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Factors influencing tooth loss in European populations

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Abstract

Aim: This study aimed to identify the factors influencing the changes in the number of teeth present and the number of healthy or filled surfaces between two time points.

Materials and Methods: Repeated cross-sectional data from population-based studies, namely the German Oral Health Studies (DMS-III vs. DMS-V), the Studies of Health in Pomerania (SHIP-START-0 vs. SHIP-TREND-0), and the Jönköping study (2003 vs. 2013), were analysed. Oaxaca decomposition models were constructed for the outcomes (number of teeth, number of healthy surfaces, and number of filled surfaces).

Results: The number of teeth increased between examinations (DMS: +2.26 [adults], +4.92 [seniors], SHIP: +1.67, Jönköping: +0.96). Improvements in education and dental awareness brought a positive change in all outcomes. An increase in powered toothbrushing and inter-dental cleaning had a great impact in DMS (adults: +0.25 tooth, +0.78 healthy surface, +0.38 filled surface; seniors: +1.19 teeth, 5.79 healthy surfaces, +0.48 filled surface). Inter-dental cleaning decreased by 4% between SHIP-START-0 and SHIP-TREND-0, which negatively affected the outcomes.

Conclusions: From this study, it can be concluded that education may be the most important factor having a direct and indirect effect on the outcomes. However, for better oral health, powered toothbrushing and inter-dental cleaning should not be neglected.

KEYWORDS
caries, inter-dental cleaning, periodontitis, powered toothbrush, risk factors

Clinical Relevance

Scientific rationale for study: Tooth loss is the final outcome of most dental diseases. Although several variables are attributed to its aetiology, there is no consensus on the hierarchy of these variables in terms of causing tooth loss.

Principal findings: In our study, education and dental awareness were found to be the variables that exert the greatest effect on the number of teeth.

Practical implications: The results of this study could be used by the dental community to promote the use of powered toothbrushes and inter-dental cleaning aids.

Jaccard/EFP research prize competition finalist

1 | INTRODUCTION

Caries and periodontitis are the two most common oral diseases that account for approximately 60% of tooth loss in Germany (Glockmann et al., 2011). Current data suggest that the tooth loss prevalence is declining in industrialized nations (König et al., 2010; Fleming et al., 2020; Bomfim & Schneider, 2021). However, it is unclear which preventive measures contribute to the reduced prevalence of tooth loss in adults on a population level.

Accumulation of biofilm on the tooth surfaces is considered as a necessary but not sufficient causal factor for caries and/or periodontitis, whereas susceptibility is influenced by lifestyle factors (smoking, obesity, or diabetes) and socio-economic status (SES; including education, occupation, and income) (Cunha-Cruz et al., 2007). These factors can be arbitrarily classified as (i) patient-related factors (e.g., better oral hygiene, frequent dental visits, etc.), (ii) factors related to the dental fraternity (comprising dentists, dental auxiliaries, and the consumer industry by recommending the use of powered toothbrushes (PTB), fluoride toothpastes and dental flosses, advertisements, etc.), and (iii) factors related to state regulation (e.g., statutory health insurance, water fluoridation, etc.).

Several studies have shown that various risk factors are associated with tooth loss, but there is no consensus on which factor is the most relevant (Müller et al., 2017). Recently, we confirmed the effectiveness of PTB through a longitudinal study (Pitchika et al., 2019) and assessed the long-term benefits of PTB and inter-dental cleaning aid (IDA) use on tooth retention on a population level through a repeated cross-sectional study design using Oaxaca decomposition models (Pitchika et al., 2021). However, the question is still unanswered as to whether the factors of dental awareness and self-performed tooth cleaning behaviour have an effect beyond that of SES. An estimation and ranking of effect sizes would help health policymakers, consumer industry, and dental institutions plan resource allocation.

Hence, using data from the German Oral Health Studies (DMS: Deutsche Mundgesundheitsstudien), the Study of Health in Pomerania (SHIP), and the Jönköping study from Sweden, we aimed to identify the factors influencing the changes in the number of teeth and the numbers of healthy or filled surfaces in three population-based studies between two time points.

2 | MATERIALS AND METHODS

2.1 | Study populations

For this study, repeated cross-sectional data from three population-based studies—two from Germany and one from Sweden—were analysed. All studies were approved by their respective regional ethics boards.

1. German Oral Health Studies (DMS): The Institute of German Dentists (IDZ: Institut der Deutschen Zahnärzte) has been conducting cross-sectional studies to assess the oral health status of the German population since 1989. For this study, cross-sectional data from 1997 (DMS-III) and 2014 (DMS-V) were considered. DMS studies were carried out for different age groups (adults: 35–44 years; seniors: 65–74 years) with differing protocols (Micheelis & Reich, 1999; Jordan & Micheelis, 2016).
2. Study of Health in Pomerania (SHIP): It is an ongoing population-based epidemiological project in northeast Germany. For this study, data from two baseline examinations were considered: SHIP-START-0 (1997–2001) and SHIP-TREND-0 (2008–2012) (Hensel et al., 2003; Völzke et al., 2011).
3. The Jönköping Study: It is a population-based study conducted every decade since 1973 on the inhabitants of four civil parishes in Jönköping city, Sweden. In the present study, two cross-sectional datasets (2003 and 2013) from the Jönköping study were included (Norderyd et al., 2015a; Norderyd et al., 2015b).

2.2 | Dental examinations

1. Number of teeth present: The primary outcome variable, the number of teeth excluding third molars, was determined from tooth-level examinations in the DMS, SHIP, and Jönköping studies.
2. Coronal caries: In DMS and SHIP studies, surface-based coronal caries status was recorded visually (with the help of a periodontal probe for plaque removal, diagnosing the filling margins, securing the findings of a fissure sealant with a transparent material) on all five surfaces of the teeth excluding third molars, according to the WHO criteria (World Health Organization, 1997). In the Jönköping study, surface-based caries examination was performed visually on occlusal, facial, and lingual/palatal surfaces, and via bitewing radiographs for proximal surfaces. Using this information, the secondary outcome variables, that is, the number of healthy surfaces and filled surfaces, were calculated.
3. Periodontitis: In DMS, different recording protocols were followed for DMS-III and DMS-V. In DMS-III, probing depths (PD) were recorded on half-mouth basis and on mesio-buccal and mid-buccal sites of all teeth on the first and fourth quadrants, excluding third molars. In DMS-V, PD was recorded on mesio-buccal, mid-buccal, and disto-lingual sites from the index teeth (11, 16, 17, 24, 26, 27, 31, 36, 37, 44, 46, and 47). In SHIP, clinical attachment loss (CAL) was measured on four sites (mesio-buccal, mid-buccal, disto-buccal, and mid-palatinal/mid-lingual) on a half-mouth basis (alternating left/right side), excluding third molars. In the Jönköping study, PD was measured categorically as <4 mm and exceeding 4 mm on all the sites of all teeth.

2.3 | Covariates

The variables that were commonly available and comparable between DMS, SHIP, and the Jönköping study included age, sex, education, smoking status, toothbrushing frequency, inter-dental cleaning, dental visit in the last 12 months, the reason for dental visits, and self-motivation towards better oral hygiene. In DMS

TABLE 1 Characteristics of the study sample at DMS-III, DMS-V, SHIP-START-0, SHIP-TREND-0, and Jönköping 2003 and 2013 examinations that were included in the Oaxaca models

		DMS-III (1997)		DMS-V (2014)				Jönköping study	
Variable	Category	Adults (35–44 years)	Seniors (65–74 years)	Adults (35–44 years)	Seniors (65–74 years)	SHIP-START-0 (1997–2001)	SHIP-TREND-0 (2008–2011)	2003	2013
n		632 (100)	849 (100)	934 (100)	857 (100)	3323 (100)	2923 (100)	532 (100)	407 (100)
Number of teeth		23.97 ± 4.2	14.50 ± 7.5	26.23 ± 2.5	19.42 ± 6.7	20.91 ± 6.8	22.58 ± 5.9	24.86 ± 4.7	25.82 ± 4.0
Number of healthy surfaces		69.52 ± 26.4	34.00 ± 28.0	107.92 ± 14.6	80.41 ± 28.8	32.34 ± 15.7	33.52 ± 16.0	101.27 ± 27.4	110.69 ± 24.5
Number of filled surfaces		19.15 ± 12.3	7.12 ± 8.0	9.14 ± 6.6	5.15 ± 6.0	14.19 ± 9.5	17.04 ± 10.1	20.19 ± 16.7	16.32 ± 15.2
Mean CAL		–	–	–	–	2.58 ± 1.9	2.44 ± 1.6	–	–
Age		39.52 ± 2.9	68.73 ± 2.7	39.81 ± 3.0	69.35 ± 3.0	46.01 ± 15.2	49.56 ± 14.5	n.a.	n.a.
Sex	Male	297 (47.0)	395 (46.5)	435 (46.6)	404 (47.1)	1621 (48.8)	1394 (47.7)	257 (48.3)	181 (44.5)
	Female	335 (53.0)	454 (53.5)	499 (53.4)	453 (52.9)	1702 (51.2)	1529 (52.3)	275 (51.7)	226 (55.5)
Education	<10 years	176 (27.8)	607 (71.5)	149 (16.0)	375 (43.8)	1047 (31.5)	493 (16.9)	132 (24.8)	82 (20.2)
	10 years	271 (42.9)	126 (14.8)	380 (40.7)	240 (28.0)	1652 (49.7)	1596 (54.6)	277 (52.1)	184 (45.2)
	>10 years	185 (29.3)	116 (13.7)	405 (43.3)	242 (28.2)	624 (18.8)	834 (28.5)	123 (23.1)	141 (34.6)
Region	West Germany	436 (69.0)	582 (68.6)	662 (70.9)	577 (67.3)	n.a.	n.a.	n.a.	n.a.
	East Germany	196 (31.0)	267 (31.4)	272 (29.1)	280 (32.7)	n.a.	n.a.	n.a.	n.a.
Monthly income		n.a.	n.a.	n.a.	n.a.	1233.14 ± 641.5	1508.87 ± 764.9	n.a.	n.a.
Smoking status	Non-smoker	261 (41.3)	532 (62.7)	444 (47.5)	474 (55.3)	1181 (35.5)	1091 (37.3)	441 (82.9)	357 (87.7)
	Former smoker	139 (22.0)	236 (27.8)	231 (24.7)	294 (34.3)	1079 (32.5)	1093 (37.4)	n.a.	n.a.
	Current smoker	232 (36.7)	81 (9.5)	259 (27.7)	89 (10.4)	1063 (32.0)	739 (25.3)	91 (17.1)	50 (12.3)
BMI		n.a.	n.a.	n.a.	n.a.	26.98 ± 4.8	27.66 ± 5.0	n.a.	n.a.
Diabetes	No	n.a.	741 (87.3)	916 (98.1)	726 (84.7)	3049 (91.8)	2643 (90.4)	n.a.	n.a.
	Yes	n.a.	108 (12.7)	18 (1.9)	131 (15.3)	274 (8.2)	280 (9.6)	n.a.	n.a.
HbA1c		n.a.	n.a.	n.a.	n.a.	5.35 ± 0.9	5.28 ± 0.8	n.a.	n.a.
Physical activity	<1 h/week or none	n.a.	n.a.	n.a.	n.a.	1789 (53.8)	863 (29.5)	n.a.	n.a.
	≥1-2 h/week	n.a.	n.a.	n.a.	n.a.	1534 (46.2)	2060 (70.5)	n.a.	n.a.
Toothbrushing	Irregular (<2 times/day)	122 (19.3)	692 (81.5)	158 (16.9)	723 (84.4)	559 (16.8)	400 (13.7)	41 (7.7)	47 (11.6)
	Regular (≥2 times/day)	510 (80.7)	157 (18.5)	776 (83.1)	134 (15.6)	2764 (83.2)	2523 (86.3)	491 (92.3)	360 (88.4)
Toothbrush type	Manual	538 (85.1)	788 (92.8)	483 (51.7)	541 (63.1)	n.a.[a]	2077 (71.1)	n.a.	n.a.
	Powered	94 (14.9)	61 (7.2)	451 (48.3)	316 (36.9)	n.a.[a]	846 (28.9)	n.a.	n.a.
Inter-dental cleaning	Not performed	442 (69.9)	758 (89.3)	343 (36.7)	386 (45.0)	2188 (65.8)	2039 (69.8)	314 (59.0)	272 (66.8)
	Performed	190 (30.1)	91 (10.7)	591 (63.3)	471 (55.0)	1135 (34.2)	884 (30.2)	218 (41.0)	135 (33.2)
Mouthrinses	Not used	472 (74.7)	518 (61.0)	610 (65.3)	501 (58.5)	n.a.[a]	1948 (66.6)	n.a.	n.a.

TABLE 1 (Continued)

Variable	Category	DMS-III (1997)		DMS-V (2014)		SHIP-START-0 (1997–2001)	SHIP-TREND-0 (2008–2011)	Jönköping study	
		Adults (35–44 years)	Seniors (65–74 years)	Adults (35–44 years)	Seniors (65–74 years)			2003	2013
	Used	160 (25.3)	331 (39.0)	324 (34.7)	356 (41.5)	n.a.[a]	975 (33.4)	n.a.	n.a.
Dental visit in last 12 months	No	84 (13.3)	116 (13.7)	119 (12.7)	74 (8.6)	345 (10.4)	0 (0)	63 (11.8)	33 (8.1)
	Yes	548 (86.7)	733 (86.3)	815 (87.3)	783 (91.4)	2978 (89.6)	2923 (100)	469 (88.2)	374 (91.9)
Reason for dental visit	Screening	441 (69.8)	577 (68.0)	721 (77.2)	801 (93.5)	1838 (55.3)[a]	1592 (54.5)[a]	93 (17.5)	80 (19.7)
	Pain/ problem	191 (30.2)	272 (32.0)	213 (22.8)	56 (6.5)	1485 (44.7)[a]	1330 (45.5)[a]	439 (82.5)	327 (80.3)
History of periodontal treatment	No	469 (74.2)	n.a.[a]	750 (80.3)	494 (57.6)[a]	n.a.[a]	2320 (79.8)[a]	n.a.	n.a.
	Yes	163 (25.8)	n.a.[a]	184 (19.7)	354 (41.3)[a]	n.a.[a]	588 (20.2)[a]	n.a.	n.a.
Self-motivation on oral health	None-to an extent	132 (20.9)	245 (28.9)	135 (14.5)	211 (24.6)	556 (16.7)	422 (14.4)	—	—
	Much	256 (40.5)	337 (39.7)	432 (46.2)	355 (41.4)	1555 (46.8)	1305 (44.7)	—	—
	Very much	244 (38.6)	267 (31.4)	367 (39.3)	291 (34.0)	1212 (36.5)	1196 (40.9)	—	—
Self-motivation on oral health	No	—	—	—	—	—	—	97 (18.2)	58 (14.3)
	Yes	—	—	—	—	—	—	435 (81.8)	349 (85.7)

Note: Data are presented as numbers (percentages) or mean ± standard deviation.

Abbreviations: BMI, body mass index; CAL, clinical attachment loss; HbA1c, haemoglobin A1c; n.a., not available.

[a]Variables were not included in the final model, but were presented for continuity with respect to other cohorts.

and SHIP, additional variables such as diabetes, toothbrush type, mouthrinses, and history of periodontal treatment within the past 5 years were available. The region was recorded in the nationwide DMS examinations. In SHIP, a few additional variables were available: monthly income (adjusted for inflation between SHIP-START-0 and SHIP-TREND-0), body mass index (BMI), HbA1c levels, and physical activity (Table 1).

2.4 | Statistical analyses

All analyses involving DMS were stratified by age (adults and seniors). The number of teeth (dentates only) was considered as the primary outcome variable. Covariates were selected a priori based on clinical knowledge. Oaxaca decomposition (O'Donnell et al., 2008) was performed to evaluate the extent to which changes in the number of teeth between two examinations (DMS-III and DMS-V; SHIP-START-0 and SHIP-TREND-0; Jönköping 2003 and 2013) can be explained by changes in the risk factors. Based on the availability of variables, models were adjusted for a maximum number of covariates in the respective datasets individually. To assess the influence of changes in periodontitis status on the outcome, SHIP models were additionally adjusted for mean CAL, reflecting the lifetime accumulated history of chronic periodontitis. Based on linear regression models of the outcome, predicted means were estimated and changes between two examinations were divided into explained and unexplained components by Oaxaca decomposition. As a part of sensitivity analyses, we repeated all the Oaxaca decomposition models with our two secondary outcomes, that is, the number of healthy surfaces and the number of filled surfaces.

All analyses were performed using Stata/SE 14.2 (StataCorp 2015, College Station, TX). A p-value < .05 was considered statistically significant. Recommendations of The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement were applied (von Elm et al., 2014).

3 | RESULTS

In all studies, the proportion of individuals having over 10 years of formal education increased between two examinations. The percentage of current smokers decreased among adults in the DMS, SHIP, and Jönköping studies. In contrast, the number of diabetic subjects increased in DMS (seniors) and SHIP, although the HbA1c levels showed a reduction between SHIP-START-0 (5.35%) and SHIP-TREND-0 (5.28%) (Table 1). The change in risk factors and their effect on the changes in the prevalence of outcomes in all cohorts are presented in Figure 1.

Between DMS-III and DMS-V, the mean number of teeth present in adults increased from 23.97 to 26.23, which corresponds to an increase of 2.26 teeth (Table 2). A significant proportion of this change could be explained by inter-dental cleaning, education >10 years, and PTB use (Table 2). Education >10 years increased from DMS-III to DMS-V by 14% (Table 1), which explained an increase of +0.23 teeth (Table 2). Similarly, the proportion of PTB and IDA use increased by 33.4% and 33.2%, respectively (Table 1), explaining an increase of +0.10 and +0.25 teeth, respectively (Table 2). Education, smoking, PTB and IDA use, the reason for dental visits, and history of periodontal treatment cumulatively explained 33% of the increase in the number of teeth between two time points (Table 2). Likewise, there was an increase in the number of healthy surfaces (+38.39) and a reduction in the number of filled surfaces (−10.01).

Factors influencing the outcome	Sub-group	DMS-III vs. DMS-V (Adults)				DMS-III vs. DMS-V (Seniors)				SHIP-START-0 vs. SHIP-TREND-0				Jönköping 2003 vs. 2013			
		Change in exposure	Number of teeth	Healthy surfaces	Filled surfaces	Change in exposure	Number of teeth	Healthy surfaces	Filled surfaces	Change in exposure	Number of teeth	Healthy surfaces	Filled surfaces	Change in exposure	Number of teeth	Healthy surfaces	Filled surfaces
Change in outcome		—	2.26	38.39	-10.1	—	4.92	46.41	-1.97	—	1.67	1.19	2.86	—	0.96	9.42	-3.87
Explained change		—	0.67	2.92	0.52	—	2.46	9.49	1.07	—	0.33	-1.64	2.63	—	0.48	3.37	-0.99
Age		0.29	↓	↓	↓↑	0.62	↓**	↓**	↓**	3.6	↓**	↓**	↑**	—			
Sex	Female	0.4	↓	↓	↓↑	-0.6	↑	↑	↑	1.1	↓	↓	↑	3.8	↓	↓	↓
Education	10 y	-2.2	↓	↓	↓	13.2	↑**	↑*	↑	4.9	↑**	↑	↑**	-6.9	↓	↓	↑
	>10 y	14	↑**	↑**	↑	14.5	↑**	↑**	↑	9.7	↑**	↑**	↑**	11.5	↑**	↑**	↓
Region	East Germany	-0.9	↑	↑	↓	1.3	↓	↓	↑	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Income		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	275.7	↑**	↑*	↑**	n.a.	n.a.	n.a.	n.a.
Smoking	Former smoker	2.7	↓	↓	↑	6.5	↓*	↓*	↓*	4.9	↓*	↓*	↓	n.a.	n.a.	n.a.	n.a.
	Current smoker	-9	↑**	↑*	↑	0.9	↓	↓	↓	-6.7	↑**	↑**	↓*	-4.8	↑	↑	↑
Body mass index		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.68	↓*	↑	↓**	n.a.	n.a.	n.a.	n.a.
Diabetes		n.a.	n.a.	n.a.	n.a.	2.6	↓	↓	↓	-1.4	↓	↓↑	↓	n.a.	n.a.	n.a.	n.a.
HbA1c		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-0.07	↑	↑	↑	n.a.	n.a.	n.a.	n.a.
Physical activity		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	24.3	↑	↓	↑	n.a.	n.a.	n.a.	n.a.
Toothbrushing frequency	Regular (≥ 2 times/day)	2.4	↓↑	↓	↑	-2.9	↓	↓	↓	3.1	↓	↓	↑	-3.9	↓	↓	↑
Type of toothbrush	PTB	33.4	↑*	↑	↑	29.7	↑**	↑**	↑**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Interdental cleaning	Performed	33.2	↑**	↑*	↑*	44.3	↑**	↑**	↑*	-4.0	↓**	↓**	↓**	-7.8	↑	↓	↑
Mouth rinses	Used	9.4	↓	↓	↓	2.5	↓	↓	↓	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Dental visit in last 12 months	Yes	0.6	↓	↓	↑	5.1	↑*	↑	↑*	10.4	↑*	↓**	↑**	3.7	↑	↑	↑
Reason for dental visit	Pain/problem	-7.4	↑*	↑*	↑	-25.5	↑**	↑*	↑*	0.8	—	—	—	-2.2	↑	↑	↓
History of periodontal treatment	Yes	-6.1	↑*	↑*	↓	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	—	—	—	—
Self-motivation on oral health	Much	5.7	↑	↑	↓	1.7	↑	↑	↑	-2.1	↓	↓	↓↑	—	—	—	—
	Very much	0.7	↓	↓↑	↓	2.6	↑	↑	↑	4.4	↓	↓	↓	—	—	—	—
Self-motivation on oral health	Yes	—	—	—	—	—	—	—	—	—	—	—	—	3.9	↑	↑	↓
Mean CAL		—	—	—	—	—	—	—	—	-0.14	↑**	↑**	↑**		—	—	—

Strong negative effect; Mild negative effect; Neutral effect; Mild positive effect; Strong positive effect

↑: increase; ↓↑: stable; ↓: decrease; *: p-value <0.05; **: p-value <0.01

FIGURE 1 The overall trends of the various risk factors as well as their influence on the change in outcomes between the two examinations (DMS-III vs. DMS-V, SHIP-START-0 vs. SHIP-TREND-0, and Jönköping 2003 vs. 2013)

TABLE 2 Results from Oaxaca decomposition for various dental parameters between DMS-III and DMS-V (dentate adults)

Model	Predicted outcome		Predicted change	Explained/unexplained change
	DMS-III	DMS-V		
Teeth present	23.97	26.23	2.26	0.67/1.59
Healthy surfaces	69.52	107.92	38.39	2.92/35.48
Filled surfaces	19.15	9.14	−10.01	0.52/−10.53

Variable	Category	Explained change (95% confidence interval)		
		Teeth present	Healthy surfaces	Filled surfaces
Age, years	—	−0.03 (−0.07; 0.00)	−0.22 (−0.45; 0.02)	0.00 (−0.04; 0.05)
Sex	Male	Ref (0)	Ref (0)	Ref (0)
	Female	−0.00 (−0.04; 0.03)	−0.02 (−0.29; 0.25)	0.00 (−0.03; 0.03)
Education	<10 years	Ref (0)	Ref (0)	Ref (0)
	10 years	−0.03 (−0.09; 0.03)	−0.11 (−0.38; 0.15)	−0.01 (−0.05; 0.03)
	>10 years	**0.23 (0.13; 0.33)**	**0.99 (0.45; 1.53)**	0.12 (−0.08; 0.32)
Region	West	Ref (0)	Ref (0)	Ref (0)
	Ost	0.01 (−0.01; 0.03)	−0.01 (−0.06; 0.04)	−0.02 (−0.06; 0.03)
Smoking status	Non-smoker	Ref (0)	Ref (0)	Ref (0)
	Former smoker	−0.00 (−0.01; 0.01)	−0.02 (−0.10; 0.05)	0.02 (−0.02; 0.06)
	Current smoker	**0.07 (0.02; 0.12)**	**0.40 (0.10; 0.70)**	0.04 (−0.06; 0.14)
Toothbrushing frequency	Irregular (<2 times/day)	Ref (0)	Ref (0)	Ref (0)
	Regular (≥2 times/day)	0.00 (−0.01; 0.02)	−0.01 (−0.09; 0.06)	0.04 (−0.03; 0.10)
Toothbrush type	Manual	Ref (0)	Ref (0)	Ref (0)
	Powered	**0.10 (0.00; 0.20)**	0.62 (−0.03; 1.27)	0.04 (−0.28; 0.35)
Inter-dental cleaning	Not performed	Ref (0)	Ref (0)	Ref (0)
	Performed	**0.25 (0.14; 0.37)**	**0.78 (0.09; 1.48)**	**0.38 (0.05; 0.72)**
Mouthrinse	Not used	Ref (0)	Ref (0)	Ref (0)
	Used	−0.03 (−0.07; 0.00)	−0.11 (−0.31; 0.09)	−0.08 (−0.18; 0.02)
Dental visit in last 12 months	No	Ref (0)	Ref (0)	Ref (0)
	Yes	−0.00 (−0.01; 0.01)	−0.02 (−0.17; 0.13)	0.01 (−0.06; 0.08)
Reason for dental visit	Screening	Ref (0)	Ref (0)	Ref (0)
	Pain/problem	**0.05 (0.00; 0.10)**	**0.32 (0.04; 0.61)**	0.04 (−0.07; 0.14)
History of periodontal treatment	No	Ref (0)	Ref (0)	Ref (0)
	Yes	**0.05 (0.01; 0.09)**	**0.28 (0.03; 0.53)**	−0.02 (−0.09; 0.06)
Self-motivation on oral health	None/to an extent	Ref (0)	Ref (0)	Ref (0)
	Much	0.00 (−0.02; 0.03)	0.05 (−0.11; 0.22)	−0.04 (−0.13; 0.05)
	Very much	−0.00 (−0.02; 0.01)	0.00 (−0.02; 0.02)	−0.01 (−0.07; 0.06)

Note: Numbers in bold face indicate that the explained changes were statistically significant (p-value <.05).
Abbreviation: DMS, Deutsche Mundgesundheitsstudie (German Oral Health Study).

Among seniors, the number of teeth increased between DMS-III and DMS-V (14.50 to 19.42), which corresponds to an increase of 4.92 teeth (Table 3). IDA and PTB use had increased by 44.7% and 29.7%, respectively (Table 1); together, these variables explained 34.3% (+1.69 teeth) of the change in the number of teeth (Table 3). Further, an increase in the number of dental screenings from DMS-III to DMS-V by 25.5%, 10 years of education by 13.2%, >10 years of education by 14.5%, and dental visits in the last 12 months by 5.1% (Table 1) explained an increase of +0.48, +0.24, +0.38, and +0.08 teeth from DMS-III to DMS-V, respectively (Table 3). Similarly, there was a change of +46.41 healthy surfaces between DMS-III and DMS-V (Table 1), which was attributed to the same variables that explained the number of teeth, except dental visits in the last 12 months (Table 3).

In the SHIP cohorts, the number of teeth increased from 20.91 to 22.58 between the two time points (Table 1), resulting in a change of 1.67 more teeth (Table 4). Increase in education level (10 years: +0.05 teeth, >10 years: +0.15 teeth) and monthly income (+0.15

TABLE 3 Results from Oaxaca decomposition for various dental parameters between DMS-III and DMS-V (dentate seniors)

Model	Predicted outcome		Predicted change	Explained/unexplained change
	DMS-III	DMS-V		
Teeth present	14.50	19.42	4.92	2.46/2.46
Healthy surfaces	34.00	80.41	46.41	9.49/36.92
Filled surfaces	7.12	5.15	−1.97	1.07/−3.04

Variable	Category	Explained change (95% confidence interval)		
		Teeth present	Healthy surfaces	Filled surfaces
Age, years	—	**−0.23 (−0.35; −0.11)**	**−0.68 (−1.08; −0.27)**	**−0.19 (−0.29; −0.08)**
Sex	Male	Ref (0)	Ref (0)	Ref (0)
	Female	0.01 (−0.05; 0.07)	0.04 (−0.26; 0.34)	0.01 (−0.04; 0.05)
Education	<10 years	Ref (0)	Ref (0)	Ref (0)
	10 years	**0.24 (0.11; 0.37)**	**0.63 (0.14; 1.11)**	0.05 (−0.07; 0.16)
	>10 years	**0.38 (0.23; 0.54)**	**1.11 (0.53; 1.68)**	0.10 (−0.03; 0.23)
Region	West	Ref (0)	Ref (0)	Ref (0)
	Ost	−0.02 (−0.09; 0.05)	−0.01 (−0.07; 0.05)	0.03 (−0.07; 0.12)
Smoking status	Non-smoker	Ref (0)	Ref (0)	Ref (0)
	Former smoker	**−0.10 (−0.18; −0.02)**	**−0.38 (−0.70; −0.06)**	**−0.11 (−0.19; −0.02)**
	Current smoker	−0.03 (−0.11; 0.06)	−0.09 (−0.38; 0.21)	−0.01 (−0.05; 0.03)
Diabetes	No	Ref (0)	Ref (0)	Ref (0)
	Yes	−0.03 (−0.08; 0.02)	−0.07 (−0.19; 0.06)	−0.02 (−0.05; 0.01)
Toothbrushing frequency	Irregular (<2 times/day)	Ref (0)	Ref (0)	Ref (0)
	Regular (≥ 2 times/day)	−0.05 (−0.12; 0.02)	−0.22 (−0.51; 0.07)	−0.01 (−0.03; 0.02)
Toothbrush type	Manual	Ref (0)	Ref (0)	Ref (0)
	Powered	**0.50 (0.27; 0.74)**	**1.87 (0.87; 2.86)**	**0.36 (0.11; 0.61)**
Inter-dental cleaning	Not performed	Ref (0)	Ref (0)	Ref (0)
	Performed	**1.19 (0.84; 1.54)**	**5.79 (4.27; 7.30)**	**0.48 (0.11; 0.85)**
Mouthrinse	Not used	Ref (0)	Ref (0)	Ref (0)
	Used	−0.02 (−0.06; 0.02)	−0.10 (−0.28; 0.09)	−0.02 (−0.07; 0.02)
Dental visit in last 12 months	No	Ref (0)	Ref (0)	Ref (0)
	Yes	**0.08 (0.01; 0.16)**	0.24 (−0.05; 0.52)	**0.11 (0.03; 0.20)**
Reason for dental visit	Screening	Ref (0)	Ref (0)	Ref (0)
	Pain/problem	**0.48 (0.21; 0.76)**	**1.13 (0.09; 2.17)**	**0.28 (0.01; 0.56)**
Self-motivation on oral health	None/to an extent	Ref (0)	Ref (0)	Ref (0)
	Much	0.02 (−0.04; 0.08)	0.11 (−0.20; 0.42)	0.00 (−0.01; 0.02)
	Very much	0.02 (−0.02; 0.06)	0.12 (−0.11; 0.34)	0.00 (−0.02; 0.03)

Note: Numbers in bold face indicate that the explained changes were statistically significant (p-value <.05).
Abbreviation: DMS, Deutsche Mundgesundheitsstudie (German Oral Health Study).

teeth) explained a considerable increase in the number of teeth. The number of current smokers had reduced from 32% to 25.3% and contributed to an increase of 0.05 teeth. Subjects who had visited a dentist in the last 12 months had increased by 10.4%, which contributed to an increase in the number of teeth (+0.06). Similarly, there was an increase in the number of healthy surfaces (+1.19) and filled surfaces (+2.86), which were contributed by almost all factors that influenced the change in the number of teeth, except for the dental visit in the last 12 months. The number of subjects who visited a dentist in the last 12 months increased by 10.4%, which contributed to a reduction in the number of healthy surfaces (−0.30), but it was compensated by an increase in the number of filled surfaces (+0.55). Age had the highest negative impact on the number of teeth, healthy surfaces, and filled surfaces. An increase in BMI between SHIP-START-0 and SHIP-TREND-0 negatively impacted the number of teeth. Furthermore, the frequency of IDA use between SHIP-START-0 and SHIP-TREND-0 dropped by 4%, which explained the reduction in the number of teeth (−0.04) and healthy surfaces (−0.04).

In the Jönköping study, the number of teeth and healthy surfaces increased from 24.86 to 25.82 and 101.27 to 110.69, respectively,

TABLE 4 Results from Oaxaca decomposition for various dental parameters including mean clinical attachment loss between SHIP-START-0 and SHIP-TREND-0

	Predicted outcome			
Model	**SHIP-START-0**	**SHIP-TREND-0**	**Predicted change**	**Explained/unexplained change**
Teeth present	20.91	22.58	1.67	0.33/1.34
Healthy surfaces	32.32	33.51	1.19	−1.64/2.84
Filled surfaces	14.19	17.04	2.86	2.63/0.23

		Explained change (95% confidence interval)		
Variable	**Category**	**Teeth present**	**Healthy surfaces**	**Filled surfaces**
Age, years		Ref (0)	Ref (0)	Ref (0)
	RCS 1	**−0.22 (−0.29; −0.14)**	**−2.21 (−2.70; −1.71)**	**1.67 (1.30; 2.04)**
	RCS 2	**−0.05 (−0.11; −0.00)**	**0.17 (0.01; 0.32)**	**−0.28 (−0.53; −0.03)**
Sex	Male	Ref (0)	Ref (0)	Ref (0)
	Female	−0.01 (−0.04; 0.02)	−0.06 (−0.18; 0.07)	0.03 (−0.03; 0.08)
Education	<10 years	Ref (0)	Ref (0)	Ref (0)
	10 years	**0.05 (0.02; 0.08)**	0.01 (−0.04; 0.05)	**0.11 (0.05; 0.18)**
	>10 years	**0.15 (0.10; 0.20)**	**0.18 (0.07; 0.29)**	**0.22 (0.14; 0.31)**
Monthly income	—	**0.15 (0.10; 0.19)**	**0.17 (0.03; 0.30)**	**0.20 (0.09; 0.30)**
Smoking status	Non-smoker	Ref (0)	Ref (0)	Ref (0)
	Former smoker	**−0.02 (−0.04; −0.00)**	**−0.05 (−0.09; −0.00)**	−0.01 (−0.03; 0.02)
	Current smoker	**0.05 (0.02; 0.07)**	**0.16 (0.09; 0.24)**	**−0.04 (−0.09; −0.00)**
Diabetes	No	Ref (0)	Ref (0)	Ref (0)
	Yes	−0.00 (−0.01; 0.00)	0.00 (−0.02; 0.02)	−0.01 (−0.03; 0.01)
HbA1c, %	—	0.01 (−0.01; 0.02)	0.01 (−0.03; 0.04)	0.02 (−0.01; 0.04)
BMI, kg/m^2	—	**−0.02 (−0.04; −0.00)**	0.03 (−0.02; 0.08)	**−0.08 (−0.12; −0.04)**
Physical activity	<1 h/week or none	Ref (0)	Ref (0)	Ref (0)
	≥ 1-2 h/week	0.03 (−0.03; 0.08)	−0.02 (−0.18; 0.14)	0.09 (−0.02; 0.21)
Toothbrushing frequency	Irregular (<2 times/day)	Ref (0)	Ref (0)	Ref (0)
	Regular (≥2 times/day)	−0.01 (−0.02; 0.00)	−0.03 (−0.07; 0.00)	0.02 (−0.01; 0.04)
Inter-dental cleaning	Not performed	Ref (0)	Ref (0)	Ref (0)
	Performed	**−0.04 (−0.07; −0.02)**	**−0.04 (−0.08; −0.01)**	**−0.05 (−0.09; −0.02)**
Dental visit in last 12 months	No	Ref (0)	Ref (0)	Ref (0)
	Yes	**0.06 (0.00; 0.11)**	**−0.30 (−0.45; −0.16)**	**0.55 (0.45; 0.65)**
Self-motivation on oral health	None/To an extent	Ref (0)	Ref (0)	Ref (0)
	Much	−0.00 (−0.01; 0.01)	−0.00 (−0.02; 0.02)	0.00 (−0.01; 0.01)
	Very much	−0.01 (−0.02; 0.01)	−0.00 (−0.04; 0.04)	−0.01 (−0.04; 0.02)
Mean CAL, mm		**0.24 (0.10; 0.39)**	**0.35 (0.13; 0.56)**	**0.20 (0.08; 0.33)**

Note: Numbers in bold face indicate that the explained changes were statistically significant (p-value <.05).
Abbreviations: BMI, body mass index; CAL, clinical attachment loss; HbA1c, haemoglobin A1c; SHIP, Study of Health in Pomerania.

which corresponds to an increase of 0.96 teeth and 9.42 healthy surfaces between the 2003 and 2013 examinations (Table 5). All the factors could cumulatively explain 0.48/0.96 increase in the number of teeth and 3.37/9.42 increase in the number of healthy surfaces. The percentage of participants with over 10 years of education increased by 11.5% (Table 1), which explained a significant increase in the number of teeth (+0.23) and healthy surfaces (+1.49). The frequency of regular toothbrushing and IDA use had reduced from 92.3% to 88.4% and from 41.0% to 33.2%, respectively. The impact of IDA use was not demonstrable in Jönköping, because there was a minor change in the frequency of factors and an inconsequential change in the number of teeth (+0.96 teeth).

4 | DISCUSSION

This study assessed the extent to which changes in frequencies of various factors explain the changes in the number of teeth between DMS-III and

TABLE 5 Results from Oaxaca decomposition for various dental parameters in the Jönköping study between 2003 and 2013

Model	Predicted outcome		Predicted change	Explained/unexplained change
	2003	2013		
Teeth present	24.86	25.82	**0.96**	0.48/0.48
Healthy surfaces	101.27	110.69	**9.42**	3.37/6.05
Filled surfaces	20.19	16.32	−3.87	−0.99/−2.87

Variable	Category	Explained change (95% confidence interval)		
		Teeth present	Healthy surfaces	Filled surfaces
Age	20	Ref (0)	Ref (0)	Ref (0)
	30	−0.01 (−0.02; 0.01)	−0.14 (−0.52; 0.24)	0.12 (−0.20; 0.44)
	40	−0.01 (−0.03; 0.01)	−0.47 (−1.11; 0.18)	0.47 (−0.17; 1.11)
	50	−0.01 (−0.08; 0.06)	−0.18 (−1.42; 1.07)	0.15 (−0.89; 1.18)
	60	0.11 (−0.01; 0.23)	1.57 (−0.10; 3.25)	−1.15 (−2.38; 0.08)
	70	0.14 (−0.07; 0.35)	1.38 (−0.65; 3.41)	−0.78 (−1.92; 0.36)
	80	−0.02 (−0.26; 0.23)	−0.12 (−2.09; 1.84)	0.05 (−0.79; 0.90)
Sex	Male	Ref (0)	Ref (0)	Ref (0)
	Female	−0.02 (−0.05; 0.02)	−0.05 (−0.17; 0.07)	−0.03 (−0.12; 0.05)
Education	<10 years	Ref (0)	Ref (0)	Ref (0)
	10 years	−0.12 (−0.25; 0.01)	−0.61 (−1.24; 0.01)	0.01 (−0.17; 0.19)
	>10 years	**0.23 (0.08; 0.38)**	**1.49 (0.62; 2.37)**	−0.26 (−0.61; 0.09)
Smoking status	Non-smoker	Ref (0)	Ref (0)	Ref (0)
	Former smoker	—	—	—
	Current smoker	0.09 (−0.00; 0.18)	0.37 (−0.02; 0.76)	0.12 (−0.04; 0.27)
Toothbrushing frequency	Irregular (<2 times/day)	Ref (0)	Ref (0)	Ref (0)
	Regular (≥ 2 times/day)	−0.01 (−0.04; 0.03)	−0.12 (−0.31; 0.07)	0.08 (−0.05; 0.20)
Inter-dental cleaning	Not performed	Ref (0)	Ref (0)	Ref (0)
	Performed	0.01 (−0.04; 0.05)	−0.07 (−0.28; 0.14)	0.07 (−0.10; 0.24)
Dental visit in last 12 months	No	Ref (0)	Ref (0)	Ref (0)
	Yes	0.07 (−0.01; 0.16)	0.13 (−0.09; 0.36)	0.24 (−0.02; 0.50)
Usual reason for visiting dentist	Screening	Ref (0)	Ref (0)	Ref (0)
	Pain/problem	0.00 (−0.01; 0.01)	0.03 (−0.06; 0.12)	−0.02 (−0.08; 0.04)
Self-motivation on oral health	No	Ref (0)	Ref (0)	Ref (0)
	Yes	0.02 (−0.02; 0.05)	0.15 (−0.07; 0.38)	−0.05 (−0.15; 0.06)

Note: Numbers in bold face indicate that the explained changes were statistically significant (p-value <.05).

DMS-V, between SHIP-START-0 and SHIP-TREND-0, and between the 2003 and 2013 datasets from the Jönköping study. Our main findings suggest that the difference in the number of teeth between the two examinations was higher in the DMS (adults: 2.26; seniors: 4.92), followed by the SHIP (1.59) and Jönköping studies (0.46). Across all studies, the change towards higher education brought about a robust increase in the number of teeth, and this observation is in line with Marmot's statement on SES as "causes of the causes" (Marmot & Allen, 2014). Beyond education, the factors that contributed to more tooth retention in the DMS and SHIP cohorts were smoking cessation, powered toothbrushing, inter-dental cleaning, and regular dental visits. Because the variables were not the same in all cohorts, a hierarchy model could not be constructed.

In this study, we had the advantage of analysing extensive population-based representative data from Germany and Sweden. Although SHIP-START and SHIP-TREND are longitudinal studies, only the baseline examinations from both cohorts were used, making the data representative of the population. Because of this, our results might apply to Western Europe with the Bismarckian insurance system. Furthermore, our results are robust concerning (i) education and smoking, which are regulated by the state; (ii) dental visits, which are supported by the statutory health insurance; and (iii) IDA or PTB use promoted through dental offices and the, consumer industry.

Our study also had its share of limitations. Because some variables were unavailable or not comparable, it was not possible to adjust for the same set of variables in all studies. Another limitation was that, although tooth loss is influenced by periodontitis and caries, we could not include these variables in the model because of the high collinearity between these variables. Furthermore, it is well known that SES significantly

influences tooth loss globally (Müller et al., 2007; Musacchio et al., 2007; Mundt et al., 2011; Nazer & Sabbah, 2018), but adjusting for SES was not feasible in our studies because monthly income was recorded as a categorical variable in the DMS and Jönköping studies, which could not be adjusted for inflation, rendering comparison between examinations impossible. However, because the SHIP cohort had recorded monthly income as a continuous variable, we adjusted it for inflation and included it as a covariate in addition to education, to explain the maximum amount of variance possible. Another limitation in our study was that we did not adjust for the health insurance status of the study participants because, contrary to the situation in the United States, where few seniors over 65 years of age have access to dental insurance (Friedman & Lamster, 2016), the majority of the European population are covered by mandatory state insurance. This motivates the individuals to frequently visit dentists, allowing earlier detection of dental problems. Perhaps it is for this reason that education and income had a higher influence on dental health than did insurance in European countries (Manski et al., 2016). Therefore, this variable was not considered as a covariate for our analyses. Tooth loss can be caused by various aetiological factors; the reasons for tooth loss were not recorded in either of the included studies. Furthermore, despite adjusting for a large number of variables, there is always a possibility of residual confounding from variables that were not included in our study. Finally, most of the research assessing the number of teeth as an epidemiological outcome to estimate oral health comes from developed nations, which makes extrapolating our results to other countries difficult.

While interpreting the results from the Oaxaca decomposition, a comparison must be made with the change in descriptive values between two examinations for the variables included in the model. For example, between SHIP-START-0 and SHIP-TREND-0, the proportion of individuals with >10 years (18.8%–28.5%) of education had increased (Table 1), which can be considered as a positive outcome and therefore contributing to a positive change in the number of teeth (+0.15). Similarly, an increased monthly income between the two examinations (€1233.14 vs. €1508.87) had a positive influence (+0.15 teeth). Conversely, the proportion of IDA users had declined from 34.2% to 30.2% between SHIP-START-0 and SHIP-TREND-0, which could be seen as a negative trend that indeed contributed to a reduction in the number of teeth (−0.04).

Age was recorded in decades in the Jönköping study. Although it was continuous in DMS, the study sample was already stratified based on age groups. Perhaps because of this, we did not observe any effect on the number of teeth due to age. However, when age (continuous) was analysed in SHIP, it had a negative impact on the number of teeth. It is generally considered that tooth loss is inevitable with ageing (Maupomé et al., 1999; Gibson et al., 2017), but elderly people have increased their ability to retain more teeth or delay the time of tooth loss (Schwendicke et al., 2018). Sex differences were not present throughout all the cohorts in our study, which was in line with the literature (Kassebaum et al., 2014; Helal et al., 2019).

Education as one domain of SES is a patient-related variable and is a greater predictor of general health (Geyer et al., 2010). In all our three studies, a higher educational level had a steady protective effect on the dental outcomes. Societies should apply more emphasis such that a larger part of the population attains better education, which has a preventive effect on dental and general health (Marmot & Allen, 2014; Matsuyama et al., 2019). One possibility could be that education improves decision-making ability. For example, there is a strong correlation between education and PTB or IDA use, as well as dental visits for screening purposes (Pitchika et al., 2019; Pitchika et al., 2021). Another reason for this correlation is that higher education also results in higher income, leading to higher purchasing power (Psacharopoulos & Patrinos, 2018).

Smoking is regarded as an important risk factor for periodontitis and tooth loss (Nociti et al., 2015). Supporting this finding, a protective effect was found on all outcomes when the number of current smokers decreased in the DMS (adults) and SHIP cohorts. On the other hand, smoking cessation is known to reduce both periodontal disease severity and tooth loss (Leite et al., 2019; Duarte et al., 2021). Unfortunately, the information on the time of smoking cessation was not collected in our studies; hence we could not assess the influence of smoking cessation on the outcomes.

Manual toothbrushes are proven to be effective in maintaining oral hygiene, but their use may be subject to poor compliance. In contrast, PTBs are effective, and consumers are more compliant with their use. Compliance with IDA is known to be poor (Warren & Chater, 1996), but the dental fraternity and the industry have constantly promoted the importance of inter-dental cleaning through patient education and marketing strategies, respectively. Although studies have demonstrated the effectiveness of IDA on periodontal parameters (Graziani et al., 2018; Kotsakis et al., 2018), evidence on the prevention of caries or tooth loss is rare. Thus, we assert that a significant change can be brought about by increasing the use of IDA and PTB, as seen in other cohorts. Similarly, self-motivation on oral health did not explain any change in either of the studies, which may indicate that advertisements might have already reached their ceiling effect.

In the Jönköping and DMS studies, filled surfaces decreased and healthy surfaces increased, which mainly contributed to an increase in the number of teeth; however, in SHIP, the number of increased filled surfaces exceeded that of increased healthy surfaces. This is probably because SHIP has a higher caries burden due to the lower SES in the region (Fink et al., 2019), influenced by the after-effects of the East–West transition and the subsequent reunification of Germany. In all three studies, having over 10 years of education had a major impact on increasing the number of healthy surfaces. An increase in inter-dental cleaning contributed more towards an increase in healthy surfaces than filled surfaces in DMS, where both adults and seniors used about 33.2% and 44.3% more IDAs between DMS-III and DMS-V, respectively, whereas in SHIP and Jönköping their use declined. These coherent data illustrate very convincingly that there is room left for prevention, which can be implemented through personal instruction in the dental office or via advertisements by the industry as a public health approach. This observed improvement of the caries situation is in sharp contrast to clinical short-term experiments, which dramatically underestimate the efficacy of inter-dental cleaning on preventing caries.

Because periodontitis is associated with tooth loss, we adjusted for mean CAL (SHIP study), which is considered as the long-term periodontal

marker and is directly related to tooth loss. This increased the predicted number of teeth from 1.59 to 1.67 and explained 0.57 teeth more than the model without mean CAL (Table 4 and Table S1), thereby decreasing the influence of age and current smoking, indicating that the improvement of periodontal status leads to greater tooth retention.

5 | CONCLUSION

From this study, we could conclude that education is a protective factor for tooth loss in three representative cross-sectional studies in Germany and Sweden. In addition to education, variables indicative of dental awareness and behaviour such as toothbrushing frequency, use of powered toothbrush, inter-dental cleaning, and frequency of dental visits seemed to have a direct effect on tooth loss in both German cohorts.

AUTHOR CONTRIBUTIONS

Conception or design of the work: Thomas Kocher, Rainer A. Jordan, Ola Norderyd. *Acquisition and analysis of data for the work*: Vinay Pitchika, Birte Holtfreter. *Interpretation of data for the work*: Vinay Pitchika, Rainer A. Jordan, Ola Norderyd, Bo Rolander, Alexander Welk, Henry Völzke, Birte Holtfreter, Thomas Kocher. *Drafting the work*: Vinay Pitchika. *Revising the work critically for important intellectual content*: All authors. *Final approval of the version to be published*: All authors. *Agreement to be accountable for all aspects of the work*: All authors.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

All studies included in this project (DMS, SHIP and Jönköping) were approved by the responsible regional ethics committee. All study participants provided written informed consent to participate in the respective study.

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SUPPORTING INFORMATION

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