-up time, years	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
6.8	0.67 (0.54; 0.83)	0.74 (0.60; 0.92)	0.91 (0.75; 1.10)	0.86 (0.70; 1.04)	1.00 (0.83; 1.21)	1.03 (0.84; 1.25)	0.98 (0.81; 1.20)	1.09 (0.88; 1.36)
6.9	0.68 (0.56; 0.83)	0.74 (0.62; 0.90)	0.88 (0.74; 1.03)	0.83 (0.70; 0.99)	0.98 (0.83; 1.16)	1.01 (0.85; 1.20)	0.97 (0.82; 1.15)	1.08 (0.89; 1.31)
7.0	0.69 (0.57; 0.83)	0.75 (0.63; 0.89)	0.85 (0.73; 0.99)	0.81 (0.69; 0.95)	0.96 (0.82; 1.12)	0.99 (0.85; 1.16)	0.96 (0.82; 1.12)	1.07 (0.90; 1.27)
7.1	0.70 (0.58; 0.83)	0.75 (0.63; 0.89)	0.82 (0.71; 0.95)	0.79 (0.68; 0.93)	0.94 (0.81; 1.09)	0.98 (0.84; 1.14)	0.95 (0.81; 1.10)	1.06 (0.89; 1.25)
7.2	0.71 (0.59; 0.85)	0.75 (0.63; 0.90)	0.80 (0.69; 0.94)	0.78 (0.66; 0.91)	0.93 (0.80; 1.08)	0.97 (0.83; 1.13)	0.94 (0.80; 1.10)	1.04 (0.87; 1.25)
7.3	0.71 (0.59; 0.86)	0.75 (0.63; 0.91)	0.79 (0.67; 0.93)	0.77 (0.65; 0.91)	0.92 (0.78; 1.08)	0.96 (0.81; 1.13)	0.93 (0.79; 1.10)	1.03 (0.85; 1.25)
7.4	0.72 (0.59; 0.88)	0.75 (0.62; 0.91)	0.78 (0.65; 0.92)	0.76 (0.64; 0.91)	0.91 (0.77; 1.07)	0.95 (0.80; 1.13)	0.93 (0.78; 1.10)	1.02 (0.83; 1.25)
7.5	0.73 (0.60; 0.89)	0.75 (0.62; 0.92)	0.77 (0.65; 0.92)	0.76 (0.63; 0.91)	0.90 (0.76; 1.08)	0.95 (0.79; 1.14)	0.93 (0.77; 1.11)	1.01 (0.82; 1.24)
7.6	0.73 (0.60; 0.90)	0.75 (0.61; 0.92)	0.77 (0.64; 0.92)	0.76 (0.63; 0.92)	0.90 (0.75; 1.08)	0.94 (0.78; 1.14)	0.93 (0.77; 1.12)	0.99 (0.80; 1.23)
7.7	0.74 (0.60; 0.90)	0.74 (0.60; 0.92)	0.77 (0.64; 0.93)	0.76 (0.63; 0.92)	0.90 (0.75; 1.08)	0.94 (0.78; 1.14)	0.94 (0.77; 1.13)	0.98 (0.79; 1.22)
7.8	0.74 (0.60; 0.91)	0.74 (0.60; 0.91)	0.78 (0.64; 0.94)	0.77 (0.64; 0.93)	0.90 (0.74; 1.09)	0.94 (0.78; 1.14)	0.94 (0.78; 1.14)	0.97 (0.78; 1.20)
7.9	0.74 (0.61; 0.92)	0.73 (0.59; 0.91)	0.78 (0.65; 0.95)	0.78 (0.64; 0.95)	0.90 (0.74; 1.10)	0.95 (0.78; 1.14)	0.95 (0.79; 1.15)	0.96 (0.77; 1.19)
8.0	0.75 (0.61; 0.92)	0.73 (0.58; 0.91)	0.80 (0.66; 0.96)	0.79 (0.65; 0.96)	0.91 (0.74; 1.11)	0.95 (0.78; 1.15)	0.96 (0.79; 1.17)	0.95 (0.76; 1.18)
8.1	0.75 (0.60; 0.93)	0.72 (0.57; 0.90)	0.81 (0.67; 0.98)	0.81 (0.66; 0.98)	0.91 (0.74; 1.12)	0.96 (0.78; 1.16)	0.97 (0.80; 1.19)	0.93 (0.75; 1.17)
	Mean CAL (N=4080)	Mean interdental CAL (N=4080)	Mean non-interdental CAL (N=4080)	CDC/AAP classification (N=4080)	DFS (N=4080)	Interdental DFS (N=4080)	Non-interdental DFS (N=4080)	Number of missing teeth (N=4080)
Follow-up time, years	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Beta (95% CI)	Beta (95% CI)	Beta (95% CI)	Odds ratio (95% CI)
6.8	1.06 (0.86; 1.31)	0.98 (0.80; 1.20)	1.16 (0.95; 1.43)	1.21 (0.94; 1.56)	0.298 (-0.716; 1.313)	0.278 (-0.268; 0.825)	0.019 (-0.578; 0.616)	0.85 (0.67; 1.08)
6.9	1.06 (0.89; 1.27)	0.97 (0.81; 1.16)	1.17 (0.98; 1.40)	1.20 (0.96; 1.49)	0.328 (-0.540; 1.195)	0.266 (-0.209; 0.741)	0.060 (-0.450; 0.571)	0.85 (0.69; 1.06)
7.0	1.06 (0.91; 1.25)	0.96 (0.82; 1.13)	1.18 (1.01; 1.38)	1.19 (0.98; 1.45)	0.356 (-0.416; 1.127)	0.254 (-0.175; 0.684)	0.100 (-0.356; 0.557)	0.86 (0.71; 1.04)
7.1	1.06 (0.91; 1.24)	0.96 (0.82; 1.12)	1.19 (1.02; 1.38)	1.18 (0.98; 1.43)	0.382 (-0.353; 1.116)	0.243 (-0.169; 0.656)	0.137 (-0.302; 0.576)	0.86 (0.72; 1.04)
7.2	1.06 (0.91; 1.24)	0.95 (0.81; 1.12)	1.19 (1.02; 1.39)	1.17 (0.97; 1.42)	0.404 (-0.343; 1.152)	0.233 (-0.186; 0.652)	0.170 (-0.280; 0.621)	0.87 (0.72; 1.04)
7.3	1.06 (0.90; 1.25)	0.95 (0.80; 1.12)	1.19 (1.01; 1.41)	1.17 (0.96; 1.42)	0.424 (-0.363; 1.211)	0.224 (-0.213; 0.662)	0.199 (-0.277; 0.675)	0.87 (0.72; 1.05)
7.4	1.06 (0.89; 1.26)	0.94 (0.79; 1.13)	1.19 (1.00; 1.42)	1.16 (0.95; 1.42)	0.439 (-0.392; 1.271)	0.216 (-0.242; 0.674)	0.223 (-0.281; 0.726)	0.87 (0.72; 1.06)
7.5	1.06 (0.88; 1.27)	0.94 (0.78; 1.13)	1.19 (0.99; 1.43)	1.16 (0.93; 1.43)	0.451 (-0.419; 1.321)	0.209 (-0.266; 0.685)	0.241 (-0.284; 0.767)	0.88 (0.72; 1.07)
7.6	1.06 (0.88; 1.27)	0.94 (0.78; 1.14)	1.19 (0.98; 1.44)	1.15 (0.93; 1.43)	0.459 (-0.440; 1.357)	0.203 (-0.286; 0.692)	0.256 (-0.285; 0.796)	0.88 (0.71; 1.08)
7.7	1.05 (0.87; 1.27)	0.94 (0.78; 1.14)	1.18 (0.97; 1.44)	1.15 (0.92; 1.43)	0.464 (-0.454; 1.382)	0.198 (-0.300; 0.697)	0.266 (-0.284; 0.815)	0.88 (0.71; 1.09)
7.8	1.05 (0.87; 1.27)	0.94 (0.78; 1.14)	1.18 (0.96; 1.43)	1.15 (0.92; 1.43)	0.467 (-0.464; 1.397)	0.194 (-0.313; 0.700)	0.273 (-0.282; 0.827)	0.88 (0.70; 1.09)
7.9	1.04 (0.86; 1.26)	0.95 (0.78; 1.15)	1.17 (0.95; 1.43)	1.14 (0.91; 1.43)	0.467 (-0.475; 1.408)	0.190 (-0.326; 0.706)	0.276 (-0.282; 0.835)	0.88 (0.70; 1.10)

8.0	1.04 (0.86; 1.26)	0.95 (0.78; 1.15)	1.16 (0.94; 1.42)	1.14 (0.91; 1.44)	0.465 (-0.491; 1.420)	0.187 (-0.342; 0.717)	0.277 (-0.288; 0.842)	0.88 (0.70; 1.11)
8.1	1.03 (0.85; 1.26)	0.95 (0.78; 1.16)	1.14 (0.93; 1.41)	1.14 (0.90; 1.44)	0.461 (-0.518; 1.440)	0.184 (-0.366; 0.735)	0.276 (-0.302; 0.855)	0.88 (0.69; 1.12)

All models were adjusted for baseline covariates, such as age, sex, education, smoking, BMI, known diabetes mellitus, HbA1c values, toothbrushing frequency, dental visits in the last 12 months, and powered tooth brush usage. Models with periodontal variables or the number of missing teeth were additionally adjusted for physical activity and gum treatment within the last 5 years. Abbreviations: PD, probing depth; CAL, clinical attachment level; BOP, bleeding on probing; DF-S, number of decayed or filled surfaces; CI, confidence interval

8 Appendix

8.1 Abkürzungsverzeichnis

AP	associated press
BMI	body mass index
BOP	bleeding on probing
CAL	clinical attachment loss
CDC/APP	Centers for Disease Control and Prevention/American Academy of Periodontology
CEJ	cement-enamel junction
CI	confidence interval
DF-S	decayed filled-surfaces
DGZMK	Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde
DMF-T/-S	decayed missing filled- teeth /- surfaces
DMS	Deutsche Mundgesundheitsstudie
FGM	free gingival margin
GBD	Global Burden of Disease
GI	gingivitis index
HbA1c	Hemoglobin A1c
IDA	interdental aids
IDB	inter dental brushes
IIR	incidence rate ratio
MTB	manual tooth brush
OR	odds ratio

P	p-value
PCPUNC 15	Parodontometer
PD	probing depth
PI	plaque index
PMN’s	polymorphonuclear neutrophils
PTB	powered tooth brush
PTFE	polytetrafluorethylene
QHI	Quigley-Hein-Index
SHIP	study of health in Pomerania
SP	severe periodontitis
STROBE	Strengthening the Reporting of Observational studies in Epidemiology
WHO	World Health Organization
WSL	white spot lesion

8.2 Eidesstattliche Erklärung

Hiermit erkläre ich, dass ich die vorliegende Dissertation selbstständig verfasst und keine anderen als die angegebenen Hilfsmittel benutzt habe.

Die Dissertation ist bisher keiner anderen Fakultät und keiner anderen wissenschaftlichen Einrichtung vorgelegt worden.

Ich erkläre, dass ich bisher kein Promotionsverfahren erfolglos beendet habe und dass eine Aberkennung eines bereits erworbenen Doktorgrades nicht vorliegt.

Datum   Unterschrift

8.3 Danksagung

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Elena Marie Conrad