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Changes in prevalence of periodontitis in two German population-based studies

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Abstract

Aim: We aimed to assess changes of periodontal status in Germany.

Materials & Methods: The Studies of Health in Pomerania (SHIP) are two cross-sectional population-based studies conducted during 1997–2001 (SHIP-0, 20–81 years, $n = 3736$) and 2008–2012 (SHIP-Trend, 20–84 years, $n = 3622$) in northeast Germany. The German Oral Health Studies (DMS, 35–44 and 65–74 years) are national cross-sectional population-based surveys conducted in 1997 (DMS III, $n = 1454$) and 2005 (DMS IV, $n = 1668$), whose results were separately reported for West and East Germany. Prevalences, percentages and numbers of teeth affected were defined.

Results: In SHIP, prevalence of attachment loss (AL) ≥3 mm decreased from 89.7% (95% confidence interval (CI): 88.6–90.8) to 85.1% (95%CI: 83.9–86.3) ($p < 0.05$) and the mean extent reduced from 62.8% (95%CI: 61.7–63.8) to 55.9% (95%CI: 54.9–56.9) ($p < 0.05$). Probing depth (PD) ≥4 mm and the respective extent remained unchanged. In West Germany, AL ≥3 mm decreased for 35–44-year-olds and increased for 65–74-year-olds ($p < 0.05$). In SHIP and DMS, the number of teeth in dentates increased significantly in all age groups.

Conclusions: Prevalences and extents of AL improved almost in all age categories in SHIP and West German adults, whereas PDs remained unchanged. Nonetheless, the improvement of periodontal conditions implies an increase of treatment needs regarding moderately diseased teeth because of simultaneous increases of the number of present teeth.

Key words: attachment loss; change; epidemiology; periodontitis; prevalence; probing depth

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Currently, the literature on changes of periodontal status is scarce. Only few studies have investigated those changes during the last decades with the majority reporting an improvement of periodontitis (Kalsbeek et al. 2000, Dye et al. 2007, Rothlisberger et al. 2007, Skudutyte-Rysstad et al. 2007, Hugoson et al. 2008, Haisman-Welsh & Thomson 2012).

In Germany, the prevalence of periodontitis is high (Holtfreter et al.

Conflict of interest and source of funding statement

The authors declare that there are no conflicts of interest in this study. SHIP is part of the Community Medicine Research net (http://www.medizin.uni-greifswald.de/cm) of the University of Greifswald, Germany, which is funded by the German Federal Ministry of Education and Research (BMBF, grants 01ZZ96030 and 01ZZ0701), the Ministry of Education, Research and Cultural Affairs as well as the Ministry of Social Affairs of the Federal State of Mecklenburg-West Pomerania. DMS III and IV were funded by the two Federal dental organizations, the Bundeszahnärztekammer/BZÄK and the Kassenzahnärztliche Bundesvereinigung/KZBV. S.S. was supported by the Institut der Deutschen Zahnärzte/IDZ (Institute of German Dentists). B.H. was financed by an unlimited educational grant from GABA, Switzerland.

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2009, 2010) and ranks in the middle to high range compared to other European countries (Konig et al. 2010). In addition, comparisons between the regional Study of Health in Pomerania (SHIP-0) and regional studies from New York, USA (Holtfreter et al. 2012b), and Niigata, Japan (Hirotomi et al. 2014) revealed that the prevalence of periodontitis was significantly higher in Germany. Considering that the prevalence of major risk factors of periodontitis such as smoking decreased and diabetes increased in Germany over the last 10 years (Atzpodien et al. 2009), it is of importance for health care planners to know whether the prevalence of periodontitis remained unchanged, improved or deteriorated. To date, only few data are available. Based on the cross-sectional nationally representative German Oral Health Studies (DMS), the Community Periodontal Index (CPI) was reported to deteriorate between 1997 and 2005 (Micheelis & Schiffner 2006). However, credibility of these results is questioned, because the CPI has several shortcomings (Baelum et al. 1993, Gjermo et al. 2002) and does not include attachment loss (AL), which is preferentially used to characterize periodontitis definitions in combination with probing depth (PD) (Savage et al. 2009). However, detailed analyses of changes of both AL and PD were not reported so far.

Additional data are provided by the Studies of Health in Pomerania (SHIP). SHIP comprises two cross-sectional regional population-based studies with almost identical age ranges, sampling region, and periodontal recordings protocols. It allows the investigation of 10-year changes in periodontitis prevalences between 1997–2001 (SHIP-0) and 2008–2012 (SHIP-Trend) in north-east Germany.

The aim of the present study was to evaluate changes in periodontitis prevalence and extent using data from the repeated regional SHIP studies (SHIP-0 and SHIP-Trend) and the two national DMS studies (DMS III and IV). Specifically, we will comprehensively (i) describe distributions according to clinically relevant diagnostic thresholds for both AL and PD and (ii) report the prevalence of moderate and severe periodontitis according to the CDC-AAP definition (Page & Eke 2007), stratified by study, region and age.

Materials and Methods

SHIP-0 and SHIP-Trend

Study design and sample

SHIP-0 is a population-based health survey in West Pomerania, a region in the North-East of Germany (John et al. 2001, Hensel et al. 2003). SHIP-0 examinations were conducted during 1997–2001 and the total population of West Pomerania selected for SHIP-0 comprised 212,157 inhabitants. A two-stage cluster sampling design was adopted from the World Health Organization Monitoring Trends and Determinants in Cardiovascular Disease (MONICA) project in Augsburg, Germany (Keil et al. 1988) yielded twelve 5-year-strata (20–79 years) for both genders, each including 292 subjects. In the first sampling stage, three cities and 12 larger towns were selected, and then 17 of 97 small villages (<1500 inhabitants) were randomly drawn. In the second sampling stage, from each of these selected communities, Caucasian subjects with German citizenship and main residency in the area were randomly drawn, proportional to each community population size, and stratified by age and gender. After exclusion of migrated ($N = 615$) and deceased persons ($N = 126$), the net sample included 6265 eligible subjects of whom 4308 subjects participated, which corresponds to a response of 68.8%. For 4288 of 4308 subjects with an oral examination, 515 subjects were edentulous in the examined side. In 37 subjects, periodontal examinations were either refused or not recordable because of medical reasons, resulting in 3736 subjects with probing depth data. Further, AL could not be determined in 185 subjects mainly due to crowns resulting in 3551 subjects with available attachment values. The study protocol was approved on the 12/12/2001 by the local Ethics committee of the University of Greifswald (Registration number: III UV 73/01) and all participants gave written informed consent.

SHIP-Trend is a second independent cohort selected from the same area as SHIP-0 (Volzke et al. 2011). Examinations were conducted during 2008–2012. A stratified random sample of 10,000 adults aged 20–79 years was drawn from population registries. 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. The target sample size was chosen to obtain a final sample size similar to that of SHIP-0. After exclusion of migrated ($N = 851$) and deceased ($N = 323$) persons, the net sample included 8826 persons. Because of several reasons (241 did not answer, 3367 refused participation, 549 did not keep the appointment and 249 agreed without an appointment), 4420 subjects were finally recruited in the study, which corresponds to a response of 50.1%. Of the 4420 participants, 4322 received an oral examination. On the basis of their participation in "SHIP mobil", 409 subjects received no periodontal examination and 237 subjects were edentulous in the examined side. In 56 subjects, periodontal examinations were either refused or not recordable because of medical reasons, resulting in 3620 subjects with probing depth data. Further, AL could not be determined in 189 subjects mainly due to crowns resulting in 3431 subjects with available attachment values. The numbers of subjects by age group and gender in each of the studies are presented in Table 1.

Dental examination

In SHIP, measurements of AL and PD were determined by a periodontal probe (SHIP-0: PCP 11; SHIP-Trend: PCPUNC 15, Hu-Friedy, Chicago, IL, USA) at distobuccal, midbuccal, mesiobuccal, and midlingual/midpalatinal sites according to the half-mouth method excluding third molars (SHIP-0: alternating on the left or right side; SHIP-Trend: left or right side randomly selected). Measurements were mathematically rounded to the next whole millimetre. PD was measured as the distance between free gingival margin (FGM) and pocket base. If the cemento–enamel junction (CEJ) was located sub-gingivally, AL was calculated as PD minus the distance between FGM and CEJ. If recession was present at the examined site, AL

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Table 1. Demographics of the study samples for subjects with periodontal data in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV). Data are presented as numbers with percentages

	SHIP-0, 1997–2001 (n = 3736)			SHIP-Trend, 2008–2012 (n = 3620)		
Age (years)	Total, n	Males, n (%)	Females, n (%)	Total, n	Males, n (%)	Females, n (%)
<25	267	126 (47.2%)	141 (52.8%)	121	58 (47.9%)	63 (52.1%)
25–34	693	316 (45.6%)	377 (54.4%)	531	257 (48.4%)	274 (51.6%)
35–44	747	358 (47.9%)	389 (52.1%)	705	320 (45.4%)	385 (54.6%)
45–54	715	333 (46.6%)	382 (53.4%)	802	395 (49.3%)	407 (50.7%)
55–64	730	360 (49.3%)	370 (50.7%)	743	357 (48.1%)	386 (51.9%)
65–74	438	246 (56.2%)	192 (43.8%)	554	277 (50.0%)	277 (50.0%)
≥75	146	78 (53.4%)	68 (46.6%)	164	100 (61.0%)	64 (39.0%)
Total	3736	1817 (48.6%)	1919 (51.4%)	3620	1764 (48.7%)	1856 (51.3%)

	DMS III, 1997 (n = 1009/445 #)				DMS IV, 2005 (n = 1115/553 #)		
	Age (years)	Total, n	Males, n (%)	Females, n (%)	Total, n	Males, n (%)	Females, n (%)
West	35–44	441	210 (47.6%)	231 (52.4%)	605	267 (44.1%)	338 (55.9%)
	65–74	568	279 (49.1%)	289 (50.9%)	510	248 (48.6%)	262 (51.4%)
East	35–44	200	94 (47.0%)	106 (53.0%)	308	134 (43.5%)	174 (56.5%)
	65–74	245	105 (42.9%)	140 (57.1%)	245	120 (49.0%)	125 (51.0%)

SHIP, Study of Health in Pomerania; DMS, German Oral Health Study; No., Number; %, percentage; #, numbers of subjects in DMS West and East.

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.

In SHIP-0, dental examinations were conducted by eight calibrated and licensed dentists. Biannually, calibration exercises were performed on test patients not connected to the study, yielding an intra-rater correlation of 0.82–0.91 per examiner and an inter-rater correlation of 0.84 regarding AL (Hensel et al. 2003). In SHIP-Trend, dental examinations were conducted by five examiners. Intra-rater correlations for AL 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.

DMS III and DMS IV

Study design and sample

The third and fourth German Oral Health Studies ("Deutsche Mundgesundheitsstudien, DMS") were planned by the Institute of German Dentists (IDZ) as representative cross-sectional studies of oral health in the German resident population in two-adult age cohorts (adults aged 35–44 years and seniors aged 65–74 years). Data collection took place in 1997 (DMS III) and 2005 (DMS IV). The design, sampling and non-response analyses of DMS III and DMS IV have been described in detail elsewhere (Micheelis & Reich 1999, Micheelis & Schiffner 2006). First, cluster samples stratified by the Federal State and by community category were selected, totaling to 90 municipalities (sample points). Second, random samples were drawn from registration offices from each of these municipalities. East Germans were oversampled. Informed consent was obtained from all subjects entered into the study. In DMS III, after exclusion of migrated and deceased persons, the net sample included 1179 (2424) eligible adults (seniors) of whom 655 (1367) subjects participated, which corresponds to a response of 55.6% (56.4%). In DMS IV, after exclusion of migrated and deceased persons, the net sample comprised 1774 (1868) eligible adults (seniors) of whom 925 (1040) subjects participated, resulting in a response rate of 52.1% (55.7%). In DMS III, of the 655 adults and 1367 seniors receiving an oral examination, seven adults (1.1%) and 367 seniors (26.9%) were edentulous. Three adults and 47 seniors refused periodontal examination. Thus, periodontal parameters were available for 645 adults and 953 seniors. In DMS IV, for 925 adults and 1040 seniors with an oral examination, nine adults (1.0%) and 240 seniors (23.1%) were edentulous. Two adults and three seniors refused periodontal examination, resulting in 914 adults and 797 seniors with available periodontal parameters.

Dental examination

In DMS III, AL and PD were determined at midbuccal and mesiobuccal sites in the first and fourth quadrant. Third molars were excluded. In DMS IV, AL and PD were assessed at midbuccal, mesiobuccal and distolingual sites at twelve index teeth (17, 16, 11, 24, 26, 27, 47, 46, 44, 31, 36, 37; two-digit notation according to the FDI World Dental Federation). All measurements were recorded with a WHO periodontal probe (PCP 11.5 WHO probe, M+W Dental, Büdingen, Germany). To ensure comparability between DMS III and IV, the analyses had to be brought down to a common denominator, i.e. at maximum two sites (midbuccal and mesiobuccal) on six teeth (17, 16, 11, 44, 46, 47). After equalization of the recording protocols of DMS III and IV to the highest common denominator, periodontal data were available for 641 adults and 813 seniors in DMS III and for 913 adults and 755 seniors in DMS IV.

Both in DMS III and IV, three mobile teams performed the oral examinations. Each team was provided with one calibrated dentist, who had been intensively trained by experts before the start of the study. At the beginning, during and at the

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end of the study, 104 subjects in DMS III and 123 subjects in DMS IV were examined by the study dentist and an expert. For mean AL, Pearsons' correlations were 0.97 in DMS III and 0.84 in DMS IV. For maximum AL, Pearsons' correlations were 0.95 and 0.87 in DMS III and IV respectively.

General part

Classification of periodontitis

The prevalence of a given condition, e.g. AL ≥3 mm, was defined as the percentage of subjects having at least one site with that condition. Extent was defined as the percentage of teeth displaying that condition. The number of teeth in dentates was counted excluding third molars. To provide comparability with other studies, individuals were classified according to the case definition published by the CDC Working Group (Page & Eke 2007). Severe periodontitis was defined as at least two interproximal sites with AL ≥6 mm (not on the same tooth) and at least one interproximal site with PD ≥5 mm. Moderate periodontitis was defined as at least two interproximal sites with AL ≥4 mm (not on the same tooth) or at least two interproximal sites with PD ≥5 mm (not on the same tooth). If neither moderate or severe periodontitis applied, the subject had mild or no periodontitis. The CDC-AAP case definition necessitates the presences of at least two teeth with CAL and PD measurements at interproximal sites (SHIP: distobuccal and mesiobuccal; DMS: mesiobuccal).

Statistical analysis

Because of the complex sample designs of SHIP and DMS, standard errors were calculated using survey methods provided by STATA/SE 11.0 (StataCorp 2009). In SHIP-0, design variables were considered, which identify strata and clusters and adjust for finite population corrections at both sampling stages. Final sample weights adjusted for non-response rates and different probabilities of subject selection with reference to the base population in Pomerania. Design variables and sampling weights in SHIP-0 were further described in detail elsewhere (Schmidt et al. 2011). In SHIP-Trend, sampling weights and the stratification variable was considered. For DMS III and IV, data were presented stratified by residence

Table 2. Prevalence and number and percentage of affected teeth by degree of attachment loss according to age in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV). Analyses were weighted

AL	Age (years)	SHIP-0, 1997–2001 (n = 3551)			SHIP-Trend, 2008–2012 (n = 3431)		
		Prevalence, % (SE)	No. of teeth affected, mean (SE)	% of teeth affected, mean (SE)	Prevalence, % (SE)	No. of teeth affected, mean (SE)	% of teeth affected, mean (SE)
≥3 mm	<25	54.4 (3.3)	2.0 (0.2)	15.4 (1.5)	37.5 (4.6)*	1.7 (0.3)*	12.4 (2.3)*
	25–34	80.4 (1.7)	4.1 (0.1)	36.6 (1.2)	62.5 (2.3)*	2.5 (0.2)*	20.2 (1.2)*
	35–44	93.8 (0.9)	5.9 (0.1)	63.1 (1.2)	86.2 (1.3)*	4.6 (0.1)*	43.2 (1.3)*
	45–54	98.2 (0.5)	6.7 (0.2)	77.1 (1.1)	95.3 (0.8)*	5.9 (0.1)*	66.6 (1.2)*
	55–64	99.3 (0.3)	6.2 (0.1)	86.7 (0.9)	98.4 (0.5)	6.0 (0.1)	78.7 (1.1)*
	65–74	100 (0)	5.3 (0.2)	94.1 (0.7)	99.4 (0.3)	5.6 (0.2)	86.4 (1.1)*
	≥75	100 (0)	3.7 (0.2)	96.4 (1.1)	99.1 (0.9)	4.4 (0.3)	93.4 (1.6)
	Total	89.7 (0.5)	5.3 (0.1)	62.8 (0.5)	85.1 (0.6)*	4.7 (0.1)*	55.9 (0.5)*
≥5 mm	<25	7.0 (1.7)	0.1 (0.02)	0.8 (0.2)	6.6 (2.4)	0.2 (0.1)	1.9 (0.9)
	25–34	23.1 (1.6)	0.5 (0.1)	4.8 (0.5)	9.9 (1.3)*	0.2 (0.03)*	1.7 (0.3)*
	35–44	50.5 (1.9)	1.7 (0.1)	20.5 (1.1)	32.5 (1.8)*	1.0 (0.1)*	9.9 (0.8)*
	45–54	72.0 (1.8)	2.8 (0.1)	34.9 (1.4)	59.6 (1.8)*	2.1 (0.1)*	26.2 (1.2)*
	55–64	83.4 (1.4)	3.1 (0.1)	48.1 (1.4)	73.2 (1.7)*	2.7 (0.1)*	39.5 (1.4)*
	65–74	88.3 (1.8)	3.1 (0.1)	62.9 (2.0)	80.8 (1.8)*	2.9 (0.1)*	48.9 (1.8)*
	≥75	90.2 (2.8)	2.5 (0.2)	72.2 (3.7)	89.4 (2.8)	3.0 (0.2)	70.0 (3.3)
	Total	54.0 (0.7)	1.9 (0.04)	27.0 (0.6)	48.2 (0.7)*	1.7 (0.04)*	24.0 (0.5)*

	AL	Age (years)	DMS III, 1997 (n = 1009/445 #)			DMS IV, 2005 (n = 1115/553 #)		
			Prevalence, % (SE)	No. of teeth affected, mean (SE)	% of teeth affected, mean (SE)	Prevalence, % (SE)	No. of teeth affected, mean (SE)	% of teeth affected, mean (SE)
West	≥3 mm	35–44	88.3 (1.6)	3.5 (0.1)	70.2 (1.7)	83.6 (1.5)*	2.9 (0.1)*	55.3 (1.4)*
		65–74	93.6 (1.0)	2.4 (0.1)	83.3 (1.3)	97.3 (0.7)*	3.1 (0.1)*	82.9 (1.1)*
	≥5 mm	35–44	45.3 (2.4)	0.9 (0.1)	19.6 (1.4)	37.6 (2.0)*	0.7 (0.05)*	14.2 (1.0)*
		65–74	61.7 (2.1)	1.1 (0.1)	41.8 (1.7)	65.5 (2.1)	1.4 (0.1)*	37.6 (1.6)
East	≥3 mm	35–44	82.9 (2.8)	2.6 (0.1)	56.3 (2.7)	94.7 (1.3)*	3.3 (0.1)*	64.9 (1.8)*
		65–74	91.5 (1.8)	2.0 (0.1)	77.6 (2.1)	96.8 (1.2)*	2.8 (0.1)*	86.1 (1.6)*
	≥5 mm	35–44	35.3 (3.7)	0.6 (0.1)	13.9 (1.7)	45.2 (3.0)*	0.9 (0.1)*	17.4 (1.5)
		65–74	64.1 (3.1)	1.1 (0.1)	43.1 (2.5)	76.4 (2.8)*	1.5 (0.1)*	49.0 (2.4)

SHIP, Study of Health in Pomerania; DMS, German Oral Health Study; No., Number; %, percentage; SE, standard error; AL, attachment loss; #, numbers of subjects in DMS West and East.

*$p < 0.05$, Mann–Whitney U test or chi-square test, as appropriate, to assess differences between SHIP-0 and SHIP-Trend or between DMS III and DMS IV.

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Table 3. Prevalence and number and percentage of affected teeth by degree of probing depth according to age in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV). Analyses were weighted

PD	Age (years)	SHIP-0, 1997–2001 (n = 3736)			SHIP-Trend, 2008–2012 (n = 3620)		
		Prevalence, % (SE)	No. of teeth affected, mean (SE)	% of teeth affected, mean (SE)	Prevalence, % (SE)	No. of teeth affected, mean (SE)	% of teeth affected, mean (SE)
≥4 mm	<25	38.8 (3.1)	1.1 (0.1)	8.5 (1.1)	49.2 (4.7)	1.5 (0.2)	10.8 (1.8)
	25–34	53.5 (2.1)	1.8 (0.1)	14.7 (0.9)	52.4 (2.3)	1.9 (0.1)	14.8 (1.0)
	35–44	74.2 (1.6)	3.0 (0.1)	30.2 (1.2)	66.6 (1.8)*	3.0 (0.1)	24.4 (1.1)*
	45–54	84.0 (1.5)	3.5 (0.1)	37.6 (1.1)	78.6 (1.5)*	3.8 (0.1)	37.0 (1.2)
	55–64	78.1 (1.6)	2.9 (0.1)	39.5 (1.4)	83.2 (1.4)*	3.8 (0.1)*	42.7 (1.3)
	65–74	80.5 (2.2)	2.4 (0.1)	45.6 (1.8)	75.7 (1.9)	3.0 (0.1)*	41.3 (1.6)
	≥75	64.1 (4.6)	1.5 (0.2)	38.8 (3.7)	77.5 (3.5)*	2.5 (0.2)*	42.7 (3.0)
	Total	69.6 (0.8)	2.6 (0.05)	29.7 (0.5)	70.5 (0.8)	3.0 (0.1)*	31.2 (0.5)
≥6 mm	<25	4.2 (1.3)	0.1 (0.02)	0.4 (0.1)	4.1 (1.9)	0.2 (0.1)	1.5 (0.8)
	25–34	10.1 (1.2)	0.2 (0.04)	1.8 (0.3)	5.4 (1.0)*	0.1 (0.02)*	0.7 (0.1)*
	35–44	25.4 (1.6)	0.7 (0.1)	7.6 (0.7)	19.2 (1.6)*	0.4 (0.1)*	3.7 (0.4)*
	45–54	37.5 (1.8)	0.9 (0.1)	10.5 (0.8)	28.7 (1.6)*	0.8 (0.1)*	8.6 (0.7)*
	55–64	36.5 (1.8)	0.9 (0.1)	13.1 (0.9)	32.5 (1.8)	0.9 (0.1)	10.1 (0.8)
	65–74	33.7 (2.4)	0.7 (0.1)	14.5 (1.4)	28.1 (1.9)	0.6 (0.1)	9.1 (0.9)*
	≥75	30.4 (4.3)	0.4 (0.1)	14.8 (2.7)	21.6 (3.3)	0.4 (0.1)	8.1 (1.6)
	Total	25.4 (0.7)	0.6 (0.03)	8.1 (0.3)	21.7 (0.7)*	0.5 (0.02)*	6.2 (0.3)*

	PD	Age (years)	DMS III, 1997 (n = 1002/445 #)			DMS IV, 2005 (n = 1115/553 #)		
			Prevalence, % (SE)	No. of teeth affected, mean (SE)	% of teeth affected, mean (SE)	Prevalence, % (SE)	No. of teeth affected, mean (SE)	% of teeth affected, mean (SE)
West	≥4 mm	35–44	41.6 (2.4)	1.0 (0.1)	20.8 (1.5)	40.3 (2.0)	0.8 (0.1)	15.5 (1.0)
		65–74	58.8 (2.1)	1.1 (0.1)	39.5 (1.7)	57.8 (2.2)	1.1 (0.1)	30.5 (1.5)*
	≥6 mm	35–44	8.2 (1.4)	0.1 (0.02)	3.0 (0.6)	5.6 (0.9)	0.1 (0.02)	1.8 (0.3)
		65–74	14.2 (1.5)	0.2 (0.02)	7.1 (0.9)	15.7 (1.6)	0.2 (0.02)	6.1 (0.8)
East	≥4 mm	35–44	51.4 (3.7)	1.1 (0.1)	25.0 (2.2)	54.8 (3.0)	1.2 (0.1)	24.8 (1.7)
		65–74	50.4 (3.2)	0.9 (0.1)	33.9 (2.5)	54.6 (3.3)	0.9 (0.1)	29.6 (2.2)
	≥6 mm	35–44	13.9 (2.4)	0.2 (0.04)	4.8 (1.0)	10.2 (1.9)	0.1 (0.03)	2.8 (0.6)
		65–74	17.8 (2.4)	0.3 (0.04)	9.9 (1.5)	15.2 (2.4)	0.2 (0.03)	5.7 (1.1)

SHIP, Study of Health in Pomerania; DMS, German Oral Health Study; No., Number; %, percentage; SE, standard error; PD, probing depth; #, numbers of subjects in DMS West and East.
*$p < 0.05$, Mann–Whitney U test or chi-square test, as appropriate, to assess differences between SHIP-0 and SHIP-Trend or between DMS III and DMS IV.

(West or East Germany). Sampling weights were used to adjust for different probabilities of subject selection and differences in gender, age, region, and Nielsen areas with regard to the base population (Micheelis & Reich 1999, Micheelis & Schiffner 2006). To compare distributions of periodontal variables between groups, chi square tests were applied. The chi-square-statistics were corrected for the final sampling weights and were converted into F-statistics. To assess differences in the numbers and percentages of the affected teeth between the studies, Mann–Whitney U tests were applied. To take the final sampling weights into account, Mann–Whitney U tests were performed by use of the Somers'D parameter. The results were considered statistically significant at $p < 0.05$. Data analysis was performed using STATA/SE 11.0 (StataCorp 2009) and R 3.0.1 (R Core Team 2013).

Results

Attachment loss

In SHIP, total prevalence of AL ≥3 mm decreased from from 89.7% (95% confidence interval (CI): 88.6–90.8) to 85.1% (95% CI: 83.9–86.3) ($p < 0.05$, Table 2), and the percentage of teeth being affected decreased from 62.8% (95% CI: 61.7–63.8) to 55.9% (95% CI: 54.9–56.9) ($p < 0.05$). The prevalence of AL ≥5 mm declined from 54.0% (95% CI: 52.4–55.5) to 48.2% (95% CI: 46.8–49.6) ($p < 0.05$) and the mean extent dropped from 27.0% (95% CI: 25.8–28.3) to 24.0% (95% CI: 23.0–24.9) ($p < 0.05$). Furthermore, prevalence and mean extent consistently decreased in all age groups in SHIP. In West Germans, both the prevalence of AL ≥3 and ≥5 mm and the respective mean extents significantly decreased in 35–44-year-olds ($p < 0.05$). In contrast, for 65–74-year-olds, the prevalence of AL ≥3 mm increased from 93.6% (95% CI: 91.6–95.5) to 97.3% (95% CI: 95.9–98.7) ($p < 0.05$). In East Germany, prevalences of AL ≥3 and ≥5 mm and the corresponding numbers of affected teeth increased significantly for both age groups ($p < 0.05$).

Probing depth

In SHIP, total prevalence of PD ≥4 mm and the corresponding mean extent remained on the same level (Table 3). No clear tendencies were identifiable within the age groups. In contrast, prevalence of severe PDs (≥6 mm) decreased from 25.4%

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Table 4. Prevalence of edentulism and number of teeth in dentates according to age in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV). Analyses were weighted

		SHIP-0, 1997–2001 (n = 4288)		SHIP-Trend, 2008–2012 (n = 4321)	
Age (years)		Edentulism, % (SE)	No. of teeth in dentates, mean (SE)	Edentulism, % (SE)	No. of teeth in dentates, mean (SE)
<25		0 (0)	26.9 (0.2)	0 (0)	27.2 (0.2)*
25–34		0 (0)	25.2 (0.1)	0 (0)	26.8 (0.1)*
35–44		0.7 (0.5)	22.2 (0.2)	0.3 (0.2)	25.1 (0.1)*
45–54		2.8 (0.6)	20.5 (0.3)	1.7 (0.4)	21.8 (0.2)*
55–64		11.7 (1.2)	16.7 (0.3)	7.9 (0.9)*	19.0 (0.3)*
65–74		32.7 (2.0)	12.1 (0.3)	15.8 (1.4)*	15.7 (0.3)*
≥75		47.8 (3.3)	8.7 (0.6)	23.5 (2.6)*	12.2 (0.5)*
Total		8.7 (0.4)	20.7 (0.1)	6.1 (0.4)*	21.6 (0.1)*
		DMS III, 1997 (n = 1340/682 #)		DMS IV, 2005 (n = 1308/657 #)	
	Age (years)	Edentulism, % (SE)	No. of teeth in dentates, mean (SE)	Edentulism, % (SE)	No. of teeth in dentates, mean (SE)
West	35–44	0.9 (0.5)	24.3 (0.2)	0.9 (0.4)	25.6 (0.1)*
	65–74	23.0 (1.4)	14.1 (0.3)	22.6 (1.6)	18.3 (0.3)*
East	35–44	1.7 (1.0)	23.2 (0.3)	1.4 (0.7)	25.0 (0.2)*
	65–74	34.5 (2.2)	12.5 (0.4)	22.9 (2.3)*	16.1 (0.5)*

SHIP, Study of Health in Pomerania; DMS, German Oral Health Study; No., Number; %, percentage; SE, standard error; #, numbers of subjects in DMS West and East.
*$p < 0.05$, Mann–Whitney U test or chi-square test, as appropriate, to assess differences between SHIP-0 and SHIP-Trend or between DMS III and DMS IV.

(95% CI: 23.9–26.9) to 21.7% (95% CI: 20.4–23.0) ($p < 0.05$) and the respective extent was reduced from 8.1% (95% CI: 7.4–8.8) to 6.2% (95% CI: 5.7–6.8) ($p < 0.05$). Except for <25 year-olds, tendencies were consistent within age groups. For both West and East Germans, the prevalences of PD ≥4 and ≥6 mm remained on the same level.

Number of teeth

Both in SHIP and DMS, the number of teeth in dentates increased significantly in all age groups ($p < 0.05$, Table 4). In SHIP, the number of teeth in dentates increased from 20.7 (95% CI: 20.5–20.9) to 21.6 (95% CI: 21.4–21.8). The percentage of edentulous persons decreased from 8.7% (95% CI: 7.8–9.6) to 6.1% (95% CI: 5.4–6.8) ($p < 0.05$). On tooth level, the percentage of subjects having a natural tooth at each specific position increased for all teeth in all quadrants (Fig. 1). For West and East German 35–44-year-olds, the number of teeth in dentates increased from 24.3 (95% CI: 23.9–24.7) to 25.6 (95% CI: 25.4–25.9)

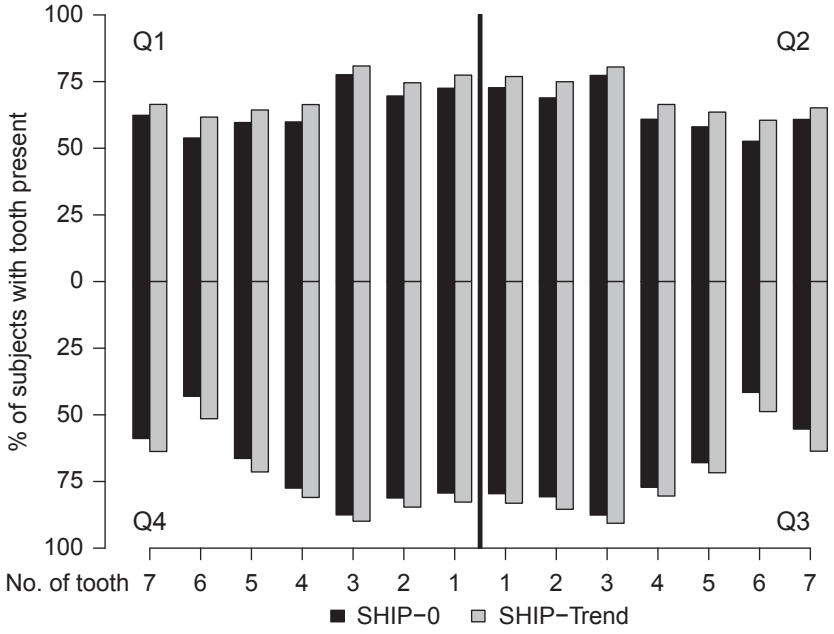

Fig. 1. Percentage of subjects with the respective tooth present at each specific position for all teeth in all quadrants in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend). Analyses were weighted.

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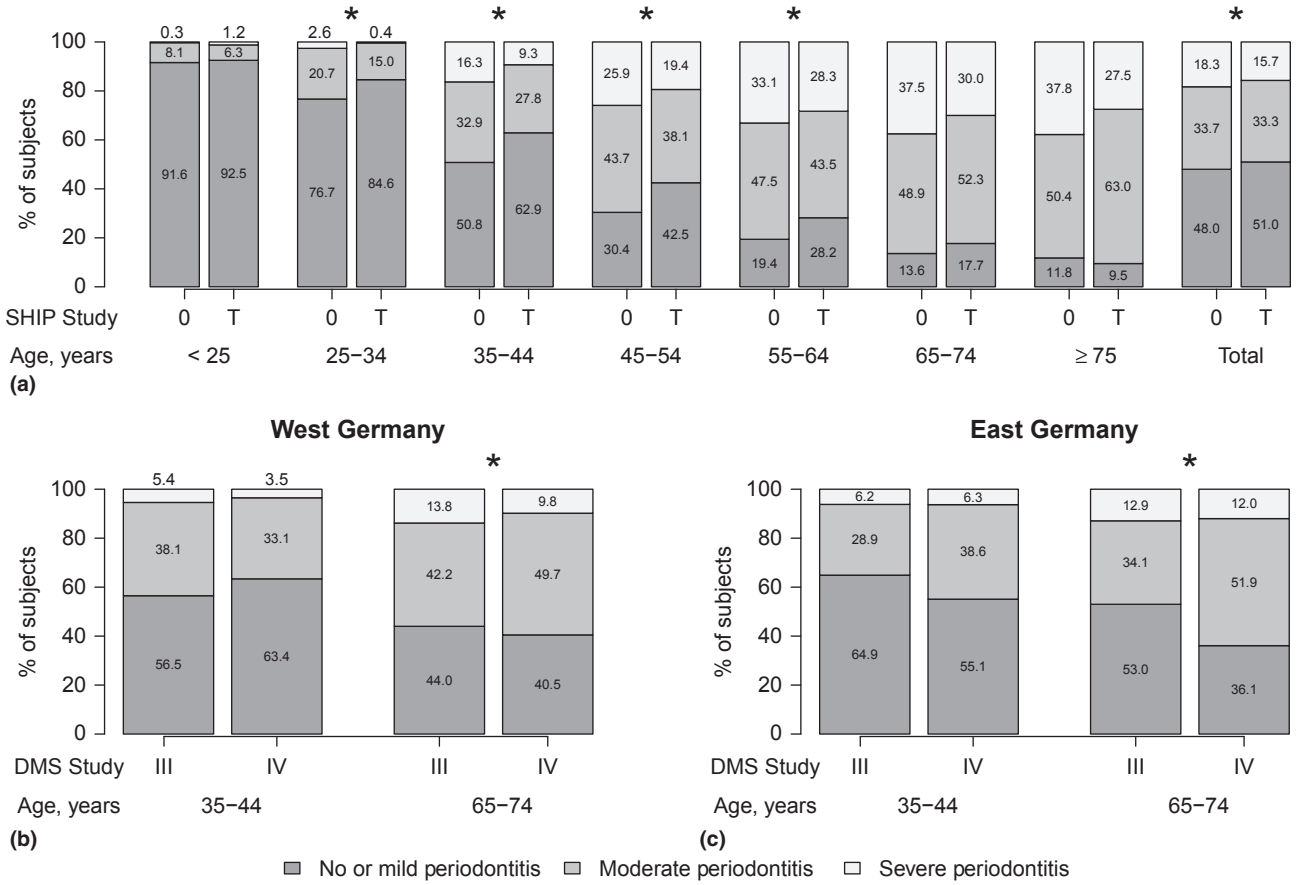

Fig. 2. Percentage distribution of subjects classified according to the CDC-AAP classification (Page & Eke 2007) and according to age in (a) the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV, separately reported for (b) West and (c) East Germany). Analyses were weighted *$p < 0.05$, chi-square test, to assess differences between SHIP-0 and SHIP-Trend or between DMS III and DMS IV.

and from 23.2 (95% CI: 22.5–23.9) to 25.0 (95% CI: 24.6–25.4), respectively. In West German 65–74-year-olds, the percentage of edentulous subjects stagnated (23.0% (95% CI: 20.2–25.8) to 22.6% (95% CI: 19.4–25.7)), while it decreased from 34.5% (95% CI: 30.2–38.9) to 22.9% (95% CI: 18.3–27.5) ($p < 0.05$) in East German 65–74-year-olds.

CDC-AAP periodontitis case definitions

In SHIP, the proportion of subjects with severe periodontitis decreased from 18.3% (95% CI: 16.8–19.8) to 15.7% (95% CI: 14.6–16.9) ($p < 0.05$, Fig. 2). In DMS, the proportion of subjects with severe periodontitis decreased significantly for 65–74-year-olds (13.8% (95% CI: 10.4–17.1) to 9.8% (95% CI: 7.0–12.6) in West and 12.9% (95% CI: 8.0–17.8) to 12.0% (95% CI: 7.2–16.7) in East Germany, $p < 0.05$). For West German 35–44-year-olds, the proportion of subjects with severe periodontitis also decreased (5.4% (95%CI: 3.1–7.7) to 3.5% (95% CI: 2.1–5.0)), even though not statistically significant ($p > 0.05$).

Changes in mean levels of AL and PD

In SHIP, mean AL decreased for all age groups, except for <25 years (Fig. 3). In contrast, mean PD remained on the same level, indicating that gingival recession (difference between mean AL and mean PD) was reduced. Similarly, for West German 35–44-year-olds, mean AL decreased suggesting a decline of gingival recession. In contrast, for West German 65–74-year-olds, gingival recession remained on the same level. Due to a rise in AL, gingival recession increased for both East German age groups.

To ensure comparability with studies using different age categories as against those used in our study, results in SHIP were also presented according to the following age groups: 20–29, 30–39, 40–49, 50–59, 60–69 and 70–81/84 (Tables S1–S5). Results were similar to those observed in Tables 1–4.

Discussion

This study explored the changes in periodontal status in Germany utilizing repeated cross-sectional data from a national (DMS) and a regional population-based study (SHIP). Both in SHIP and West German adults, prevalences and extents of AL decreased suggesting an improvement in periodontal status. In SHIP, prevalences and extents of PD ≥4 mm remained on the same level but prevalences and extents of PD ≥6 mm improved. In DMS, prevalences of

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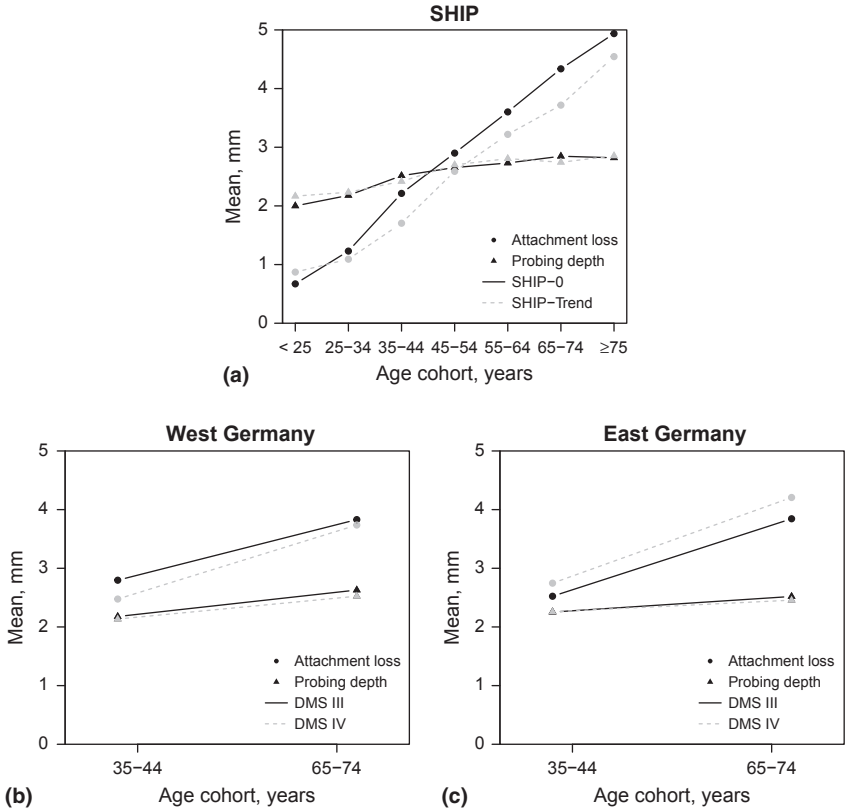

Fig. 3. Changes in mean attachment loss and mean probing depth according to age in (a) the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV, separately reported for (b) West and (c) East Germany). Analyses were weighted.

PD remained unchanged. Both in SHIP and DMS, the proportion of subjects with severe periodontitis according to the CDC-AAP definition decreased and the number of teeth in dentates increased. Because we observed similar tendencies in SHIP and DMS, we assume that the observed temporal changes within SHIP and DMS reflect ongoing real changes in periodontitis prevalences.

The observed improvement in periodontitis in SHIP and in West German adults conform to the findings of other studies on changes in periodontal conditions. Repeated cross-sectional data on periodontal health of 35-year-olds from Oslo, Norway, attained between 1973 and 2003 showed an improvement (Skudutyte-Rysstad et al. 2007) in that the proportions of subjects without radiographically recorded bone loss increased significantly from 46% to 76%. In the Jönköping study, Sweden, which was conducted over the same time period, the proportion of periodontally healthy subjects (no alveolar bone loss and no or low levels of gingivitis) increased from 8% in 1973 to 44% in 2003, while the percentage of subjects with gingivitis or moderate aleveolar bone loss decreased from 88% to 46% (Hugoson et al. 2008). In contrast, the proportion of subjects with severe periodontitis remained on the same level. Between 1988/1994 and 1999/2004 in the USA, the prevalence of moderate and severe periodontitis dropped from 9.6% to 5.1% for 20–64-year-olds and from 26.6% to 17.2% for seniors aged 65 years and older (Dye et al. 2007). During the time period 1998–2009 in England, the prevalence of PD ≥4 mm decreased from 55% to 45%, whereas the prevalence of PD ≥6 mm increased from 6% to 9% (White et al. 2011), which is in agreement with the Jönköping study. Several studies reported reductions in gingivitis and mild/moderate periodontitis without obvious observable improvements of severe forms of periodontitis (Gjermo 2005). It was argued that this pattern may reflect higher restraints in extracting periodontally diseased teeth nowadays as compared to previous decades (Baelum & Lopez 2013). However, direct comparisons between different studies are difficult because of the dissimilarities of the classification systems used.

In SHIP, the prevalence of edentulism almost halved in older age groups. We assume that these figures represent real changes in the prevalence of edentulism, especially when the data of SHIP is compared to the data of DMS. In West Germany, the prevalence of edentulism stagnated, while in East Germany the prevalence also considerably decreased (35.4% to 22.9%). Here, edentulism in East and West Germany converged, probably due to an equalization of health care systems after reunification (Schutzhold et al. 2013). This is in line with the observed decrease in the prevalence of edentulism in SHIP, which also represents data from the Eastern part of Germany.

The simultaneous analysis of changes in periodontal status in two German population-based studies (SHIP and DMS) is a unique strength of our study, because even though SHIP and DMS were planned and designed by two independent teams and research centers, analyses were similiarly conducted in both cohorts. Our analyses are limited by the partial recording protocols used in SHIP and DMS, which leads to an underestimation of the prevalences of periodontitis (Kingman & Albandar 2002, Susin et al. 2005). However, underestimation was present for both studies in SHIP and DMS and therefore of minor concern for our analyses. Another problem to overcome was the different recording protocols in DMS. In DMS III, periodontal status was determined in all teeth in the first and fourth quadrant. In DMS IV, however, periodontal status was assessed at index teeth, which are inherently composed of a higher percentage of molars. Moreover, in DMS III, mesiobuccal and midbuccal sites were recorded, whereas in DMS IV, the disto-oral surface was additionally recorded. As a result, the ratio of midsites and approximal sites varied between the DMS studies. Disease levels at midsites considerably differ from approximal sites (Owens et al.

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2003). To ensure that the observed differences between the DMS studies reflected real changes and were not solely attributed to the different recording protocols, we had to bring down the measurements to the highest common denominator. Consequently, the analyses in DMS were restricted to two sites at six teeth. This restriction led to a small number of sites entering the analyses, especially in older people inherently having fewer teeth. The medians with percentiles (25%; 75%) for the number of sites entering the analyses for both AL and ST were higher for adults than for seniors [adults: 10 (8; 12) and seniors: 6 (4; 8) in DMS III and adults: 12 (10; 12) and seniors: 8 (4; 10) in DMS IV].

As the halfmouth recording protocols in SHIP were identical and, therefore, did not necessitate any equalization, analyses in SHIP were more robust than those of the DMS studies. The wide age range (20–84 years) represents another strength of SHIP. However, the SHIP studies are limited by their regionality and are therefore not representative for the whole of Germany. Moreover, the use of different periodontal probes in SHIP-0 and SHIP-Trend may have led to a possible overestimation of PD ≥3 mm and an underestimation of PD ≥4 mm in SHIP-0 as compared to SHIP-Trend (Holtfreter et al. 2012a).

Non-response bias might have affected estimates of periodontitis in both SHIP and DMS. In SHIP-0, the overall response rate was 68.8% and after removal of the oldest age group (70+), a mean response of 71.2% was obtained (Hensel et al. 2003). However, the percentage of non-responders was 49.9% in SHIP-Trend, indicating a potential selection bias in the direction of having selected healthier subjects. In DMS, non-response was as high as in SHIP-Trend (~55%). Nonresponse analyses based on short basic questionnaires revealed that 35–44-year-old responders were more often women, whereas, contrariwise, 65–74-year-old responders were more often men (Micheelis & Reich 1999, Micheelis & Schiffner 2006). In both age groups, study participants visited the dentist for regular check-ups more frequently than non-responders. Potentially, prevalences of periodontitis were slightly underestimated in both DMS studies with probably negligible consequences for interpretation of changes in periodontal status.

Considering that periodontal treatment needs are defined by pockets with PD ≥4 mm, periodontal treatment needs did not seem to have changed at first view. But although the prevalences of PD ≥4 mm and the respective mean extents predominantly did not change significantly within the age groups in SHIP and DMS, the simultaneous increase of the number of present teeth led to an increase of treatment needs as indicated by the number of teeth requiring periodontal treatment (Table 3). Thus, with regard to moderately diseased teeth, the number of teeth requiring periodontal treatment increased.

During the last decades, comprehensive caries prevention campaigns led to a higher tooth retention (Kalsbeek et al. 1998, Skudutyte-Rysstad & Eriksen 2007, Holst & Schuller 2011). However, this positive development might also be explained by the reduction in prevalence and extent of attachment loss as seen in SHIP. In a preliminary work, AL best predicted tooth loss across age and gender groups as compared with PD measures (Houshmand et al. 2012). Thus, reduced levels of attachment loss as seen in SHIP might have translated into less tooth loss and might thus have partially contributed to the observed increase in the number of teeth.

In conclusion, our results suggest an improvement in periodontitis in SHIP and West German adults. The rise in treatment needs with regard to moderately diseased teeth represents an important issue to be addressed by the dental community. Currently, the fifth German Oral Health Study (DMS V) is in process and will be completed in the middle of the next year. As the examinations in DMS V are performed on index teeth, DMS V will provide valuable data for comparisons with DMS IV.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Demographics of the study samples for subjects with probing depth data in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend).
Table S2. Prevalence and number and percentage of affected teeth by degree of attachment loss according to age in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend).
Table S3. Prevalence and number and percentage of affected teeth by degree of probing depth according to age in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend).
Table S4. Prevalence of edentulism and number of teeth in dentates according to age in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend).
Table S5. Percentage distribution of subjects classified according to the CDC-AAP classification (Page and Eke, 2007) and according to age in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend).

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Clinical relevance

Scientific rationale for the study: It is of importance for health care planners to know if the prevalence of periodontitis changed in Germany during the last decade.
Principal findings: Prevalences and extents of attachment loss improved in almost all age categories in SHIP and West German adults, whereas probing depths remained unchanged. However, treatment needs with regard to moderately diseased teeth rised because of a simultaneous increase of the number of teeth.
Practical implications: The decline of attachment loss might have partially attributed to the increase of the number of teeth. The rise in treatment demands with regard to moderately diseased teeth represents an important issue to be addressed by the dental community.

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