Aus dem Funktionsbereich für Parodontologie
(Leiter: Univ.-Prof. Dr. med. dent. Thomas Kocher)
in der Poliklinik für Zahnerhaltung, Parodontologie, Endodontologie
(Direktor: Univ.-Prof. Dr. med. dent. Dr. h.c. Georg Meyer)
im Zentrum für Zahn-, Mund- und Kieferheilkunde
(Geschäftsführender Direktor: Univ.-Prof. Dr. med. dent. Dr. h.c. Georg Meyer)
der Universitätsmedizin der Ernst-Moritz-Arndt-Universität Greifswald

Aspects of oral health in the German Oral Health Studies

Inaugural-Dissertation

zur

Erlangung des akademischen

Grades

Doktor der Wissenschaften in der Medizin
(Dr. rer. med.)

der

Universitätsmedizin

der

Ernst-Moritz-Arndt-Universität

Greifswald

2015

vorgelegt von: Svenja Schützhold
geb. am: 14.01.1986
in: Papenburg

Dekan: Prof. Dr. med. dent. Reiner Biffar

1. Gutachter: Prof. Thomas Kocher

2. Gutachter: Prof. Christoph Bandt

3. Gutachter: PD Dr. Nicole Pischon

Ort, Raum: Bibliothek, Ellernholzstr. 1-2 des Institutes für Community Medicine, Greifswald

Tag der Disputation: 04.12.2015

Table of contents

1 Introduction

According to the World Health Organization (WHO), 'oral health is a state of being free from chronic mouth and facial pain, oral and throat cancer, oral sores, birth defects as cleft lip and palate, periodontal (gum) disease, tooth decay and tooth loss, and other diseases and disorders that affect the oral cavity' [1].

The oral health status has a significant impact on daily life [2, 3]. The status of the teeth plays an important role for smile attractiveness, which, in turn, is associated with self-confidence and self-esteem [4]. Esthetics, social and professional success were more often attributed to individuals with normal dentition than to individuals with well-perceivably decayed teeth [5]. The particular importance of the dental status is emphasized by the fact that the presence of a reduced functional dentition (nine teeth or fewer) was found to be negatively associated with the physical index of quality of life (QOL) [6]. The presence of nine or fewer teeth in the maxilla was even ranked on the physical index of QOL between renal diseases and cancer. Moreover, median Oral Health Impact Profile (OHIP) scores significantly differed between partially edentulous patients and fully dentate patients [7]. The most frequently reported problems in the group of partially edentulous patients were chewing difficulties, psychological disappointment and dissatisfaction with appearance due to problems with teeth, mouth or dentures. In addition, missing teeth may lead to tooth migration and tipping. The altered jaw function, as the long-term effect of missing teeth, may be related to the formation of temporomandibular disorders [8].

Self-perception of oral health by single-item questions is a simple and validated tool to gather information of people`s perception of oral health [9]. Self-rated oral health captures the patients` subjective and objective perception of oral health and is strongly associated with dental care-seeking behaviors [10, 11]. In the past few years, numerous studies included single-item questions to assess self-perceived oral health [12]. Numbers of missing teeth were associated with a higher probability of perceiving oral health as poor [12-14]. Subjects who assessed their oral health as 'poor' had three times as many missing teeth as subjects assessing their oral health as 'excellent' [15]. It was stated that the variable missing teeth 'is clearly the most important clinical factor in determining patients` evaluations of their oral health status' [16]. However, self-perceived general health is not only influenced by the awareness of the clinical status but also by social and cultural backgrounds, and particularly, by comparisons with people of a similar age [17].

Against this background, a 'natural experiment' such as the German reunification in 1990 is of great interest to researchers due to the possibility of getting new insights into the determinants of self-perceived health. In 1992, the proportion of participants reporting less than good health was significantly lower in East than in West Germany (47.2% versus 53.5%) [18]. Interestingly, the prevalence of poor self-perceived health increased both in East and West Germany until 1997, with the result that the gap between East and West almost diminished (56.6% in East and 55.9% in West Germany). The authors ascribe these observations to 'the view of an 'assimilation' process towards west German attitudes or beliefs in East Germany after reunification' [18]. After reunification, East Germany adopted the West German health-care system, which fundamentally differed from its Eastern counterpart. Before reunification, almost all dentists were salaried employees in East Germany, not receiving any commissions beyond their salaries. In contrast, in West Germany, there was a system of reimbursement, in which health insurances paid dentists for each treatment. Great efforts were made after reunification to bring East Germany into line with the West German social market economy. Although economic differences diminished over time, East Germans remained socioeconomically deprived; in 1997 the unemployment rate was 19.1% in East and 10.8% in West Germany [19]. An international collaborative study examined the impact of different health-care systems on oral health by comparing data for Hannover, West Germany (1973), and Leipzig, East Germany (1979) [20]. For 35-44-year-olds, the percentages of missing teeth were higher in the metropolitan (8.1%) and nonmetropolitan (7.4%) parts of Hannover than in the metropolitan (4.3%) and nonmetropolitan areas (4.7%) of Leipzig. In comparison with other European countries, the mean number of missing teeth in Germany ranks in the middle to high range [21].

A review of the literature on the epidemiology of tooth loss showed a significant decline in prevalence and incidence of severe tooth loss between 1990 and 2010 at the global, regional, and country levels [22]. The global age-standardized prevalence of severe tooth loss decreased from 4.4% (95% CI: 4.1%-4.8%) to 2.4% (95% CI: 2.2%-2.7%), and the incidence rate decreased from 374 cases (95% CI: 347-406) to 205 cases (95% CI: 187-226) per 100,000 person-years. The higher tooth retention might be explained by comprehensive caries prevention campaigns during the last decades [23, 24]. Additionally, a higher number of teeth was associated with lower mean attachment loss (AL) [25]. Periodontitis at least partially seemed to account for tooth loss [21]. Thus, the positive development towards higher tooth retention may not only be attributed to the caries decline [26], but also to a possible decrease of the prevalance and severity of periodontitis. Hence, it is important for health care planners to know whether the prevalence of periodontitis in Germany changed during the last decades. However, only few studies have examined periodontal trends so far. During the last decades, most studies referred to an improvement of periodontitis [27-32], whereas some studies reported improvements of gingivitis and mild/moderate periodontitis without obviously observable reductions in severe forms of periodontits [33]. Possibly, this pattern represents today's restraints in extracting periodontally diseased teeth in contrast to previous decades [34]. For Germany, only few data are currently available, e.g. on the basis of the cross-sectional and nationally representative German Oral Health Studies ('Deutsche Mundgesundheitsstudien', DMS). As reported in previous studies, the Community Periodontal Index (CPI) deteriorated between 1997 and 2005 [35]. However, the CPI has several shortcomings [36, 37] and does not include AL, which is preferably used to define periodontitis in combination with probing depth (PD) and/or bleeding on probing [38].

2 Aims

Against this background, the aims of this thesis were as follows:

- Assessment of the relative contributions of clinical oral health variables to self-perceived oral health by means of an age-specific approach

- Evaluation of the changes in dental health in West and East Germany between 1989 and 2005

- Detailed evaluation of changes in periodontal health and number of teeth within the last decade based on data from the DMS studies and the Studies of Health in Pomerania (SHIP)

This thesis is based on the following three published original articles:

1. Schützhold S, Holtfreter B, Schiffner U, Hoffmann T, Kocher T, Micheelis W (2014). Clinical factors and self-perceived oral health. European Journal of Oral Sciences 122:134-141.

2. Schützhold S, Holtfreter B, Hoffmann T, Kocher T, Micheelis W (2013). Trends in dental health of 35- to 44-year-olds in West and East Germany after reunification. Journal of Public Health Dentistry 73:65-73.

3. Schützhold S, Kocher T, Biffar R, Hoffmann T, Schmidt CO, Micheelis W, Jordan R, Holtfreter B (2015). Changes in prevalence of periodontitis in two German population-based studies. Journal of Clinical Periodontology 42:121-130 (which was awarded the Eugen-Fröhlich-Preis of the DG PARO 2014).

3 Methods

3.1 Design of included studies

The German Oral Health Studies (DMS)

The Institute of German Dentists [Institut der Deutschen Zahnärzte (IDZ)] conducted four national cross-sectional surveys of oral health in the German resident population (DMS): in 1989 (DMS I, only West Germany), 1992 (DMS II, only East Germany), 1997 (DMS III), and 2005 (DMS IV). In this study, the first two surveys (1989/92) were merged to achieve comparability with the last two studies [39]. Random cluster samples stratified by Federal State and by community category were drawn, altogether of 80 (DMS I), 40 (DMS II), 90 (DMS III), and 90 (DMS IV) municipalities. Random samples were selected from the records of registration offices from each of these municipalities. East Germans were oversampled. Samples from 35-44-year-olds (adults) were taken in all four DMS studies (DMS I-IV), whereas samples from 65-74-year-olds (seniors) were only drawn in DMS III and IV. For adults, participation rates averaged 56%, 72%, 56% and 52%, respectively. Both in DMS III and IV, the participation rates equaled 56% for seniors (Table 1).

Table 1. Information on sampling design for adults and seniors in DMS I–IV.

Survey name	Birth cohort	Survey year	Age (year)	Sampling size	Number of invited subjects	Participation rate (%)
Adults						
DMS I	1945-1954	1989	35-54*	1700*	1544*	858 (56%)*
DMS II	1948-1957	1992	35-54*	1039*	1014*	731 (72%)*
DMS III	1953-1962	1997	35-44	1260	1179	655 (56%)
DMS IV	1961-1970	2005	35-44	1980	1774	925 (52%)
Seniors						
DMS III	1923-1932	1997	65-74	2520	2424	1367 (56%)
DMS IV	1931-1940	2005	65-74	1980	1868	1040 (56%)

* Information was only available for the cohort aged 35-54

Studies of Health in Pomerania (SHIP)

The Studies of Health in Pomerania (SHIP) are two independent cross-sectional population-based studies conducted during 1997-2001 (SHIP-0) and 2008-2012 (SHIP-Trend) in northeast Germany. In SHIP-0, a two-stage cluster sampling design 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, proportionally 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%.

SHIP-Trend is a second independent cohort selected from the same area as SHIP-0. 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 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 of whom 4420 subjects participated, which corresponds to a response of 50.1%.

Table 2. Overview of study populations chosen for the three articles

Article name	Study	Age groups
1. Clinical factors and self-perceived oral health	DMS IV	35-44-year-olds; 65-74-year-olds
2. Trends in dental health of 35- to 44-year-olds in West and East Germany after reunification	DMS I-IV	35-44-year-olds
3. Changes in prevalence of periodontitis in two German population-based studies	DMS III+IV SHIP-0 + SHIP-Trend	35-44-year-olds; 65-74-year olds 20-81/84 years

3.2 Variables and statistical analyses

Schützhold, S., et al. (2014). "Clinical factors and self-perceived oral health." <u>Eur J Oral Sci</u> 122(2): 134-41

Self-perceived oral health was evaluated by the question: 'Thinking of your teeth, how would you rate their condition?' (with the response options: 'very good', 'good', 'satisfactory', 'less good', or 'poor'). We combined the first and the last two answers and, therefore, the dependent variable had three categories: very good/good, satisfactory, and less good/poor (subsequently referred to as good, satisfactory, and poor). We additionally assessed the following clinical oral health variables: numbers of decayed teeth, numbers of filled teeth, and numbers of unreplaced teeth, mean AL, bleeding on probing (BOP), the presence of a fixed denture, and the presence of a removable denture. Separate multinomial logistic regression models were developed for both age groups in DMS IV (Table 2) to evaluate associations of self-perceived oral health with clinical oral health variables. Stepwise forward and backward regression analyses were performed. Following recent recommendations for the conduct of such analyses [40], we chose p for inclusion as 0.15 and p for exclusion as 0.20. All analyses were weighted.

Schützhold, S., et al. (2013). "Trends in dental health of 35- to 44-year-olds in West and East Germany after reunification." <u>J Public Health Dent</u> 73(1): 65-73

Because only 35-44-year-olds provided the longest observation period with examinations between 1989 (DMS I) and 2005 (DMS IV), analyses were restricted to 35-44-year-old subjects (Table 2). Numbers of decayed, missing and filled teeth were determined and the DMFT-index was calculated. The number of sound teeth was calculated as the difference between 28 and the DMFT-index. Subjects were stratified into those with more versus less than or equal to 20 teeth. Regression models were applied to assess associations between region, survey year, their interactions and variables assessing dental disease status (number of missing, filled, decayed and sound teeth, the DMFT-index and the probability of having $\leq$20 teeth). Negative binomial regression models were applied to account for the highly positively skewed counts of decayed and missing teeth. Multiple linear regressions were used to model the number of filled and sound teeth and the DMFT-index. Logistic models were applied to model the probability of having $\leq$20 teeth. To assess effects of region within specific survey years, linear combinations of estimators were tested using Wald tests. Analyses were weighted and adjusted for potential risk factors for caries, namely gender, age, school education, marital status, utilization of dental services, number of snacks, use of dental floss / tooth sticks, and the last dental visit.

Schützhold, S., et al. (2015). "Changes in prevalence of periodontitis in two German population-based studies." J Clin Periodontol 42(2): 121-30

In SHIP, measurements of AL and PD were taken at distobuccal, midbuccal, mesiobuccal, and midlingual/palatinal 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). In DMS III, AL and PD were determined at midbuccal and mesiobuccal sites in the first and fourth quadrant. 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). To ensure comparability between DMS III and IV, teeth and sites had to be brought down to a common denominator for further analyses, i.e. at maximum two sites (midbuccal and mesiobuccal) on six teeth (17, 16, 11, 44, 46, 47). The number of teeth in dentates was determined excluding third molars.
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. For DMS III and IV, data were presented stratified by residence (West or East Germany). Because of the complex sample designs of DMS and SHIP, analyses were weighted. In SHIP-0, design variables were additionally considered to identify strata and clusters and to adjust for finite population corrections at both sampling stages. In SHIP-Trend, both sampling weights and the stratification variable were included into the analyses. To compare distributions of periodontal variables between groups, chi square tests were applied, whose statistics were corrected for the final sampling weights. To assess differences in the numbers and percentages of the affected teeth between the studies, Mann-Whitney U tests were applied, which were performed by use of the Somers' D parameter to account for the final sampling weights.

The results were considered statistically significant at $p<0.05$. Data analyses were performed using Stata/SE 11.0 [41] and R 2.12.1 [42] or 3.0.1 [43].

4 Results

Schützhold, S., et al. (2014). "Clinical factors and self-perceived oral health." <u>Eur J Oral Sci</u> 122(2): 134-41

Data of 891 adults (35-44-year-old) and 760 seniors (65-74-year-old) from DMS IV were evaluated. The proportions of participants reporting poor oral health were 18.5% in adults and 16.1% in seniors. After stepwise regression analysis, the number of unreplaced teeth, the number of filled teeth, the number of decayed teeth, the presence of a removable denture, and mean AL were added in this order to the final model for adults (Table 3).

Table 3: Outcome of stepwise multinomial regression analysis for adults (35-44-year-old) in DMS IV

	Final multinomial model			
	Satisfactory vs. Good		Poor vs. Good	
Variable	RRR (95% CI)	*p* value	RRR (95% CI)	*p* value
Unreplaced teeth (cont.)	1.27 (1.14; 1.40)	<0.001	1.42 (1.25; 1.61)	<0.001
Filled teeth (cont.)	1.10 (1.06; 1.14)	<0.001	1.12 (1.06; 1.18)	<0.001
Decayed teeth (ref. 0)	1.00		1.00	
> 0	1.68 (1.08; 2.60)	0.02	3.45 (2.11; 5.65)	<0.001
Removable denture (ref. No)	1.00		1.00	
Yes	2.71 (0.99; 7.45)	0.053	8.46 (3.09; 23.19)	<0.001
Mean AL, mm (ref. 1st Tertile)	1.00		1.00	
2nd Tertile	0.68 (0.46; 1.00)	0.052	0.64 (0.37; 1.10)	0.11
3rd Tertile	1.40 (0.92; 2.13)	0.12	1.35 (0.80; 2.28)	0.26

AL, attachment loss ; Analyses were weighted; The reference category for the dependent variable was 'good'.
Source: Schützhold et al. 2014 [44].

For seniors, the variables entered the model in the following order: the presence of a removable denture, the number of unreplaced teeth, the number of decayed teeth, mean AL, the number of filled teeth, and BOP (Table 4). Interestingly, the number of unreplaced teeth was the first variable to enter the model for adults and the second variable to enter the model for seniors.

Table 4: Outcome of stepwise multinomial regression analysis for seniors (65-74-year-old) in DMS IV

	Final multinomial model			
	Satisfactory vs. Good		Poor vs. Good	
Variable	RRR (95% CI)	*p* value	RRR (95% CI)	*p* value
Removable denture (ref. No)	1.00		1.00	
Yes	2.18 (1.43; 3.33)	<0.001	5.37 (3.07; 9.38)	<0.001
Unreplaced teeth (cont.)	1.18 (1.07; 1.29)	<0.001	1.33 (1.20; 1.47)	<0.001
Decayed teeth (ref. 0)	1.00		1.00	
> 0	1.76 (1.15; 2.70)	0.01	2.07 (1.17; 3.64)	0.01
Mean AL, mm (ref. 1st Tertile)	1.00		1.00	
2nd Tertile	0.81 (0.54; 1.22)	0.31	1.18 (0.63; 2.23)	0.61
3rd Tertile	1.22 (0.78; 1.93)	0.38	2.24 (0.19; 4.22)	0.01
Filled teeth (cont.)	1.04 (1.00; 1.09)	0.03	1.00 (0.95; 1.06)	0.98
BOP, % (cont.)	1.01 (1.00; 1.01)	0.03	1.01 (1.00; 1.02)	0.06

AL, attachment loss; BOP, Bleeding on probing; Analyses were weighted. The reference category of the dependent variable was ‘good’. Source: Schützhold et al. 2014 [44].

Schützhold, S., et al. (2013). "Trends in dental health of 35- to 44-year-olds in West and East Germany after reunification." J Public Health Dent 73(1): 65-73

Between 1989/92 and 1997, the number of missing teeth remained constant in West and slightly increased in East Germany, whereas it considerably decreased in both regions between 1997 and 2005. In each survey year, East Germans had consistently more missing teeth and a higher probability of having ≤20 teeth than West Germans (Figure 1 a, e), which was statistically significant (p<0.05, post hoc tests after regression techniques). Thus, no equalization between East and West Germany was observed with regard to the number of missing teeth and to the probability of having ≤20 teeth. However, the numbers of filled, decayed and sound teeth and the DMFT-index converged between both German regions at the latest in 2005 (Figure 1 b-d, f).

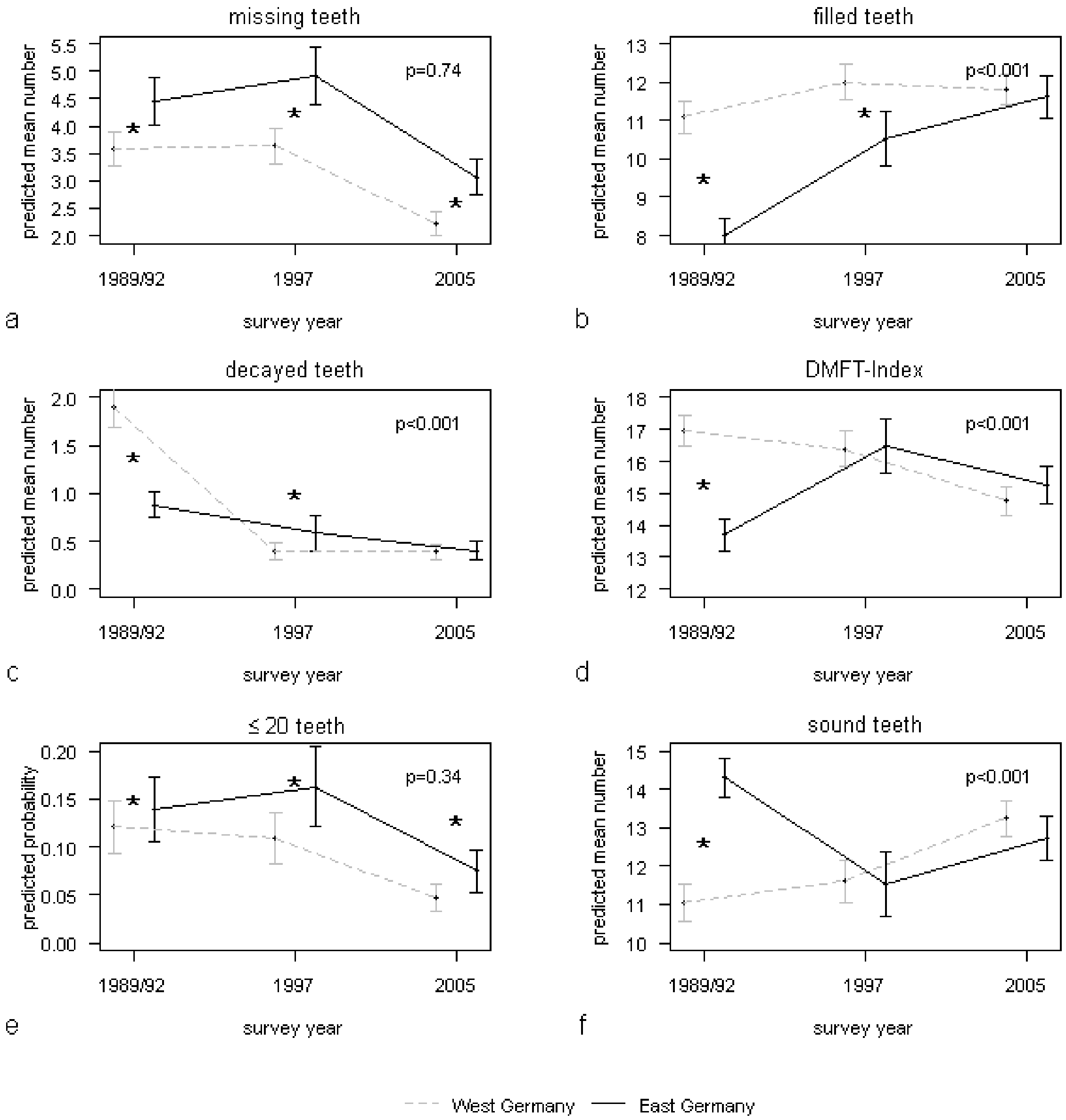

Figure 1. Trends in dental health variables for adults (35-44-year-old) in DMS I-IV [(a) number of missing teeth, (b) number of filled teeth or (c) number of decayed teeth, (d) DMFT-index, (e) predicted probability of having ≤20 teeth, (f) number of sound teeth] according to region and survey year; * indicates $p<0.05$ for differences between West and East Germany within survey years received from regression post hoc tests. P-values are given for overall test of significance of interaction terms between region and survey year. Analyses were weighted and adjusted for gender, age, school education, marital status, utilization of dental services, number of snacks, use of dental floss/tooth sticks and the last dental visit, using the following types of regression: negative binomial regression (a, c), linear regression (b, d, f) and logistic regression (e). Whiskers denote 95% confidence intervals. Source: Schützhold et al. 2013 [45].

Schützhold, S., et al. (2015). "Changes in prevalence of periodontitis in two German population-based studies." J Clin Periodontol 42(2): 121-30

Both in SHIP and DMS, the number of teeth in dentates increased significantly in all age groups (p<0.05, Table 5). In the total SHIP population, the percentage of edentulous persons decreased from 8.7% to 6.1% (p<0.05) and the number of teeth in dentates increased from 20.7 to 21.6. In DMS for West German 65-74-year-olds, the percentage of edentulous subjects remained on the same level (23.0% to 22.6%), while it decreased from 34.5% to 22.9% in East German 65-74-year-olds. Both for West and East German 35-44-year-olds, the number of teeth in dentates increased from 24.3 to 25.6 and from 23.2 to 25.0, respectively.

Table 5: 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. Source: Schützhold et al. 2015 [46].

SHIP		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		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.

In SHIP, the total prevalence of AL ≥3 mm decreased from 89.7% to 85.1% and the percentage of teeth being affected decreased from 62.8% to 55.9% ($p<0.05$). The prevalence of PD ≥4 mm and the respective mean extent remained unchanged. In West Germany, the prevalence of AL ≥3 mm decreased for 35-44-year-olds and increased for 65-74-year-olds ($p<0.05$). In SHIP, mean PD remained on the same level for all age groups, whereas mean AL decreased, except for those aged <25 years (Figure 2). Similarly, in DMS for West German 35-44-year-olds, mean AL decreased, whereas for 65-74-year-olds, mean AL remained unchanged. In contrast, mean AL increased for both East German age groups.

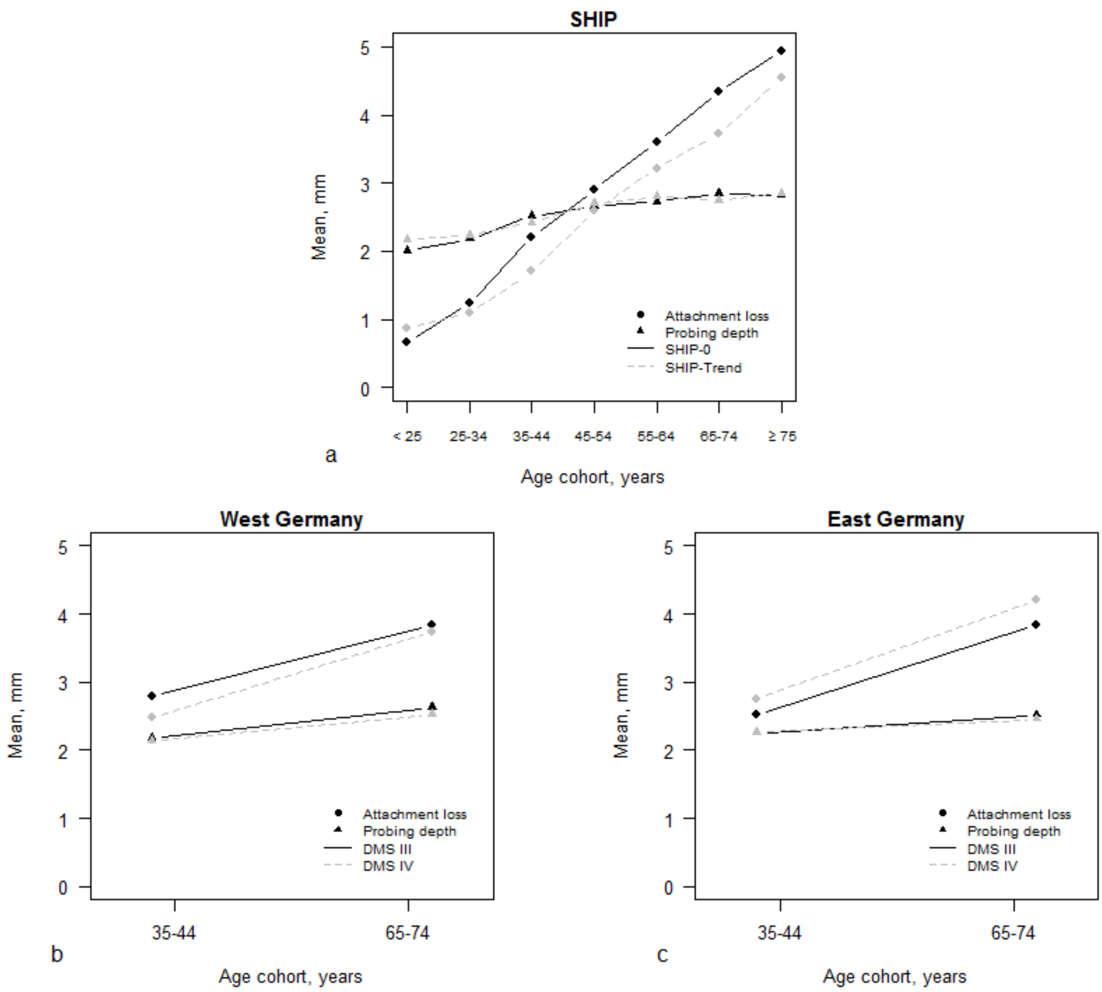

Figure 2. Changes in mean attachment loss and mean probing depth according to age in (a) the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV, separately reported for (b) West and (C) East Germany). Analyses were weighted. Source: Schützhold et al. 2015 [46].

5 Discussion

The evidence generated in this thesis can be summarized as follows:

1. The number of unreplaced teeth showed the strongest association with self-perceived oral health in adults and was the second variable to enter the model for seniors during the stepwise selection process.

2. Although the number of missing teeth decreased between 1997 and 2005 in the whole Republic, East Germany was not able to completely catch up with West Germany.

3. The periodontal status significantly improved in SHIP and in West German adults during the last decade.

In our study, the number of unreplaced teeth was most strongly associated with self-perceived oral health. It was the first variable to enter the model for adults and the second variable to enter the model for seniors. Strong associations between missing teeth and self-perceived oral health were also observed in other studies [12, 13]. These findings underline the importance of missing teeth for the self-perception of oral health. Possible reasons are the reduced chewing efficiency, the unfavorable appearance, and the necessity for prosthetic restorations. Generally, we proceeded on the assumption that the awareness of adverse oral conditions translates into poor self-perceived oral health. However, answers to the open-ended question about factors that influence the self-perception of health revealed that most participants reported that they compare their health with that of reference groups, for example with 'people their age' or 'friends/acquaintances' [17]. Social factors, such as culture, class, and race, also influence the extent of translation of adverse clinical conditions into poor self-perceived oral health [47].

Tooth loss mainly reflects past oral disease experiences and the access to oral care during people`s lives. In our study, East Germans had consistently more missing teeth than West Germans in each survey year. The almost parallel running curves of missing teeth indicate that even East German participants of DMS IV, having lived 20-30 years in the German Democratic Republic (GDR) and 15 years in the re-united Federal Republic of Germany, were not able to catch up with their Western counterparts. The explanation might be found in the completely different health-care systems. Before reunification, almost all East German dentists were salaried employees in state-owned clinics and availability of material was often poor [48]. In constrast to the tooth-maintaining attitudes of West German dentists, East German dentists pursued attitudes toward tooth extractions. These concepts changed after reunification, as, by the end of 1992, 88% of all East German dentists moved from salaried employment into private practices [48]. The differences in the reasons for extractions between East and West Germany evened out just in the last 15 years [49]. Possibly, a complete convergence between East and West Germany might only be achieved for birth cohorts born after reunification.

We observed a decrease of the number of missing teeth between 1997 and 2005 in Germany. A declining trend of tooth loss over the last decades has also been observed in other studies [27, 28, 30, 50]. Moreover, the authors of a review on edentulism stated that the prevalence of edentulism will drop by up to 50-60% over the next 20 years in Finland, Sweden and the UK [51]. The improved tooth retention might be explained by comprehensive caries prevention campaigns, especially by the increased utilization of fluoridated toothpastes in the last decades and by the resulting caries decline [26]. Caries is one of the two main reasons for tooth extractions, the other main factor is periodontitis [49]. In our study, we observed an improvement of the periodontal status in SHIP and in West German adults during the last decade. A recently published review article supports the assumption that periodontal disease prevalence is declining, though to varying degrees [52]. Based on these findings, it can be expected that the improvement of periodontal status might translate into a even higher tooth retention in the future.

Besides caries and periodontitis as the two main reasons for tooth extractions, there are other factors that determine the fate of a tooth, for example dental traumas, orthodontic reasons or prosthetic treatments [49]. Additionally, social determinants like race and socioeconomic status can also have strong impacts on tooth loss incidence [53]. Given the same disease extent and severity, African Americans and persons with lower socioeconomic status were more likely to receive a dental extraction once they enter the dental care system than non-Hispanic whites. Additionally, they were less likely to report that dentists had discussed alternative treatments with them [53]. According to Preshaw et al. [54], 'the patients` decisions are likely to be influenced by variables such as the strategic location of the tooth, the importance they place on retaining teeth, their ability (and willingness) to pay for the necessary care that is required of a tooth can be saved, their willingness to undergo treatment, and the availability of specialist cares to resolve complex issues'. Another important aspect worth mentioning is the subjectivity of the dentist's clinical decision making. Even when differences in patients were controlled, the variations in dentists` decisions were omnipresent [55].

Some strengths and limitations of the studies deserve consideration. A strength of our analyses is the examination of trends over a time span of 16 years (1989-2005) in DMS, combined with the concurrent consideration of socioeconomic variables. In addition, the simultaneous analyses of changes in periodontal status in two German population-based studies (SHIP and DMS) represents another unique strength of our analyses. One limitation might be the potential selection bias due to the high percentage of nonresponders in DMS and SHIP-Trend. Nonresponse analyses in DMS III and IV, which were based on short questionnaires with basic questions sent to nonresponders, revealed that study participants were more often women and visited the dentist more frequently than nonresponders [35, 56]. Conversely, in seniors, study participants were more often men. Therefore, periodontal and carious prevalences might have been affected differentially. However, as there were only minor differences between responders and nonresponders, the consequences of selection bias might be negligible. As a consequence, disease prevalences were potentially slightly underestimated. Another limitation concerns the equalization of the recording protocols of DMS III and IV in the course of the trend analyses of periodontal prevalences, because, for that reason, the analyses in DMS were restricted to two sites at six teeth, which led to only a small number of sites entering the analyses. The medians with percentiles (25%; 75%) for the number of sites entering the analyses in DMS III were for adults: 10 (8; 12) and for seniors: 6 (4; 8). In DMS IV, the respective numbers were 12 (10; 12) for adults and 8 (4; 10) for seniors. As opposed to this, analyses in SHIP were more robst because the recording protocols were identical and did not necessitate any equalization. Another strength of SHIP is the wide age range (20-84 years). However, the SHIP studies are limited by their regionality and are therefore not representative for the whole of Germany. Moreover, different periodontal probes were used, which 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 [57].

In summary, we observed strong associations between the number of unreplaced teeth and self-perceived oral health. Overall, the number of unreplaced teeth was the most important factor in multivariate modeling. The awareness of relative contributions of clinical variables to self-perceived oral health is important for obtaining a clearer understanding of patients` subjective and objective self-perceptions of oral health. Between 1997 and 2005, the number of missing teeth considerably decreased in DMS but East Germans had consistently more missing teeth than West Germans. Further, during the last decade, the periodontal status improved in SHIP and in West German adults, which might translate into a even higher tooth retention in the future. The rapidly changing dental and oral health during the last decades necessitates regular new data to keep up with ongoing changes in the dental community [50]. For that reason the recently completed fifth German Oral Health Study (DMS V) [58] is of great interest to researchers as it provides valuable data for comparisons with DMS IV. It remains to be seen how fast the declining trends of tooth loss will develop in the future.

6 Summary

The Institute of German Dentists [Institut der Deutschen Zahnärzte (IDZ)] conducted four national cross-sectional surveys of oral health in the German resident population [German Oral Health Studies, 'Deutsche Mundgesundheitsstudien', (DMS)]: in 1989 (DMS I, only West Germany), 1992 (DMS II, only East Germany), 1997 (DMS III), and 2005 (DMS IV). In this study, the first two surveys (1989/92) were merged to achieve comparability with the last two studies. The Studies of Health in Pomerania (SHIP) are two independent regional cross-sectional population-based studies conducted during 1997-2001 (SHIP-0) and 2008-2012 (SHIP-Trend) in northeast Germany.

In this thesis, we addressed three main questions: First, we aimed to explore the relative contributions of clinical oral health variables assessing caries, periodontal status, and prosthetic status to self-perceived oral health by means of an age-specific approach in DMS IV. Second, we aimed to assess the changes of dental health in West and East Germany between 1989 and 2005 in DMS I-IV. Third, we aimed to evaluate the changes of periodontal status and number of teeth within the last decade based on data from the DMS and the SHIP studies.

To explore the associations of self-perceived oral health with clinical oral health variables, we developed separate multinomial logistic regression models for adults and seniors in DMS IV by using stepwise methods. To assess the changes of dental health in West and East Germany between 1989 and 2005, we applied regression models and assessed associations between region, survey year, their interactions and variables assessing dental disease status (number of missing, filled, decayed and sound teeth, the DMFT-index and the probability of having ≤20 teeth), adjusting for potential risk factors for caries. To assess changes of periodontal status in Germany, prevalences, percentages and numbers of teeth affected were defined.

In summary, the number of unreplaced teeth showed the strongest association with self-perceived oral health in adults and was the second variable to enter the model for seniors during the stepwise selection process. Between 1997 and 2005, the number of missing teeth considerably decreased in DMS but East Germans had consistently more missing teeth than West Germans in each survey year. Further, during the last decade, the periodontal status significantly improved in SHIP and in West German adults, which might translate into a even higher tooth retention in the future.

7 Zusammenfassung

Das Institut der Deutschen Zahnärzte (IDZ) führte vier nationale Querschnittstudien über die Mundgesundheit der deutschen Bevölkerung (Deutsche Mundgesundheitsstudien, DMS) in 1989 (DMS I, nur Westdeutschland), 1992 (DMS II, nur Ostdeutschland), 1997 (DMS III) und 2005 (DMS IV) durch. Um die Vergleichbarkeit mit den letzten beiden Studien zu gewährleisten, wurden die ersten beiden Studien (1989/92) zusammengefügt. Die „Studies of Health in Pomerania“ (SHIP) sind zwei unabhängige, regionale, populationsbasierte Querschnittstudien, die zwischen 1997 und 2001 (SHIP-0) und zwischen 2008 und 2012 (SHIP-Trend) in Nordostdeutschland durchgeführt wurden.

In dieser Doktorarbeit wurden im Wesentlichen drei Fragestellungen verfolgt: Das erste Ziel stellte die Untersuchung der Einflüsse klinischer Variablen (Karies, parodontaler und prothetischer Status) auf die orale Selbstwahrnehmung mithilfe eines altersspezifischen Ansatzes in der DMS IV dar. Das zweite Ziel war die Einschätzung der Veränderungen der dentalen Gesundheit sowohl in West- als auch in Ostdeutschland zwischen 1989 und 2005 anhand der DMS I-IV. Unser drittes Ziel bestand in der Bewertung der Veränderungen der parodontalen Gesundheit und der Zahnzahl innerhalb des letzten Jahrzehnts, basierend auf den DMS und den SHIP-Studien.

Für die Untersuchung der Assoziationen zwischen klinischen Mundgesundheitsvariablen und oraler Selbstwahrnehmung wurden, für Erwachsene und Senioren getrennt, multinomiale logistische Regressionen mit schrittweiser Vorwärts- und Rückwärts-Technik durchgeführt. Für die Einschätzung der Veränderungen der dentalen Gesundheit in West- und Ostdeutschland zwischen 1989 und 2005 verwendeten wir Regressionsmodelle (mit gleichzeitiger Adjustierung für mögliche Risikofaktoren für Karies) und untersuchten die Assoziationen zwischen der Region, dem Erhebungsjahr, ihren Interaktionen und den Mundgesundheitsvariablen (Anzahl der fehlenden, der kariösen und der naturgesunden Zähne, DMFT-Index und die Wahrscheinlichkeit, $\leq$20 Zähne zu haben). Für die Untersuchung der Veränderungen des Parodontalstatus in Deutschland wurden Prävalenzen, relative Ausmaße und absolute Zahlen der betroffenen Zähne bestimmt.

Zusammengefasst konnten wir zeigen, dass die Zahl der fehlenden, nicht ersetzten Zähne die stärkste Assoziation mit der oralen Selbstwahrnehmung bei den Erwachsenen aufwies. Die Zahl der fehlenden, nicht ersetzten Zähne stellte zudem die zweite Variable dar, die während der schrittweisen Regression in das Modell der Senioren aufgenommen wurde. Zwischen

1997 und 2005 verringerte sich die Zahl der fehlenden Zähne der Probanden in den DMS deutlich, allerdings wiesen die Ostdeutschen durchgängig zu allen Erhebungszeitpunkten eine höhere Anzahl fehlender Zähne auf als die Westdeutschen. Überdies wurde eine signifikante Verbesserung des Parodontalstatus in SHIP und bei den westdeutschen Erwachsenen in DMS innerhalb des letzten Jahrzehnts beobachtet, was zu einem noch höheren Zahnerhalt in der Zukunft führen könnte.

8 References

1. WHO. *Oral Health*. 2014 [cited 2014 25.10.]; Available from: http://www.who.int/topics/oral_health/en/.
2. Gomes, A.S., C. Abegg, and J.M. Fachel, *Relationship between oral clinical conditions and daily performances.* Braz Oral Res, 2009. **23**(1): p. 76-81.
3. Dahl, K.E., N.J. Wang, and K. Ohrn, *Does oral health matter in people's daily life? Oral health-related quality of life in adults 35-47 years of age in Norway.* Int J Dent Hyg, 2012. **10**(1): p. 15-21.
4. Van der Geld, P., et al., *Smile attractiveness. Self-perception and influence on personality.* Angle Orthod, 2007. **77**(5): p. 759-65.
5. Eli, I., Y. Bar-Tal, and I. Kostovetzki, *At first glance: social meanings of dental appearance.* J Public Health Dent, 2001. **61**(3): p. 150-4.
6. Mack, F., et al., *The impact of tooth loss on general health related to quality of life among elderly Pomeranians: results from the study of health in Pomerania (SHIP-O).* Int J Prosthodont, 2005. **18**(5): p. 414-9.
7. Nickenig, H.J., et al., *Oral health-related quality of life in partially edentulous patients: assessments before and after implant therapy.* J Craniomaxillofac Surg, 2008. **36**(8): p. 477-80.
8. Tallents, R.H., et al., *Prevalence of missing posterior teeth and intraarticular temporomandibular disorders.* J Prosthet Dent, 2002. **87**(1): p. 45-50.
9. Thomson, W.M., et al., *Construct validity of Locker's global oral health item.* J Dent Res, 2012. **91**(11): p. 1038-42.
10. Afonso-Souza, G., et al., *Association between routine visits for dental checkup and self-perceived oral health in an adult population in Rio de Janeiro: the Pro-Saude Study.* Community Dent Oral Epidemiol, 2007. **35**(5): p. 393-400.
11. Gilbert, G.H., et al., *The paradox of dental need in a population-based study of dentate adults.* Med Care, 2003. **41**(1): p. 119-34.
12. Locker, D., E.W. Mscn, and A. Jokovic, *What do older adults' global self-ratings of oral health measure?* J Public Health Dent, 2005. **65**(3): p. 146-52.
13. Wu, B., et al., *Differences in self-reported oral health among community-dwelling black, Hispanic, and white elders.* J Aging Health, 2011. **23**(2): p. 267-88.
14. Ekanayke, L. and I. Perera, *Factors associated with perceived oral health status in older individuals.* Int Dent J, 2005. **55**(1): p. 31-7.
15. Matthias, R.E., et al., *Factors affecting self-ratings of oral health.* J Public Health Dent, 1995. **55**(4): p. 197-204.
16. Reisine, S.T. and H.L. Bailit, *Clinical oral health status and adult perceptions of oral health.* Soc Sci Med Med Psychol Med Sociol, 1980. **14A**(6): p. 597-605.
17. Kaplan, G. and O. Baron-Epel, *What lies behind the subjective evaluation of health status?* Soc Sci Med, 2003. **56**(8): p. 1669-76.
18. Nolte, E. and M. McKee, *Changing health inequalities in east and west Germany since unification.* Soc Sci Med, 2004. **58**(1): p. 119-36.
19. Bundesagentur für Arbeit. *Registered Unemployed, Unemployment rate by area* 2011 01.04.2011 [cited 2011 05.12.]; Available from: https://www.destatis.de/EN/FactsFigures/Indicators/LongTermSeries/LabourMarket/lrarb003.html.
20. Arnljot, H.A., et al., *Oral health care systems. An international collaborative study.* 1985, Geneva: World Health Organization.
21. Konig, J., B. Holtfreter, and T. Kocher, *Periodontal health in Europe: future trends based on treatment needs and the provision of periodontal services--position paper 1.* Eur J Dent Educ, 2010. **14 Suppl 1**: p. 4-24.

22. Kassebaum, N.J., et al., *Global Burden of Severe Tooth Loss: A Systematic Review and Meta-analysis.* J Dent Res, 2014. **93**(7 suppl): p. 20S-28S.
23. Holst, D. and A.A. Schuller, *Equality in adults' oral health in Norway. Cohort and cross-sectional results over 33 years.* Community Dent Oral Epidemiol, 2011. **39**(6): p. 488-97.
24. Skudutyte-Rysstad, R. and H.M. Eriksen, *Changes in caries experience among 35-year-old Oslo citizens, 1973-2003.* Acta Odontol Scand, 2007. **65**(2): p. 72-7.
25. Holtfreter, B., et al., *Epidemiology of periodontal diseases in the Study of Health in Pomerania.* J Clin Periodontol, 2009. **36**(2): p. 114-23.
26. Marthaler, T.M., *Changes in dental caries 1953-2003.* Caries Res, 2004. **38**(3): p. 173-81.
27. Kalsbeek, H., et al., *Trends in periodontal status and oral hygiene habits in Dutch adults between 1983 and 1995.* Community Dent Oral Epidemiol, 2000. **28**(2): p. 112-8.
28. Dye, B.A., et al., *Trends in oral health status: United States, 1988-1994 and 1999-2004.* Vital Health Stat 11, 2007(248): p. 1-92.
29. Rothlisberger, B., et al., *Periodontal conditions in Swiss army recruits: a comparative study between the years 1985, 1996 and 2006.* J Clin Periodontol, 2007. **34**(10): p. 860-6.
30. Skudutyte-Rysstad, R., H.M. Eriksen, and B.F. Hansen, *Trends in periodontal health among 35-year-olds in Oslo, 1973-2003.* J Clin Periodontol, 2007. **34**(10): p. 867-72.
31. Hugoson, A., B. Sjodin, and O. Norderyd, *Trends over 30 years, 1973-2003, in the prevalence and severity of periodontal disease.* J Clin Periodontol, 2008. **35**(5): p. 405-14.
32. Haisman-Welsh, R.J. and W.M. Thomson, *Changes in periodontitis prevalence over two decades in New Zealand: evidence from the 1988 and 2009 national surveys.* N Z Dent J, 2012. **108**(4): p. 134-8.
33. Gjermo, P.E., *Impact of periodontal preventive programmes on the data from epidemiologic studies.* J Clin Periodontol, 2005. **32 Suppl 6**: p. 294-300.
34. Baelum, V. and R. Lopez, *Periodontal disease epidemiology - learned and unlearned?* Periodontol 2000, 2013. **62**(1): p. 37-58.
35. Micheelis, W. and U. Schiffner, *Vierte Deutsche Mundgesundheitsstudie (DMS IV)*, ed. Institut der Deutschen Zahnärzte (IDZ). 2006, Köln: Deutscher Zahnärzte Verlag
36. Baelum, V., et al., *Validity of CPITN's assumptions of hierarchical occurrence of periodontal conditions in a Kenyan population aged 15-65 years.* Community Dent Oral Epidemiol, 1993. **21**(6): p. 347-53.
37. Gjermo, P., et al., *Periodontal diseases in Central and South America.* Periodontol 2000, 2002. **29**: p. 70-8.
38. Savage, A., et al., *A systematic review of definitions of periodontitis and methods that have been used to identify this disease.* J Clin Periodontol, 2009. **36**(6): p. 458-67.
39. Micheelis, W. and J. Bauch, *Mundgesundheitszustand und -verhalten in Ostdeutschland*, ed. Institut der Deutschen Zahnärzte (IDZ). 1993, Köln: Deutscher Ärzte-Verlag.
40. Hosmer, D.W., Jr., S. Lemeshow, and R.X. Sturdivant, *Applied Logistic Regression*, Wiley, Editor. 2013, John Wiley & Sons, Inc.: Hoboken, New Jersey. p. 89-226.
41. StataCorp, *Stata Statistical Software: Release 11*. 2009, StataCorp LP: College Station, TX.
42. R Development Core Team, *R: A language and environment for statistical computing*. 2010, R Foundation for Statistical Computing: Vienna, Austria.
43. R Core Team, *R: A Language and Environment for Statistical Computing*. 2013, R Foundation for Statistical Computing: Vienna, Austria.
44. Schutzhold, S., et al., *Clinical factors and self-perceived oral health.* Eur J Oral Sci, 2014. **122**(2): p. 134-41.
45. Schutzhold, S., et al., *Trends in dental health of 35- to 44-year-olds in West and East Germany after reunification.* J Public Health Dent, 2013. **73**(1): p. 65-73.
46. Schutzhold, S., et al., *Changes in prevalence of periodontitis in two German population-based studies.* J Clin Periodontol, 2015. **42**(2): p. 121-30.
47. Gilbert, L., *Social factors and self-assessed oral health in South Africa.* Community Dent Oral Epidemiol, 1994. **22**(1): p. 47-51.

48. Widstrom, E., et al., *Oral healthcare in transition in Eastern Europe.* Br Dent J, 2001. **190**(11): p. 580-4.
49. Glockmann, E., et al., *"Ursachen des Zahnverlustes in Deutschland"- Dokumentation einer bundesweiten Erhebung (2007) ["Reasons for tooth loss in Germany"- Documentation of a nationwide survey (2007)]*, in *IDZ-Information* I.o.G.D. (IDZ), Editor. 2011: Köln.
50. Muller, F., M. Naharro, and G.E. Carlsson, *What are the prevalence and incidence of tooth loss in the adult and elderly population in Europe?* Clin Oral Implants Res, 2007. **18 Suppl 3**: p. 2-14.
51. Mojon, P., J.M. Thomason, and A.W. Walls, *The impact of falling rates of edentulism.* Int J Prosthodont, 2004. **17**(4): p. 434-40.
52. Holtfreter, B., S. Schützhold, and T. Kocher, *Is Periodontitis Prevalence Declining? A Review of the Current Literature.* Current Oral Health Reports, 2014. **1**(4): p. 251-261.
53. Gilbert, G.H., R.P. Duncan, and B.J. Shelton, *Social determinants of tooth loss.* Health Serv Res, 2003. **38**(6 Pt 2): p. 1843-62.
54. Preshaw, P.M., et al., *Association of removable partial denture use with oral and systemic health.* J Dent, 2011. **39**(11): p. 711-9.
55. Bader, J.D. and D.A. Shugars, *Variation in dentists' clinical decisions.* J Public Health Dent, 1995. **55**(3): p. 181-8.
56. Micheelis, W. and E. Reich, *Dritte Deutsche Mundgesundheitsstudie (DMS III)*, ed. Institut der Deutschen Zahnärzte (IDZ). 1999, Köln: Deutscher Ärzte-Verlag.
57. Holtfreter, B., et al., *Effects of different manual periodontal probes on periodontal measurements.* J Clin Periodontol, 2012. **39**(11): p. 1032-41.
58. Jordan, R.A., et al., *The Fifth German Oral Health Study (Funfte Deutsche Mundgesundheitsstudie, DMS V) - rationale, design, and methods.* BMC Oral Health, 2014. **14**(1): p. 161.

Appendix

Verzeichnis wissenschaftlicher Arbeiten von Svenja Schützhold

Publikationen

Schützhold S, Kocher T, Biffar R, Hoffmann T, Schmidt CO, Micheelis W, Jordan R, Holtfreter B. Changes in prevalence of periodontitis in two German population-based studies. Journal of Clinical Periodontology. 2015. 42(2): 121-130

Holtfreter B, Schützhold S, Kocher T. Is periodontitis prevalence declining? A review of the current literature. Current Oral Health Reports. 2014. 1(4):251-261

Schützhold S, Holtfreter B, Schiffner U, Hoffmann T, Kocher T, Micheelis W. Clinical factors and self-perceived oral health. European Journal of Oral Sciences. 2014. 122(2): 134-41.

Graetz C, Schwendicke F, Kahl M, Dörfer C, Sälzer S, Springer C, Schützhold S, Kocher T, König J, Rühling A. Prosthetic rehabilitation of patients with history of moderate to severe periodontitis: a long-term evaluation. Journal of Clinical Periodontology. 2013. 40(8):799-806.

Schützhold S, Holtfreter B, Hoffmann T, Kocher T, Micheelis W. Trends in dental health of 35-44-year-olds in West and East Germany after reunification. Journal of Public Health Dentistry. 2013. 73(1):65-73.

Konferenzbeiträge

Mense M, Schützhold S, Holtfreter B, Kocher T. Verlauf klinischer Parameter und Zahnverlust während der parodontalen Erhaltungstherapie (Poster). Jahrestagung der Deutschen Gesellschaft für Parodontologie (DGParo e.V.). 2014. Sep 19. Münster.

Schützhold S, Kocher T, Biffar R, Hoffmann T, Micheelis W, Jordan R, Holtfreter B. Trends in periodontal disease in two German population-based studies (Vortrag). IADR General Session & Exhibition and IADR Africa/Middle East Regional Meeting; 2014 Jun26, Kapstadt, Südafrika.

Schützhold S, Mense M, Holtfreter B, Kocher T. Factors associated with tooth loss in supportive periodontal therapy (Poster). Jahrestagung der Deutschen Gesellschaft für Parodontologie (DGParo e.V.). 2013. Sep 20. Erfurt.

Schützhold S, Holtfreter B, Hoffmann T, Kocher T, Micheelis W. Trends in oral health in West and East Germany after reunification (Poster). EuroPerio 7. 2012 Jun 06. Wien. In: Journal of Clinical Periodontology. 39 (Supplement s13) 1-429.

Kahl M, Schützhold S, Springer C, El-Sayed KM Fawzy, Rühling A, Kocher T, Dörfer C.E., Graetz C. Influence of the variable age for long-term tooth retention after 15 years of periodontal supportive therapy (SPT) (Poster). EuroPerio 7. 2012 Jun 06. Wien. In: Journal of Clinical Periodontology. 39 (Supplement s13) 1-429 und im: International Poster Journal (IPJ) 2013, Ausgabe 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, 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

Danksagung

Allen voran möchte ich Herrn Prof. Thomas Kocher für die freundliche Überlassung des Themas danken, darüber hinaus für die intensive Betreuung meiner Doktorarbeit, für die stetige Unterstützung und für das entgegengebrachte Vertrauen. Außerdem möchte ich mich für die zahlreichen Möglichkeiten, Kongresse und Tagungen zu besuchen, bedanken.

Einen ganz besonderen Dank möchte ich Dr. Birte Holtfreter aussprechen. Birte, danke für deine unerschöpfliche Geduld und für dein immer offenes Ohr! Ebenso möchte ich meiner Bürokollegin Christiane für die angenehme Arbeitsatmosphäre und für die vielen schönen Momente in unserem Büro danken!

Ich danke Dr. Christian Schwahn für die immer bereitwillige Bereitstellung seiner Literatur, für die anregenden Gespräche und für die kritischen Denkanstöße.

Ich danke dem Institut der Deutschen Zahnärzte (IDZ) für das Forschungsstipendium, das es mir ermöglichte, diese Doktorarbeit zu schreiben. Ganz herzlich danke ich auch den Mitwirkenden und Teilnehmern der Study of Health in Pomerania (SHIP) und der Deutschen Mundgesundheitsstudien (DMS), die dadurch das Fundament für meine Doktorarbeit schufen.

Ich danke von Herzen meinen Eltern, die mir das Studium, das die Grundlage für diese Promotion darstellte, ermöglicht haben. Ihnen und auch meinen Freunden danke ich für die zu jeder Tageszeit erfolgten Aufmunterungen.

Meinem Freund Thomas danke ich für sein unglaubliches Maß an Rückhalt. Ohne seine liebevolle Unterstützung und ohne seine unendlich großen Motivationshilfen besonders in der Endphase der Dissertation hätte sich die Durchführung dieser Arbeit weitaus schwieriger gestaltet.

Anlage der Originalarbeiten zur Dissertationsschrift

1. Schützhold, S., et al. (2014). "Clinical factors and self-perceived oral health." Eur J Oral Sci **122** (2): 134-41
2. Schützhold, S., et al. (2013). "Trends in dental health of 35- to 44-year-olds in West and East Germany after reunification." J Public Health Dent **73**(1): 65-73
3. Schützhold, S., et al (2015). "Changes in prevalence of periodontitis in two German population-based studies." J Clin Periodontol **42**(2): 121-30

European Journal of
Oral Sciences

Eur J Oral Sci 2014; 122: 134–141
DOI: 10.1111/eos.12117
Printed in Singapore. All rights reserved

European Journal of
Oral Sciences

Clinical factors and self-perceived oral health

Svenja Schützhold[1], Birte Holtfreter[1], Ulrich Schiffner[2], Thomas Hoffmann[3], Thomas Kocher[1], Wolfgang Micheelis[4]

[1]Unit of Periodontology, Department of Restorative Dentistry, Periodontology and Endodontology, University Medicine, Ernst-Moritz-Arndt-University Greifswald, Greifswald, Germany; [2]Department of Restorative and Preventive Dentistry, School of Dental and Oral Medicine, Hamburg, Germany; [3]Department of Periodontology, Medical Faculty Carl Gustav Carus, Dresden, Germany; [4]Institute of German Dentists, Köln, Germany

Schützhold S, Holtfreter B, Schiffner U, Hoffmann T, Kocher T, Micheelis W. Clinical factors and self-perceived oral health.
Eur J Oral Sci 2014; 122: 134–141. © 2014 Eur J Oral Sci

Self-perceived oral health is affected not only by awareness of the clinical status but also by comparisons with people of a similar age. This study explored the relative contributions of clinical variables assessing caries, periodontal status, and prosthetic status to self-perceived oral health within two age groups. Data of 891 adults (35–44 yr of age) and 760 older people (65–74 yr of age) from the Fourth German Oral Health Study (DMS IV, 2005) were evaluated. Self-perceived oral health was obtained from questionnaires. Numbers of decayed, filled, and unreplaced teeth, mean attachment loss, bleeding on probing (BOP), the presence of a fixed denture, and the presence of a removable denture were assessed. Multinomial logistic regression models were developed for both age groups, separately, using stepwise methods. For adults, unreplaced teeth, filled teeth, decayed teeth, the presence of a removable denture, and mean attachment loss were added to the final model. For older people, the presence of a removable denture, unreplaced teeth, decayed teeth, mean attachment loss, filled teeth, and BOP were included in the final model. Awareness of the relative contributions of clinical variables to self-perceived oral health is important for obtaining a clearer understanding of patients' subjective and objective self-perceptions of oral health.

Svenja Schützhold, Unit of Periodontology, Department of Restorative Dentistry, Periodontology and Endodontology, University Medicine, Ernst-Moritz-Arndt-University Greifswald, Rotgerberstr. 8, 17475 Greifswald, Germany

E-mail: svenja.schuetzhold@uni-greifswald.de

Key words: adult; caries; German oral health study; older people; self-perceived oral health

Accepted for publication December 2013

Recently, single-item questions of oral health have been increasingly included in dental surveys (1). As self-perceived oral health reflects patients' subjective and objective assessments of their oral health, it is highly associated with the patient's perception of treatment needs and thus with the demand for dental services. Those who regularly visit a dentist for routine dental check-ups are more likely to assess their oral health as good (2). Conversely, people who report poor oral health have a less marked dental care-seeking behavior (3).

In recent years, numerous studies have assessed self-perceived oral health by single-item questions, and a number of clinical factors were found to be associated with self-perceived oral health (1, 4–8). With respect to caries status, some studies reported that the numbers of missing and decayed teeth were proportional to the probability of rating oral health as poor (1, 8, 9). Conversely, larger numbers of filled teeth were associated with a higher probability of perceiving oral health as good (1, 9). Across the single-item responses, caries, tooth loss, and periodontitis experience showed mainly consistent gradients (8).

The understanding of periodontitis as a silent disease was questioned recently (10) when significant associations between periodontal disease severity and self-perceived oral health were found. Results consistent with this finding were also reported in other studies (1, 4). Although the sensitivity of single self-reported items in diagnosing periodontal disorders is low (11), combinations of demographic measures and self-report oral health questions perform well in predicting periodontitis (12).

Self-perceptions of general health depend on social and cultural backgrounds and are affected by prevailing social and medical ideologies (13). Thus, self-perception of health varies among social groups (13) and is partly based on comparisons with others, especially with people of a similar age (14). Different social backgrounds of age groups inherently influence people's understanding of 'normality' (15).

Only a few studies have identified the most predictive clinical factors for self-perceived oral health using an age-specific approach. Therefore, the aim of this study was to explore the relative contributions of clinical variables assessing caries, periodontal status, and prosthetic status to self-perceived oral health among participants 35–44 and 65–74 yr of age from representative samples of the German resident population.

Material and methods

Study design

The national cross-sectional Fourth German Oral Health Study ('Vierte Deutsche Mundgesundheitsstudie', DMS IV) was conducted by the Institute of German Dentists (IDZ) in 2005. Random cluster samples stratified by Federal State and by community category were drawn from 90 municipalities. Random samples were selected from the population registry of each of these municipalities. People from East Germany were oversampled. Informed consent was obtained from all participants. The participation rates for adults (35–44 yr of age) and for older people (65–74 yr of age) were 52.1% and 55.7%, respectively. The low response rates might be explained by the fact that examiners were present at each sample point for only 2 days. Therefore, it was difficult to arrange convenient appointments for study participants. Design, sampling, and non-response analyses have previously been described in detail (16–19).

Dependent variable

Self-perceived oral health was assessed by the following question: 'Thinking of your teeth, how would you rate their condition?' (with the response options: 'very good', 'good', 'satisfactory', 'not so good', or 'poor'). After evaluation of frequency distributions, the first two answers were combined into 'very good/good' and the last two answers were combined into 'not so good/poor'. Therefore, the dependent variable had three categories: very good/good, satisfactory, and not so good/poor (referred to subsequently as good, satisfactory, and poor).

Covariates

Sociodemographic and behavioral variables, including age, gender (female/male), region (West Germany/East Germany), school education (<10/10/>10 yr), smoking status (never/former/current), cohabiting (no/yes), and dental visit within the last 12 months (yes/no), were obtained from questionnaires. In addition, self-perceived general health was assessed by the question: 'How would you rate your general health status?' with the possible answers (in this order): 'very good', 'good', 'satisfactory', 'not so good', or 'poor'. The multimorbidity score was defined as the sum of all positive answers to questions assessing self-reported general systemic diseases, namely hypertension, circulatory disorders of the heart, myocardial infarction, cardiac insufficiency, stroke, varicose veins, bronchial asthma, gastritis, gastric or duodenal ulcer, diabetes mellitus with or without insulin treatment, cancer, arthrosis, inflammatory joint or spine disease, osteoporosis, mental illness, or the presence of other diseases not mentioned in the questionnaire. The multimorbidity score was considered as a continuous variable and ranged from 0 to 17. A participant was given a multimorbidity score of 0 if none of the above questions was answered with 'yes'. Conversely, the highest score, of 17, was achieved if all the questions were answered with 'yes'. All interviews were conducted as verbal and personal face-to-face interviews by specially trained interviewers.

Oral status

Decayed and filled teeth were assessed visually in a full-mouth examination (20). The number of missing teeth that had not been replaced with either a fixed/removable denture or by an implant were determined. These teeth are subsequently referred to as unreplaced teeth. Teeth were extracted because of caries and other reasons. Third molars were excluded from the analysis. Because the distribution of the number of decayed teeth was skewed, participants were classified into those with no decayed teeth versus those with at least one decayed tooth. Filled and unreplaced teeth were considered as continuous variables.

Periodontal status was assessed by measuring attachment loss and calculation of the papillary bleeding index (PBI) (21). Periodontal measurements were performed at 12 index teeth (17, 16, 11, 24, 26, 27, 47, 46, 44, 31, 36, and 37; two-digit notation according to the FDI World Dental federation), using a periodontal probe (PCP 11.5 WHO probe; M1W Dental, Büdingen, Germany). Attachment loss was measured at three sites per tooth (mesiobuccal, midbuccal, and distolingual). The PBI was assessed at two sites per tooth (buccal and lingual). To avoid collinearity problems, probing pocket depth was not considered.

Mean attachment loss was calculated and tertiles were determined because linearity assumptions in regression models were not met. Tertiles were specific for both age groups (adults: 1st tertile, −0.91 to 2.28; 2nd tertile, 2.29–2.97; and 3rd tertile, 2.99–8.81; and older people: 1st tertile, 1.08–3.50; 2nd tertile, 3.53–4.67; and 3rd tertile, 4.70–11.67). The PBI was dichotomized as present or absent bleeding at site level, and the percentage of sites with bleeding on probing (BOP) was determined. Bleeding on probing was considered as a continuous variable.

To evaluate the prosthetic status, participants were classified into those with no fixed denture versus those with at least one fixed denture and into those with no removable denture versus those with at least one removable denture.

Study participants

Of 925 adults originally included in the study, there was no information on self-perceived oral health for four, who were therefore excluded. Additionally, we excluded eight edentulous participants and three participants without periodontal measurements. Nineteen other participants had missing covariate data, leaving 891 adult participants for analyses. Of 1,040 older people originally included in the study, there was no information on self-perceived oral health for 29, who were therefore excluded. Moreover, we excluded 215 edentulous participants and four participants without periodontal measurements. Thirty-two other participants had missing covariate data, leaving 760 older participants for analyses.

Statistical analyses

Chi-square tests and Kruskal–Wallis tests were applied to analyze differences in various variables among participants with good, satisfactory, and poor self-perceived oral health. Multinomial logistic regression was applied to assess associations of self-perceived oral health with clinical oral health variables. Multinomial logistic regression is an extension of the binary logistic regression for outcome variables with more than two categories. A separate binary logit is estimated for each pair of outcome categories (22). Good self-perceived oral health was chosen as the reference category.

Separate regression models were developed for each age group. Stepwise forward and backward regression analyses were performed considering all clinical oral health variables. To test for all categories of one categorical variable simultaneously, overall Wald tests were used. P for inclusion was 0.15 and P for exclusion was 0.20 (23). The analyses were weighted. For each step, areas under receiver-operating characteristic (ROC) curves (AUC) were determined. Because the dependent variable had three categories, the following AUCs (with 95% CI) were calculated: AUC separating good from satisfactory/poor, AUC separating satisfactory from good/poor, and AUC separating good/satisfactory from poor. To internally validate final models, bootstrap analyses with 200 replications were performed and optimism-corrected estimates of AUC values were calculated.

The results were considered statistically significant at $P \leq 0.05$. Statistical analyses were performed with STATA/SE 11.0 (24).

Results

The proportions of participants reporting poor oral health were 18.5% in adults and 16.1% in older people (Table 1). Sociodemographic and behavioral variables were not significantly associated with self-perceived oral health, except for dental visit within the last 12 months in older people ($P < 0.001$). In contrast, the distribution of self-perceived oral health differed significantly across categories of all clinical oral health variables in both age groups (Table 2).

Stepwise regression models

In adults, all clinical oral health variables, except for the presence of a fixed denture and BOP, were included in the final model after stepwise regression analysis (Table 3). The variables entered the model in the following order: unreplaced teeth, filled teeth, decayed teeth, the presence of a removable denture, and mean attachment loss. The AUC values quantifying the separation between good and satisfactory/poor for stepwise multinomial regression models increased from 0.61 (the first step of stepwise regression analysis) to 0.71 (the final model; Table 3). The AUC values quantifying the separation between satisfactory and good/poor increased from 0.55 to 0.60, and the AUC values quantifying the separation between good/satisfactory and poor increased from 0.60 to 0.70. After bootstrap analyses, values for optimism were 0.01, 0.02, and 0.02, respectively. Thus, optimism-corrected estimates of AUC values for the final model were 0.70, 0.58, and 0.68, respectively.

In older people, all clinical oral health variables were included in the final model, except for the presence of a fixed denture (Table 4). The variables entered the model in the following order: the presence of a removable denture, unreplaced teeth, decayed teeth, mean attachment loss, filled teeth, and BOP. The AUC values increased from 0.58 to 0.68 for the separation between good and satisfactory/poor and from 0.51 to 0.61 for the separation between satisfactory and good/poor (Table 4). The AUC values for the separation between good/satisfactory and poor increased from 0.62 to 0.72. After bootstrap analyses, values for optimism were 0.02, 0.03, and 0.02, respectively. Thus, optimism-corrected estimates of AUC values for the final model were 0.66, 0.58, and 0.70, respectively.

Sensitivity analyses in older people

After addition of the multimorbidity score to the final model (Table 5), similar coefficients for clinical oral

Table 1

Distribution of socio-economic and behavioral variables according to self-perceived oral health and age group

	Self-perceived oral health of adults (35–44 yr of age)					Self-perceived oral health of older people (65–74 yr of age)				
Variable	*n*	Good	Satisfactory	Poor	*P*	*n*	Good	Satisfactory	Poor	*P*
n	891	40.9	40.6	18.5		760	38.4	45.5	16.1	
Age	891	39.5 ± 2.7	39.8 ± 3.0	39.4 ± 2.7	0.29	760	68.8 ± 2.6	68.6 ± 2.7	68.8 ± 2.8	0.50
Gender										
Female	503	42.4	37.8	19.8		392	35.7	44.9	19.4	
Male	388	38.6	43.0	18.4	0.34	368	40.5	45.1	14.4	0.17
Region										
West Germany	591	39.7	40.0	20.3		508	37.4	44.5	18.1	
East Germany	300	44.3	42.2	13.5	0.055	252	40.2	47.1	12.7	0.18
School education										
<10 yr	208	37.9	39.9	22.2		494	35.8	48.1	16.1	
10 yr	391	38.7	42.5	18.8		110	38.1	42.1	19.8	
>10 yr	292	44.3	38.6	17.1	0.47	156	45.1	37.2	17.7	0.20
Smoking status										
Never	400	44.3	39.5	16.2		474	39.4	45.1	15.5	
Former	178	38.9	44.0	17.1		237	35.4	45.9	18.7	
Current	313	36.7	39.4	23.9	0.10	49	36.6	40.8	22.6	0.65
Cohabiting										
Non-cohabiting	171	37.5	43.8	18.7		158	38.3	41.1	20.6	
Cohabiting	720	41.2	39.6	19.2	0.64	602	37.9	46.1	16.0	0.37
Dental visit within last 12 months										
Yes	809	41.6	40.4	18.0		690	39.2	45.9	14.9	
No	82	30.7	40.5	28.8	0.06	70	26.6	37.6	35.8	<0.001

Data are presented as mean ± SD or as row percentages. Analyses were weighted.
n, number.

Table 2

Distribution of clinical oral health variables according to self-perceived oral health and age group

	Self-perceived oral health of adults (35–44 yr of age)					Self-perceived oral health of older people (65–74 yr of age)				
Variable	*n*	Good	Satisfactory	Poor	*P*	*n*	Good	Satisfactory	Poor	*P*
n	891	40.9	40.6	18.5		760	38.4	45.5	16.1	
Decayed teeth										
0	675	44.8	40.2	15.0		588	41.3	43.4	15.3	
>0	216	27.1	41.1	31.8	<0.001	172	26.6	50.7	22.7	0.002
Filled teeth	891	10.9 ± 4.9	12.4 ± 4.6	12.3 ± 4.9	<0.001	760	10.7 ± 5.3	10.6 ± 5.0	8.1 ± 4.9	<0.001
Unreplaced teeth	891	1.0 ± 1.5	1.6 ± 1.9	2.0 ± 2.3	<0.001	760	1.4 ± 1.8	1.9 ± 2.3	2.6 ± 3.9	0.002
Mean AL (mm)										
1st tertile	301	43.2	39.7	17.1		262	42.2	47.5	10.3	
2nd tertile	293	48.6	35.2	16.2		248	43.0	42.2	14.8	
3rd tertile	297	30.1	46.0	23.9	<0.001	250	27.7	45.3	27.0	<0.001
BOP (%)	891	53.3 ± 26.1	57.1 ± 25.9	64.5 ± 25.6	<0.001	760	65.4 ± 27.6	71.9 ± 26.5	77.2 ± 25.2	<0.001
Fixed denture										
No	611	43.6	39.5	16.9		357	35.6	41.8	22.6	
Yes	280	33.9	42.5	23.6	0.02	403	40.0	47.7	12.3	0.002
Removable denture										
No	852	41.5	40.5	18.0		383	45.2	44.5	10.3	
Yes	39	16.8	37.7	45.5	<0.001	377	30.3	45.6	24.1	<0.001

Data are presented as mean ± SD or as row percentages. Analyses were weighted.
AL, attachment loss; BOP, bleeding on probing; *n*, number.

Table 3

Outcome of stepwise multinomial regression analysis for adults (35–44 yr of age)

	Final multinomial model				Discriminatory power for stepwise built models		
	Satisfactory versus Good		Poor versus Good		AUC (95% CI) for the three classes		
Variable	RRR (95% CI)	*P*	RRR (95% CI)	*P*	Good	Satisfactory	Poor
Unreplaced teeth (cont.)	1.27 (1.14–1.40)	<0.001	1.42 (1.25–1.61)	<0.001	0.61 (0.58–0.65)	0.55 (0.51–0.59)	0.60 (0.55–0.65)
Filled teeth (cont.)	1.10 (1.06–1.14)	<0.001	1.12 (1.06–1.18)	<0.001	0.66 (0.62–0.70)	0.58 (0.54–0.62)	0.62 (0.57–0.67)
Decayed teeth							
0 (ref.)	1.00		1.00				
>0	1.68 (1.08–2.60)	0.02	3.45 (2.11–5.65)	<0.001	0.68 (0.64–0.72)	0.59 (0.55–0.63)	0.67 (0.62–0.72)
Removable denture							
No (ref.)	1.00		1.00				
Yes	2.71 (0.99–7.45)	0.053	8.46 (3.09–23.19)	<0.001	0.70 (0.66–0.73)	0.59 (0.55–0.64)	0.70 (0.65–0.74)
Mean AL (mm)							
1st tertile (ref.)	1.00		1.00				
2nd tertile	0.68 (0.46–1.00)	0.052	0.64 (0.37–1.10)	0.11			
3rd tertile	1.40 (0.92–2.13)	0.12	1.35 (0.80–2.28)	0.26	0.71 (0.67–0.75)	0.60 (0.56–0.65)	0.70 (0.65–0.75)

Analyses were weighted. The reference category for the dependent variable was 'Good'.
AL, attachment loss; AUC, area under the receiver–operating characteristics (ROC) curve for stepwise inclusion of predictive variables; cont., continuous; ref., reference; RRR, relative risk ratio.

health variables were observed. The multimorbidity score was significantly associated with self-perceived oral health ($P < 0.001$) when poor self-perceived oral health was compared with good self-perceived oral health. The corresponding AUC values increased by 0.01 for the separation between satisfactory and good/poor and by 0.02 for the separation between good/satisfactory and poor.

After addition of self-perceived general health to the final model (Table 6), similar coefficients for clinical oral health variables were observed. Self-perceived general health was significantly associated with self-perceived oral health in all categories ($P < 0.05$). For each separation, the respective AUC values increased by 0.06.

Discussion

This study explored the relative contributions of clinical characteristics (such as caries, periodontal status, and prosthetic status) to self-perceived oral health among adult (35–44 yr of age) and older (65–74 yr of age) participants in the DMS IV study. In multivariate modeling, the number of unreplaced teeth showed the strongest association with self-perceived oral health in adults,

Table 4

Outcome of stepwise multinomial regression analysis for older people (65–74 yr of age)

	Final multinomial model				Discriminatory power for stepwise built models		
	Satisfactory versus Good		Poor versus Good		AUCs (95% CI) for the three classes		
Variable	RRR (95% CI)	*P*	RRR (95% CI)	*P*	Good	Satisfactory	Poor
Removable denture							
No (ref.)	1.00		1.00				
Yes	2.18 (1.43–3.33)	<0.001	5.37 (3.07–9.38)	<0.001	0.58 (0.54–0.62)	0.51 (0.47–0.54)	0.62 (0.58–0.67)
Unreplaced teeth (cont.)	1.18 (1.07–1.29)	<0.001	1.33 (1.20–1.47)	<0.001	0.64 (0.60–0.68)	0.55 (0.50–0.59)	0.69 (0.64–0.74)
Decayed teeth							
0 (ref.)	1.00		1.00				
>0	1.76 (1.15–2.70)	0.01	2.07 (1.17–3.64)	0.01	0.66 (0.62–0.70)	0.57 (0.52–0.61)	0.69 (0.65–0.74)
Mean AL (mm)							
1st tertile (ref.)	1.00		1.00				
2nd tertile	0.81 (0.54–1.22)	0.31	1.18 (0.63–2.23)	0.61			
3rd tertile	1.22 (0.78–1.93)	0.38	2.24 (0.19–4.22)	0.01	0.66 (0.62–0.70)	0.59 (0.55–0.63)	0.71 (0.67–0.76)
Filled teeth (cont.)	1.04 (1.00–1.09)	0.03	1.00 (0.95–1.06)	0.98	0.67 (0.63–0.71)	0.60 (0.56–0.64)	0.72 (0.67–0.76)
BOP (%) (cont.)	1.01 (1.00–1.01)	0.03	1.01 (1.00–1.02)	0.06	0.68 (0.64–0.72)	0.61 (0.56–0.65)	0.72 (0.67–0.77)

Analyses were weighted. The reference category of the dependent variable was 'Good'.
AL, attachment loss; AUC, area under the receiver–operating characteristics (ROC) curve for stepwise inclusion of predictive variables; BOP, bleeding on probing; cont., continuous; ref., reference; RRR, relative risk ratio.

Table 5

Outcome of sensitivity analyses (including the multimorbidity score) after stepwise multinomial regression analysis for older people (65–74 yr of age; n = *758*[a]*)*

	Final multinomial model				Discriminatory power for stepwise built models		
	Satisfactory versus Good		Poor versus Good		AUCs (95% CI) for the three classes		
Variable	RRR (95% CI)	*P*	RRR (95% CI)	*P*	Good	Satisfactory	Poor
Removable denture							
No (ref.)	1.00		1.00				
Yes	2.18 (1.43–3.34)	<0.001	5.51 (3.12–9.70)	<0.001	0.58 (0.54–0.62)	0.51 (0.47–0.54)	0.62 (0.58–0.67)
Unreplaced teeth (cont.)	1.20 (1.09–1.31)	<0.001	1.35 (1.22–1.50)	<0.001	0.64 (0.60–0.68)	0.55 (0.50–0.59)	0.69 (0.64–0.74)
Decayed teeth							
0 (ref.)	1.00		1.00				
>0	1.76 (1.15–2.70)	0.01	2.11 (1.20–3.72)	0.01	0.66 (0.62–0.70)	0.57 (0.52–0.61)	0.69 (0.65–0.74)
Mean AL (mm)							
1st tertile (ref.)	1.00		1.00				
2nd tertile	0.81 (0.54–1.21)	0.30	1.16 (0.62–2.20)	0.64			
3rd tertile	1.27 (0.80–2.00)	0.31	2.50 (1.31–4.76)	0.01	0.66 (0.62–0.70)	0.59 (0.55–0.63)	0.71 (0.67–0.76)
Filled teeth (cont.)	1.05 (1.01–1.09)	0.02	1.01 (1.00–1.07)	0.68	0.67 (0.63–0.71)	0.60 (0.56–0.64)	0.72 (0.67–0.76)
BOP (%) (cont.)	1.01 (1.00–1.01)	0.03	1.01 (1.00–1.02)	0.06	0.68 (0.64–0.72)	0.61 (0.56–0.65)	0.72 (0.67–0.77)
Multimorbidity score (cont.)	1.05 (0.95–1.16)	0.37	1.27 (1.12–1.45)	<0.001	0.68 (0.64–0.72)	0.62 (0.58–0.66)	0.74 (0.69–0.79)

Analyses were weighted. The reference category of the dependent variable was 'Good'.
AL, attachment loss; AUC, area under the receiver–operating characteristics (ROC) curve for stepwise inclusion of predictive variables; BOP, bleeding on probing; cont., continuous; RRR, relative risk ratio; [a]two subjects were excluded in the sensitivity analyses because of missing values for the multimorbidity score and self-perceived general health.

whereas in older people the presence of at least one removable denture was the most important factor. Although periodontal variables were included in the final model in both age groups, they were not as strongly associated with self-perceived oral health as were variables assessing caries and prosthetic status. The AUC values showed an acceptable ability of classification (23), indicating an acceptable perception of clinical oral health variables by both adults and older people.

Some limitations deserve consideration. First, self-perceived oral health was assessed using a single-item question. Although multi-item scales are more consistent and stable (25), single-item questions have advantages over multi-item scales in that they are cost-effective and easily interpretable (25). Furthermore, a single-item question, similar to the one used in this study, was successfully validated in a recent study of 35- to 44-yr-old adults (8). Here, caries, tooth loss, and periodontitis experiences showed mostly consistent gradients across single-item responses. Second, analyses were restricted to dentates for whom periodontal measures were available. Consequently, the numbers of adults and older people were reduced by 3.7% and 26.9%, respectively. Especially in older people, the association

Table 6

Outcome of sensitivity analyses (including self-perceived general health) after stepwise multinomial regression analysis for older people (65–74 yr of age; n = *758*[a]*)*

	Final multinomial model				Discriminatory power for stepwise built models		
	Satisfactory versus Good		Poor versus Good		AUCs (95% CI) for the three classes		
Variable	RRR (95% CI)	*P*	RRR (95% CI)	*P*	Good	Satisfactory	Poor
Removable denture							
No (ref.)	1.00		1.00				
Yes	2.06 (1.33–3.20)	0.001	5.02 (2.79–9.04)	<0.001	0.58 (0.54–0.62)	0.51 (0.47–0.54)	0.62 (0.58–0.67)
Unreplaced teeth (cont.)	1.20 (1.09–1.32)	<0.001	1.34 (1.20–1.49)	<0.001	0.64 (0.60–0.68)	0.55 (0.50–0.59)	0.69 (0.64–0.74)
Decayed teeth							
0 (ref.)	1.00		1.00				
>0	1.76 (1.12–2.75)	0.01	1.95 (1.07–3.56)	0.03	0.66 (0.62–0.70)	0.57 (0.52–0.61)	0.69 (0.65–0.74)
Mean AL (mm)							
1st tertile (ref.)	1.00		1.00				
2nd tertile	0.69 (0.46–1.05)	0.09	0.97 (0.50–1.86)	0.92			
3rd tertile	1.22 (0.76–1.96)	0.41	2.57 (1.31–5.05)	0.01	0.66 (0.62–0.70)	0.59 (0.55–0.63)	0.71 (0.67–0.76)
Filled teeth (cont.)	1.05 (1.01–1.09)	0.01	1.01 (0.95–1.07)	0.71	0.67 (0.63–0.71)	0.60 (0.56–0.64)	0.72 (0.67–0.76)
BOP (%) (cont.)	1.01 (1.00–1.01)	0.03	1.01 (1.00–1.02)	0.07	0.68 (0.64–0.72)	0.61 (0.56–0.65)	0.72 (0.67–0.77)
Self-perceived general health							
Very good/good (ref.)	1.00		1.00				
Satisfactory	3.42 (2.35–5.00)	<0.001	4.04 (2.31–7.07)	<0.001			
Not so good/poor	2.20 (1.09–4.45)	0.03	13.13 (5.95–28.95)	<0.001	0.74 (0.70–0.78)	0.67 (0.63–0.71)	0.78 (0.74–0.83)

Analyses were weighted. The reference category of the dependent variable was 'Good'.
AL, attachment loss; AUC, area under the receiver–operating characteristics (ROC) curve for stepwise inclusion of predictive variables; BOP, bleeding on probing; cont., continuous; RRR, relative risk ratio; [a]two subjects were excluded in the sensitivity analyses because of missing values for the multimorbidity score and self-perceived general health.

between the presence of a removable denture and self-perceived oral health might have been underestimated. Third, the periodontal recording protocol required assessment of attachment loss only at three sites per tooth, at 12 index teeth. Compared with a full-mouth protocol, index teeth include a high percentage of molars and mandibular incisors, which are more often afflicted by periodontitis (26). Thus, mean attachment loss might have been slightly overestimated in the present study. The bias caused by assessing only three sites per tooth, instead of six sites, might be negligible. Fourth, we used mean attachment loss to assess periodontal disease experience. Although mean attachment loss estimates are robust against probe- or examiner-associated bias, their use might reduce much of the interindividual variation. Extent measures of attachment loss would not reduce much of the interindividual variation. However, because both estimates performed comparatively well regarding their discriminative power for the specific outcome, we decided to use mean attachment loss in this study. Finally, the high percentage of nonresponders might have led to selection bias. Short basic questionnaires sent to nonresponders revealed that adult nonresponders were more often men (54.7% vs. 50.6%) and visited the dentist for regular check-ups less frequently (64.9% vs. 76.1%). Conversely, in older people, nonresponders were more often women (57.9% vs. 53.8%). Thus, periodontal and carious prevalences might have been affected differentially. However, as there were only minor differences between responders and nonresponders, selection bias might be marginal.

We generally assume that awareness of adverse oral conditions implies poor self-perceived oral health. However, answers to an open-ended question about factors influencing the self-perception of health revealed that most participants reported comparing their health with that of reference groups, especially with that of their age peers (13). Social factors, such as culture, class, and race, also influence the extent of translation of adverse clinical conditions into poor self-perceived oral health (15).

Many participants were satisfied with their oral health; only 18.5% of adults and 16.1% of older people reported having poor oral health. Apparently, older people consider an impaired oral health status as being part of the ordinary aging process (27, 28). In our study, sensitivity analyses revealed that the multimorbidity score was significantly associated with self-perceived oral health in older people when poor self-perceived oral health was compared with good self-perceived oral health. Apparently, the presence of other medical diseases was also associated with self-perceived oral health in older people. The more medical diseases reported, the higher the likelihood that participants rated their oral health as poor.

Overall, the number of unreplaced teeth was the most important factor. It was the first variable to enter the model for adults and the second variable to enter the model for older people. Strong associations between missing teeth and self-perceived oral health were also observed in other studies (1, 9, 29). Possible reasons are the reduced chewing efficiency, the unfavorable appearance, and the necessity for prosthetic restorations.

Factors assessing caries status were highly predictive. In both age groups, the number of decayed teeth was the third variable to enter the model. This strong association is consistent with other studies (1, 9). In adults, both bivariate and multinomial analyses revealed that the probability of assessing oral health as poor increased proportionally to the number of filled teeth. In contrast, older people with a higher number of filled teeth tended to rate their oral health as good or satisfactory; however, this effect was severely diminished in multivariate regression. Discrepancies between these age groups might be explained by the fact that older people with removable dentures have fewer natural teeth, which, in turn, implies a low maximum number of possibly filled teeth. Additionally, filled teeth also encompassed crowned teeth, which are needed to attach removable dentures, and thus they were perceived as being necessary and inevitable. Other studies consistently reported that in older participants a higher number of filled teeth correlated with a higher probability of perceiving oral health as good (1, 9). These findings once more underline the age-dependent shift of perception.

Mean attachment loss was included in the final model in both age groups but it was not as strongly associated with self-perceived oral health as caries and prosthetic factors. The AUC values only slightly improved after the addition of mean attachment loss in both age groups. In the literature, periodontal disease is often considered as a silent disease (11, 30). In contrast, other studies found that periodontal inflammation (6) and mean attachment loss (1, 4) were significantly associated with self-perceived oral health. Moreover, models combining screening questions for periodontitis and risk factors performed well in predicting periodontitis (12, 31). All in all, periodontal problems might indeed be perceived by participants, but to a much lesser extent than caries and prosthetic factors.

In summary, the number of unreplaced teeth was most strongly associated with self-perceived oral health in adults, whereas for older people the presence of a removable denture was the most important factor. In both age groups, periodontal status was not as strongly associated with self-perceived oral health as were caries and prosthetic status, which indicates that periodontal disease severity does not contribute to self-perceived oral health in multivariate models. Awareness of the relative contributions of clinical variables to self-perceived oral health is important for gaining a clearer understanding of the patients' subjective and objective self-perceptions of oral health.

Acknowledgements – DMS IV was funded by the two Federal dental organizations, the Bundeszahnärztekammer/BZÄK and the Kassenzahnärztliche Bundesvereinigung/Cologne. 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.

Conflicts of interest – There are no conflicts of interest associated with this work.

References

1. Locker D, Wexler EW, Jokovic A. What do older adults' global self-ratings of oral health measure? *J Public Health Dent* 2005; **65**: 146–152.
2. Afonso-Souza G, Nadanovsky P, Chor D, Faerstein E, Werneck GL, Lopes CS. Association between routine visits for dental checkup and self-perceived oral health in an adult population in Rio de Janeiro: the Pro-Saude Study. *Commun Dent Oral Epidemiol* 2007; **35**: 393–400.
3. Gilbert GH, Shelton BJ, Chavers LS, Bradford EH Jr. The paradox of dental need in a population-based study of dentate adults. *Med Care* 2003; **41**: 119–134.
4. Gift HC, Atchison KA, Drury TF. Perceptions of the natural dentition in the context of multiple variables. *J Dent Res* 1998; **77**: 1529–1538.
5. Andrade FB, Lebrao ML, Santos JL, Duarte YA, Teixeira DS. Factors related to poor self-perceived oral health among community-dwelling elderly individuals in Sao Paulo, Brazil. *Cad Saude Publica* 2012; **28**: 1965–1975.
6. Northridge ME, Chakraborty B, Kunzel C, Metcalf S, Marshall S, Lamster IB. What contributes to self-rated oral health among community-dwelling older adults? Findings from the ElderSmile program. *J Public Health Dent* 2012; **72**: 235–245.
7. Pattussi MP, Peres KG, Boing AF, Peres MA, da Costa JS. Self-rated oral health and associated factors in Brazilian elders. *Commun Dent Oral Epidemiol* 2010; **38**: 348–359.
8. Thomson WM, Mejia GC, Broadbent JM, Poulton R. Construct validity of Locker's global oral health item. *J Dent Res* 2012; **91**: 1038–1042.
9. Wu B, Plassman BL, Liang J, Remle RC, Bai L, Crout RJ. Differences in self-reported oral health among community-dwelling black, Hispanic, and white elders. *J Aging Health* 2011; **23**: 267–288.
10. Cunha-Cruz J, Hujoel PP, Kressin NR. Oral health-related quality of life of periodontal patients. *J Periodontal Res* 2007; **42**: 169–176.
11. Dietrich T, Stosch U, Dietrich D, Schamberger D, Bernimoulin JP, Joshipura K. The accuracy of individual self-reported items to determine periodontal disease history. *Eur J Oral Sci* 2005; **113**: 135–140.
12. Eke PI, Dye BA, Wei L, Slade GD, Thornton-Evans GO, Beck JD, Taylor GW, Borgnakke WS, Page RC, Genco RJ. Self-reported measures for surveillance of periodontitis. *J Dent Res* 2013; **92**: 1041–1047.
13. Kaplan G, Baron-Epel O. What lies behind the subjective evaluation of health status? *Soc Sci Med* 2003; **56**: 1669–1676.
14. Krause NM, Jay GM. What do global self-rated health items measure? *Med Care* 1994; **32**: 930–942.
15. Gilbert L. Social factors and self-assessed oral health in South Africa. *Commun Dent Oral Epidemiol* 1994; **22**: 47–51.
16. Holtfreter B, Kocher T, Hoffmann T, Desvarieux M, Micheelis W. Prevalence of periodontal disease and treatment demands based on a German dental survey (DMS IV). *J Clin Periodontol* 2010; **37**: 211–219.
17. Schiffner U, Hoffmann T, Kerschbaum T, Micheelis W. Oral health in German children, adolescents, adults and senior citizens in 2005. *Community Dent Health* 2009; **26**: 18–22.
18. Geyer S, Schneller T, Micheelis W. Social gradients and cumulative effects of income and education on dental health in the fourth German oral health study. *Commun Dent Oral Epidemiol* 2010; **38**: 120–128.
19. Micheelis W, Schiffner U. *Vierte Deutsche Mundgesundheitsstudie (DMS IV)*. Köln: Deutscher Zahnärzte Verlag, 2006.
20. World Health Organization. *Oral health surveys. Basic methods*, 4th edn. Geneva: World Health Organization, 1997.
21. Saxer UP. Muhlemann HR [Motivation and education]. *SSO Schweiz Monatsschr Zahnheilkd* 1975; **85**: 905–919.
22. Long JS, Freese J. *Regression Models for Categorical Dependent Variables Using Stata*, , 2nd edn. College Station, Texas: Stata Press, 2006.
23. Hosmer Jr DW, Lemeshow S, Sturdivant RX. Applied Logistic Regression. In: Wiley, ed. *Hoboken*. New Jersey: John Wiley & Sons, 2013; 89–226.
24. StataCorp. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP, 2009.

25. Bowling A. Just one question: If one question works, why ask several? *J Epidemiol Community Health* 2005; **59**: 342–345.
26. Albandar JM, Brunelle JA, Kingman A. Destructive periodontal disease in adults 30 years of age and older in the United States, 1988-1994. *J Periodontol* 1999; **70**: 13–29.
27. MacEntee MI, Hole R, Stolar E. The significance of the mouth in old age. *Soc Sci Med* 1997; **45**: 1449–1458.
28. Slade GD, Sanders AE. The paradox of better subjective oral health in older age. *J Dent Res* 2011; **90**: 1279–1285.
29. Reisine ST, Bailit HL. Clinical oral health status and adult perceptions of oral health. *Soc Sci Med Med Psychol Med Sociol* 1980; **14A**: 597–605.
30. Gilbert AD, Nuttall NM. Self-reporting of periodontal health status. *Br Dent J* 1999; **186**: 241–244.
31. Slade GD. Interim analysis of validity of periodontitis screening questions in the Australian population. *J Periodontol* 2007; **78**: 1463–1470.

Journal of Public Health Dentistry . ISSN 0022-4006

Trends in dental health of 35- to 44-year-olds in West and East Germany after reunification

Svenja Schützhold, MSc[1]; Birte Holtfreter, PhD[1]; Thomas Hoffmann, PhD[2]; Thomas Kocher, PhD[1]; Wolfgang Micheelis, PhD[3]

1 Unit of Periodontology, University Medicine, Ernst-Moritz-Arndt University Greifswald, Greifswald, Germany
2 Department of Periodontology, Medical Faculty Carl Gustav Carus, Dresden, Germany
3 Institute of German Dentists, Köln, Germany

Keywords
national oral health studies; dental caries; adult; epidemiologic studies; cross-sectional survey.

Correspondence
Ms. Svenja Schützhold, Unit of Periodontology, University Medicine, Ernst-Moritz-Arndt University Greifswald, Rotgerberstr. 8, 17475 Greifswald, Germany. Tel.: +49-3834-867397; Fax: +49-3834-867171; e-mail: svenja.schuetzhold@uni-greifswald.de. Svenja Schützhold, Birte Holtfreter, and Thomas Kocher are with the Unit of Periodontology, University Medicine, Ernst-Moritz-Arndt University Greifswald. Thomas Hoffmann is with the Department of Periodontology, Medical Faculty Carl Gustav Carus. Wolfgang Micheelis is with the Institute of German Dentists.

Received: 5/10/2012; accepted: 11/20/2012.

doi: 10.1111/jphd.12007

Journal of Public Health Dentistry **73** (2013) 65–73

Abstract

Objectives: The German reunification (1990) resulted in huge social upheavals in East Germany involving changes in health-care systems. We aimed to assess the changes of dental health between 1989 and 2005, hypothesizing that dental health converged in West and East Germany.
Methods: We evaluated data from 855 East and 1,456 West Germans aged 35-44 years from the cross-sectional German Oral Health Studies (*Deutsche Mundgesundheitsstudien*) conducted in 1989/92, 1997, and 2005. Regression models were applied to assess associations between region, survey year, their interactions and variables assessing dental disease status [number of decayed (DT), missing (MT), and filled teeth (FT), the DMFT-index, the probability of having ≤20 teeth and the number of sound teeth (ST)], adjusting for potential risk factors for caries.
Results: After a slight increase of MT between 1989/92 and 1997 (West: 3.6 to 3.6; East: 4.5 to 4.9), numbers of MT considerably decreased between 1997 and 2005 (West: 3.6 to 2.2; East: 4.9 to 3.1). East Germans had consistently more MT. Numbers of FT, DT, ST, and the DMFT-index equalized at the latest in 2005. The East German DMFT-index increased between 1989/92 and 1997 and slightly decreased between 1997 and 2005, whereas the West German DMFT-index steadily decreased between 1989/92 and 2005.
Conclusions: Dental health converged in West and East Germany, but the higher number of MT in 2005 indicates that East Germany was not able to catch up completely with West Germany.

Introduction

Before the reunification in 1990, both the former Federal Republic of Germany (FRG) (old Federal States, referred to as West Germany) and the former German Democratic Republic (GDR) (new Federal States, referred to as East Germany) had completely different political, economic, and health-care systems. Until now, these inequalities decreased due to huge efforts made after reunification to bring East Germany into line with the West German social market economy. To develop a modern infrastructure and to promote a competitive economy, the rebuilding of East Germany was financed with high amounts of transfer payments. This led to an increase of the East German gross domestic product to 71 percent of the West German average in 2008 (1). Although economic differences diminished over time, East Germans remained socioeconomically deprived; in 1997 the unemployment rate was 19.1 percent in East and 10.8 percent in West Germany (2).

In other fields of medical research the impact of these changes on health had already been explored. Between 1991 and 2007, a decrease and steady approximation of mortality rates related to prostate and cervix cancer were observed in West and East Germany (1). Over the same period, cardiovascular mortality rates decreased and converged in both German parts, but East Germans still had a higher risk in 2007. We hypothesized that similar trends might also be observed regarding dental health.

An international collaborative study (3) focused on the impact of health-care systems on oral health, comparing data for Hannover, FRG (1973), and Leipzig, GDR (1979). For 35- to 44-year-olds, a higher DMFT-index and a higher number of missing (MT) and filled teeth (FT) were reported in Hannover, whereas the number of decayed teeth (DT) was higher in Leipzig. Before reunification, the health-care system of the GDR fundamentally differed from its Western counterpart. In the GDR, almost all dentists were salaried employees, not receiving any commissions beyond their salaries. In contrast, the FRG had a system of reimbursement, in which health insurances paid dentists for each treatment.

In the last decades a parallel decline of caries was reported in most of the industrialized countries (4). It can be assumed that both West and East Germany show similar improvements in dental health. Furthermore, the broader range of fluoridated toothpastes after reunification might have positively influenced dental health in East Germany. Factors that might have negatively influenced dental health in East Germany comprehend cessations of water fluoridation, which was mandated by law and led to complete abandonment of water fluoridation until 1993 (5), and the necessary process of familiarization with new health-care services accompanied by possible inhibitions to utilize them (6).

The time period after reunification is of particular interest as East Germany adopted the West German health-care system. In 1989/92, 1997, and 2005 the German Oral Health Studies [*Deutsche Mundgesundheitsstudien* (DMS)] were conducted in West and East Germany. The repetition of cross-sectional studies allows for evaluation of time-lag differences (7), which are differences between individuals of the same age in different survey years and can aid in determining both period and cohort effects. Period effects represent the impact of events on people at a particular time point, common to people of all ages. Cohort effects describe the phenomenon that members of one cohort sharing common life experiences (e.g., growing up in the 1960s) can be separated from a second cohort (e.g., growing up in the 1970s) due to the presence of different environmental circumstances. The aim of this study was to evaluate the dental health of 35- to 44-year-olds in West and East Germany between 1989/92 and 2005 and to assess the degree to which dental health converged during that period.

Methods

Study design

The Institute of German Dentists [*Institut der Deutschen Zahnärzte* (IDZ)] conducted four national cross-sectional surveys of oral health in the German resident population (DMS): in 1989 (DMS I, only West Germany), 1992 (DMS II, only East Germany), 1997 (DMS III), and 2005 (DMS IV). The first two surveys (1989/92) were merged (8) to achieve comparability with the last two studies.

Random cluster samples stratified by Federal State and by community category were drawn, altogether of 80 (DMS I), 40 (DMS II), 90 (DMS III), and 90 (DMS IV) municipalities. Random samples were selected from the records of registration offices from each of these municipalities. East Germans were oversampled. Informed consent was obtained from all subjects entered into the study.

Analyses were restricted to 35- to 44-year-olds, who were continuously sampled in all four studies. Study participants were born in 1945-1954, 1948-1957, 1953-1962, and 1961-1970, respectively. Participation rates averaged 56 percent, 72 percent, 56 percent, and 52 percent, respectively (Table 1). Design, sampling and nonresponse analyses were described in detail elsewhere (9,10).

Dental examinations

In DMS I/II caries status was assessed by a sharp probe (11). In DMS III and IV caries status was examined as recommended by the World Health Organization (WHO) (12); caries status was assessed only visually and not by probing with a sharp probe. A blunt probe was used for the removal of plaque. The utilization of a sharp probe did not lead to a better detection of caries, thus the different methods did not have consequences for the results (13). Numbers of DT, MT, and FT were determined and the DMFT-index was calculated. Number of sound teeth (ST) was calculated as the difference between 28 and the DMFT-index. Subjects were stratified into those with more versus less than or equal to 20 teeth; this threshold is based on a recommendation of WHO, which describes as global goal for oral health to increase the

Table 1 Information on Sampling Design for DMS I-IV

Survey name	Birth cohort	Survey year	Age (year)	Sampling size	Number of invited subjects	Participation rate (%)
DMS I	1945-1954	1989	35-54*	1,700*	1,544*	858 (56)*
DMS II	1948-1957	1992	35-54*	1,039*	1,014*	731 (72)*
DMS III	1953-1962	1997	35-44	1,260	1,179	655 (56)
DMS IV	1961-1970	2005	35-44	1,980	1,774	925 (52)

* Information was only available for the cohort aged 35-54 years. For the analysis, only the cohort aged 35-44 years was considered.

number of individuals with functional dentitions (>20 natural teeth) aged 35-44 years until 2020 (14). All dental examinations excluded wisdom teeth.

Examinations were carried out by 80 dentists in private practices in DMS I, two mobile teams (calibrated dentist, interviewer, and contact person) in DMS II and three mobile teams (calibrated dentist, interviewer, and contact person) in DMS III and IV. Regarding DMS I, a double-stage calibration method was applied with five Federal calibrators who trained six local calibrators. Together with at least one Federal calibrator, these local calibrators trained the study dentists.

For DMS II, the study dentists of the two mobile teams took part in a 1-day calibration session before the start of the study, for which the Federal calibrators of DMS I served as the gold standard. This session was repeated during and at the end of the study. Similarly, the three mobile teams of DMS III and DMS IV were intensively trained by experts before each survey in one and a half day sessions.

Regarding the DMFT-index, inter-rater correlations between dentists and experts were high; for DMS I, II, III, and IV Pearson's correlation coefficients were 0.98, 0.98, 0.99, and 0.85, respectively.

Covariates

Socioeconomic variables were retrieved from questionnaires, including gender, age (continuously), school education (<10/10/>10 years), and marital status (married/single/divorced or widowed). Further, utilization of dental services (regular/irregular), number of snacks (no snacks/once or twice/≥three times daily), using dental floss/tooth sticks (no/yes) were used. In addition, the time of the last dental visit (last 12 months/last 2 years/less frequent) was reported, which not only pictures the regularity but also visits because of pain. Only socioeconomic variables similarly collected across survey years were included in our analyses. All interviews were conducted as verbal and personal face-to-face interviews by specially trained interviewers.

Statistical analyses

Chi-square tests and Wilcoxon rank-sum tests were applied to analyze differences in variables assessing oral health behavior between East and West Germany. Including the categorical variable for survey years as a continuous variable in linear models delivers *P* values for linear trends (see Table 2).

Table 2 Subjects' Characteristics according to Region and Survey Year

	DMS I/II			DMS III			DMS IV		
Variable	West	East	*P*	West	East	*P*	West	East	*P*
n	442	354		428	200		586	301	
Gender (ref. female)									
Male	47.7%	50.6%	0.43	50.7%	50.1%	0.88	50.7%	50.7%	0.99
Age, years	39.0 ± 2.9	38.3 ± 2.8	0.001	39.5 ± 2.8	39.6 ± 3.0	0.32	39.6 ± 2.8	39.8 ± 2.9	0.34
School education									
<10 years	57.0%	22.6%		36.0%	16.6%		28.1%	13.0%	
10 years	21.5%	51.4%		33.6%	54.1%		34.5%	61.8%	
>10 years	21.5%	26.0%	<0.001	30.4%	29.3%	<0.001	37.4%	25.2%	<0.001
Marital status									
Married	80.8%	85.0%		76.3%	76.4%		70.2%	69.7%	
Single	12.2%	9.3%		13.6%	10.1%		21.9%	22.2%	
Divorced/widowed	7.0%	5.7%	0.28	10.1%	13.5%	0.27	7.9%	8.1%	0.99
Utilization of dental services (ref. irregular)									
Regular	69.9%	76.6%	0.04	79.4%	85.0%	0.10	85.9%	92.1%	0.01
Number of snacks									
No snacks	27.4%	9.3%		6.1%	6.3%		6.7%	6.2%	
Once or twice daily	59.5%	65.3%		50.4%	64.1%		51.1%	63.3%	
≥three times daily	13.1%	25.4%	<0.001	43.5%	29.6%	<0.01	42.2%	30.5%	<0.01
Use of dental floss/tooth sticks (ref. no)									
Yes	34.8%	13.3%	<0.001	35.4%	15.7%	<0.001	58.1%	48.3%	<0.01
Last dental visit within									
Last 12 months	82.3%	85.3%		85.3%	88.0%		90.0%	92.1%	
Last 2 years	10.2%	8.5%		7.6%	7.5%		6.5%	6.3%	
Less frequent	7.5%	6.2%	0.53	7.1%	4.5%	0.49	3.5%	1.6%	0.35

Data are presented as percentages or mean with standard deviation. Data were weighted.
n, number of subjects.

Regression models were applied to assess associations between region, survey year, their interactions and variables assessing dental disease status (number of MT, FT, DT, the DMFT-index, the probability of having ≤20 teeth and ST), adjusting for potential risk factors for caries. Negative binomial regression models were applied for the highly positively skewed counts of DT and MT. Multiple linear regressions were used to model the number of FT and ST and the DMFT-index. Logistic models were applied to model the probability of having ≤20 teeth. Because East Germans were oversampled, analyses were weighted. To assess effects of region within specific survey years, linear combinations of estimators were tested using Wald tests.

Results were considered statistically significant at $P < 0.05$. Statistical analyses were performed with STATA/SE 11.0 (15) and R 2.12.1 (16).

Results

Utilization of dental services improved over time (Table 2). In West Germany, 69.9 percent of study participants of DMS I/II reported a regular utilization of dental services, in contrast to 85.9 percent in DMS IV. The corresponding numbers increased from 76.6 percent to 92.1 percent in East Germany. Additionally, differences in oral health behavior between East and West Germany diminished. The difference in the use of dental floss or tooth sticks was reduced from 21.5 percent in DMS I/II to 9.8 percent in DMS IV.

Dental health considerably changed across survey years (Table 3). In both German regions, the numbers of MT and DT and the probability of having ≤20 teeth showed significant downward trends ($P_{trend} \leq 0.001$, respectively; based on linear models). The number of FT revealed significant upward trends in both regions (West: $P_{trend} = 0.03$; East: $P_{trend} < 0.001$). Regarding the number of ST, we found a significant upward trend in West and a significant downward trend in East Germany ($P_{trend} < 0.001$, respectively). The DMFT-index showed a significant downward trend in West and a significant upward trend in East Germany ($P_{trend} < 0.001$, respectively).

Post hoc tests after regression modeling revealed statistically significant differences in the mean number of MT and the probability of having ≤20 teeth ($P < 0.05$) between West and East Germany for each survey year (Figure 1a,e). Thus, we did not observe any convergence for the number of MT and for the probability of having ≤20 teeth. East Germans had consistently more MT and a higher probability of having ≤20 teeth than West Germans. Between 1989/92 and 1997, the number of MT was constant in West Germany and slightly increased in East Germany and considerably decreased in the entire republic between 1997 and 2005. Numbers of FT and DT strongly equalized (Figure 1b,c); the effect of region was significant in 1989/92 and 1997 ($P < 0.05$) but disappeared in 2005 ($P > 0.05$). The number of ST and the DMFT-index had already converged in 1997 ($P > 0.05$, Figure 1d,f).

Table 3 Distribution of Dental Health Variables according to Region and Survey Year

	West Germany			
Variable	DMS I	DMS III	DMS IV	P_{trend}
Number of MT	2 (1; 5)	3 (1; 5)	1 (0; 4)	<0.001
Number of FT	12 (8; 15)	12 (9; 15)	12 (9; 15)	0.03
Number of DT	1 (0; 3)	0 (0; 0)	0 (0; 0)	<0.001
DMFT-index	17 (14; 21)	17 (13; 20)	15 (11; 19)	<0.001
≤20 teeth	15.6%	14.3%	7.7%	<0.001
Number of ST	11 (7; 14)	11 (8; 15)	13 (9; 17)	<0.001
	East Germany			
Variable	DMS II	DMS III	DMS IV	P_{trend}
Number of MT	3 (1; 6)	4 (2; 7)	2 (1; 4)	<0.001
Number of FT	8 (5, 11)	10 (7; 14)	12 (9; 15)	<0.001
Number of DT	0 (0; 1)	0 (0; 1)	0 (0; 0)	<0.001
DMFT-index	14 (10; 17)	17 (12; 21)	16 (12; 19)	<0.001
≤20 teeth	17.5%	21.5%	7.6%	0.001
Number of ST	14 (11; 18)	11 (7; 16)	12 (9; 16)	<0.001

Data are presented as median with percentiles (25%; 75%) or as percentages.

Discussion

We described trends in dental health in 35- to 44-year-old German adults between 1989/92 and 2005. In West Germany, the DMFT-index decreased during this period. In East Germany, the DMFT-index increased between 1989/92 and 1997 and decreased between 1997 and 2005. Numbers of MT and the probability of having ≤20 teeth considerably decreased between 1997 and 2005 in the whole republic. Numbers of FT, DT and ST and the DMFT-index equalized between West and East Germany at the latest in 2005.

In 1989, the IDZ conducted DMS I as a national representative cross-sectional study of dental health of the FRG. Because of the unforeseen reunification in 1990, data of DMS I suddenly became incomplete. Consequently, only 2 years after reunification, DMS II was conducted in 1992, methodologically and content-wise based on DMS I. Despite this time lag, we assume that data of DMS II reflect dental health of the GDR. This raises, however, the question of the impact of selective migration during the transition period. Between January 1989 and June 1992, a total of 1.127 million out of 16.675 million East Germans emigrated from East to West (17,18). After subtraction of immigrants into East Germany, the net out-migration was estimated to be about 955,000. Emigrants were more often young, men, employable and well-educated (19). Presumably, those with a higher risk for

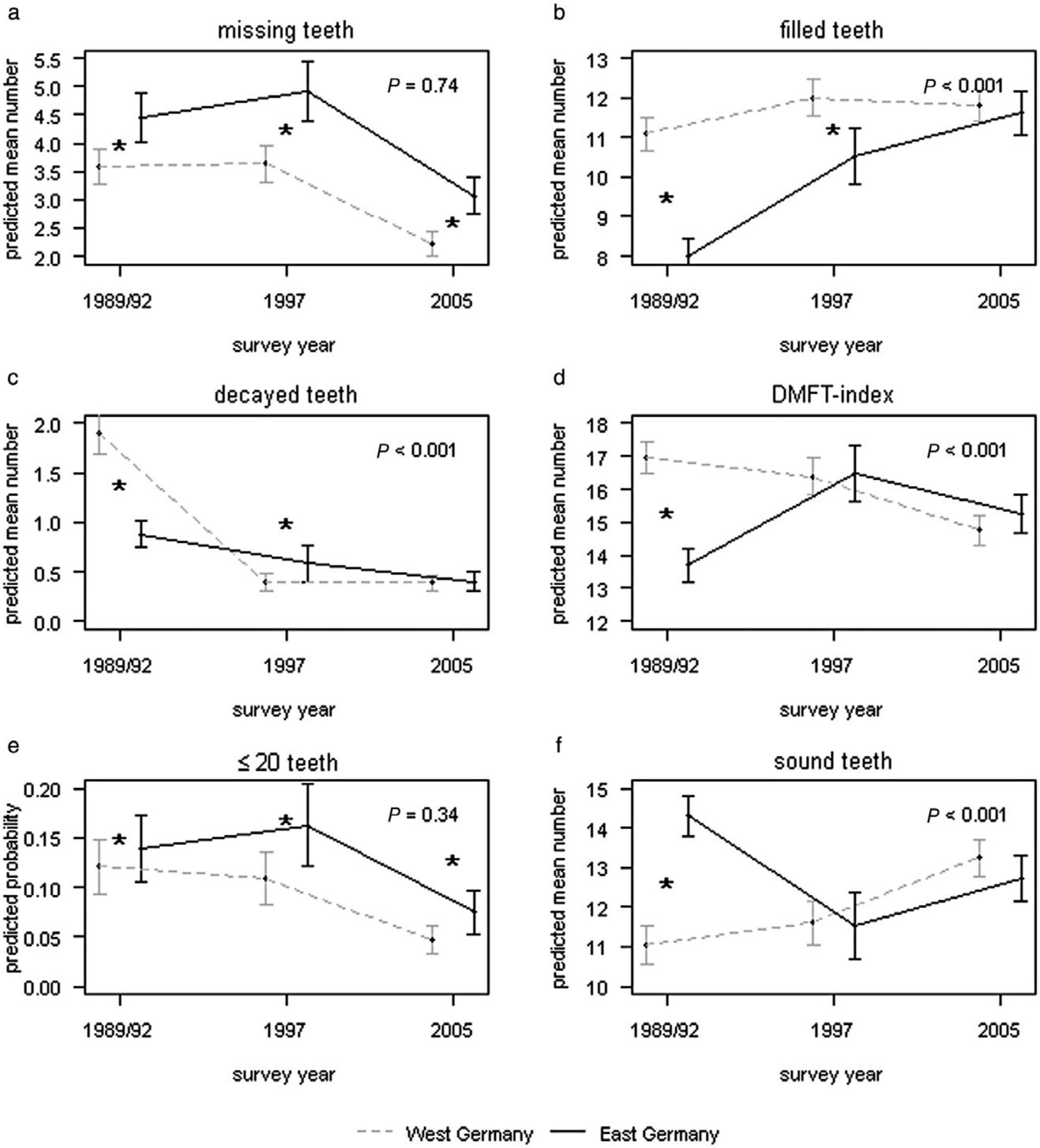

Figure 1 Trends in dental health variables [(a) number of MT, (b) number of FT, (c) number of DT, (d) DMFT-index, (e) predicted probability of having ≤20 teeth, (f) number of ST] according to region and survey year; * indicates $P < 0.05$ for differences between West and East Germany within survey years received from regression post hoc tests. *P* values are given for overall test of significance of interaction terms between region and survey year. Analyses were weighted and adjusted for gender, age, marital status, utilization of dental services, number of snacks, use of dental floss/tooth sticks, and the last dental visit, using the following types of regression: negative binomial regression (a, c), linear regression (b, d, f), and logistic regression (e). Whiskers denote 95 percent confidence intervals.

oral diseases were left behind. A case study in Saxony (former GDR) revealed that the East–West migration could have affected the decline in life expectancy between 1989 and 1990 by about 3 percent in men and 9 percent in women (20). Conclusively, the impact of selective migration on the dental variables might be negligible.

At about the same time as the reunification, the health-care reform in 1989, which introduced co-payments for medical treatments, affected dentists and patients both in West and East Germany. The observed decrease of MT both in West and East Germany between 1997 and 2005 is contrary to the hypothesis that patients allowed more teeth to be extracted as a consequence of the health-care reform. Thus, we think that the health-care reform might have had an unremarkable impact on oral health. Furthermore, there was not only one health-care reform but many other additional reforms in the 1990s, which makes a discussion of the impact of these various reforms on oral health even harder.

It is crucial to take the age cohorts' life experiences into consideration because MT and FT mainly describe past caries experience. Economically, FRG and GDR diverged after World War II. Particularly the European Recovery Program ("Marshall Plan") led to an economic boost in the FRG in the postwar era. The Soviet Union demanded huge amounts of reparations payments from the GDR, inhibiting economic growth and leading to a deprived economy.

Age cohorts were born in 1945-1954, 1948-1957, 1953-1962, and 1961-1970, respectively (Figure 2). Participants of DMS I/II were born in the early postwar years. Across the decades after World War II, improvement of general health was reflected in the steady rise of life expectancies at birth in both FRG and GDR (Figure 2). Similarly, our results showed that the number of MT and the probability of having ≤20 teeth considerably decreased between 1997 and 2005 in the whole republic, revealing a strong impact of cohort effects on

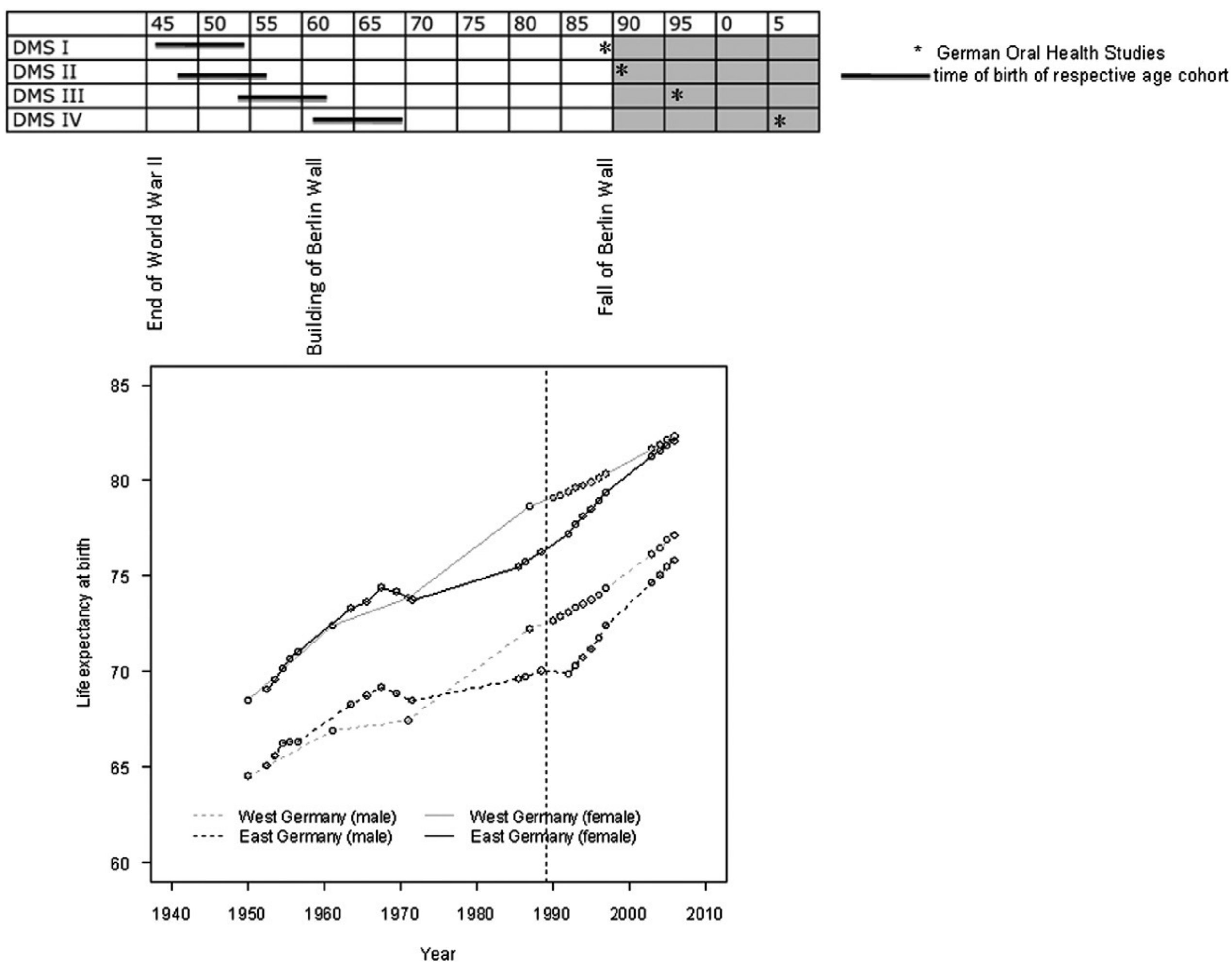

Figure 2 Period life expectancies at birth according to region and gender. Source: Human Life-Table Database (35). Vertical dashed line denotes the year of the fall of the Berlin Wall.

dental health. Improved oral health behavior might explain positive trends (Table 2).

The improvement of MT and DT and the probability of having ≤20 teeth might be further explained by the period effect of a broader use of fluoridated toothpastes, especially in East Germany after 1990 (21). Between 1985 and 1989, only 15 percent of all toothpastes were fluoridated in the GDR, in contrast to 95 percent in the FRG. The sudden increase in fluoridated toothpastes from 15 percent to 90 percent between 1990 and 1994 may have contributed to the caries decline. Participants of DMS IV were longest exposed to fluoridated toothpastes and probably benefited the most.

Another possible period effect is water fluoridation, which was implemented only locally in the former GDR (8). In DMS II, samples were drawn from 40 East German municipalities, of which six sample points had water fluoridation: Schwerin, Magdeburg, Salzwedel, Cottbus, Chemnitz (former Karl-Marx-Stadt), and Flöha (8). However, in DMS II, water fluoridation did not affect the DMFT-index of children and adolescents significantly (8). Though water fluoridation was reported to be beneficial (22), caries prevalence did not increase after cessation of water fluoridation at the end of 1993 (5). In parallel, a national caries decline was observed (6), which was explained by improvements of oral health behavior and a broader use of preventive measures, such as fluoridated salt and fluoridated toothpastes (6).

In West Germany, 13.1 percent of study participants of DMS I/II reported to eat more than three times daily some kind of snack between meals, contrary to 42.2 percent in DMS IV. The corresponding numbers increased from 25.4 percent to 30.5 percent in East Germany. High sugar consumption is a risk factor for caries (23). After World War II sugar consumption steadily increased both in FRG and GDR until the early 1970s and remained constant after 1975 with a higher consumption in the GDR (39-42 kg/person/year up to 1991) (6,24). Similar results were reported by Kramer (25), who mentioned a sugar consumption of 32.8 kg for the FRG and 40.9 kg for the GDR in 1987. After reunification, sugar consumption in East Germany decreased to 35.1 kg, which might also be explained by changes in data sources. The Western Office of Statistics reported figures for glucose and isoglucose in addition to sugar consumption (4-5 kg/person/year), which were already included in the overall sugar consumption in the GDR. Thus, changes in data sources might limit informative value and possibly explains the supposed differences in sugar consumptions between FRG and GDR before reunification (6).

Despite the high sugar consumption, the number of DT decreased in the whole republic between 1989/92 and 2005. Studies in the GDR between 1959 und 1995 impressively showed that the prevalence of caries of 12-year-olds decreased in spite of high sugar consumption, when fluorides were present due to water fluoridation (6). Sugar and caries correlate in the absence of fluorides, but this correlation weakens in the presence of fluorides, as it is the case in most industrial countries (26). However, the unique historical situation of the reunification associated with the sudden appearance of a wide range of "Western food" might have contributed to the short-term increase of the East German DMFT-index between 1989/92 and 1997.

In 1989/92 the number of FT was much higher in West compared with East Germany (Figure 1b). Consistent results were reported for an international collaborative study conducted in Leipzig (GDR, 1973) and Hannover (FDR, 1979) (3). The explanation might be found in the completely different health-care systems. Before reunification, almost all East German dentists were salaried employees. Moreover, availability of material was often poor in the GDR. Although all services were free of charge for patients, it was of no use if the resources were unavailable. By the end of 1992, 88 percent of all East German dentists moved from salaried employment into private practices (27) and adopted the Western system of reimbursement. The attitude toward tooth extraction of East German dentists changed into a tooth-maintaining attitude because East German dentists realized that each filling was covered by insurance. Consequently, the high increase of FT in East Germany between 1989/92 and 1997 led to a deterioration of the DMFT-index (Figure 1b,d).

In 1989/92 the DMFT-index was much lower in East than in West Germany, which might have been mainly attributable to the well-developed system of specialist dentists for pediatric dentistry in the former GDR. Already in 1954, unified regulations for the pediatric dentistry implying annual serial and individual examinations with subsequent treatments were introduced (28). In addition, the installation of water fluoridation in several large cities in the GDR, at a time when other preventive measures such as fluoridated salt and fluoridated toothpastes were still not available, might have contributed to the lower DMFT-index in East Germany in 1989/92.

The almost parallel curves of MT demonstrated that even East German participants of DMS IV, having lived 20-30 years in the GDR and 15 years in Germany as a whole, were not able to catch up with their Western counterparts. In the former GDR, teeth were more often extracted for caries reasons. The differences in the reasons for extractions between East and West Germany evened out just in the last 15 years (29). Only if oral prevention and operative dentistry starts early in life, a convergence of MT in West and East Germany will be achieved.

Between 1989/92 and 2005, we observed no complete convergence of dental health in West and East Germany. Similarly, other diseases also approximated without clear equality. After a peak in the early 1990s, mortality from ischemic heart disease decreased both in West and East Germany until 2000 without clear equalization (30). Unequal rates were explained by differences in cardiovascular risk factors. Hypertension is one of the most important risk factors for cardiovascular diseases. In 1990/92, prevalence of hypertension for 25- to 69-year-olds were higher in East than in West Germany (1). This difference diminished but was still present in 1998. In addition, national health surveys in the time periods 1990-1992, 1997-1999, 2002-2003, 2003-2004, and 2004-2005 revealed higher prevalence of diabetes for East Germans than for West Germans for nearly all survey times (31). Further, life satisfaction was 1.5 points higher (of an 11-stage scale) in West Germany compared with East Germany after reunification (1). In the subsequent years, the difference reduced to 0.5 points in the mid-90s and remained constant afterward. Studies suggested that a complete convergence of general and dental health can only be expected for birth cohorts born after reunification.

Our study has strengths and limitations. The examination of trends in dental health over 16 years (1989-2005) with simultaneous consideration of socioeconomic variables is a unique feature offered by our study. One shortcoming is that smoking, alcohol drinking, and physical fitness were not consistently collected across surveys, possibly leading to residual confounding. Possibly, effects of region and survey year were slightly overestimated because controlling for smoking, for example, could have mitigated the effects. Another limitation is the potential selection bias due to the high percentage of nonresponders (28-44 percent). According to nonresponse analyses, based on a short questionnaire with basic questions sent to nonresponders, nonresponders were more often men and visited the dentist less frequently than study participants (32). However, differences were only marginal and might have only slightly affected selection bias. Potentially, disease prevalence was slightly underestimated. In addition, DMS I-IV were restricted to the German resident population because knowledge of the German language was needed to answer the questionnaires. The proportions of foreigners in the FRG were 8.0 percent in 1989, 8.2 percent in 1992, 9.0 percent in 1997, and 8.8 percent in 2005 (33). Again, disease prevalence might be slightly underestimated because migrants are more likely to suffer from dental diseases (34).

This study enlarges our understanding to which degree dental health of 35- to 44-year-olds converged in West and East Germany between 1989/92 and 2005. Solely the number of MT, which mainly describes past caries experience, did not equalize and only birth cohorts born after reunification might achieve complete convergence of oral health. Because the last study was conducted in 2005, more recent data are needed to assess the degree to which numbers of MT converge. To continue monitoring oral health in Germany, the Fifth German Oral Health Study (DMS V) is in the course of preparation and is expected to start in 2013. While maintaining all relevant examinations, this cross-sectional survey will again be representative for the German population and will sample those age groups defined by the WHO (12). Additionally, the age group >75 years will be included for the first time to collect data about morbidity and care nationwide for old and very old persons in Germany.

In summary, between 1989/92 and 2005 numbers of FT, DT, ST, and the DMFT-index converged in the 35- to 44-year-old age group. The East German DMFT-index increased between 1989/92 and 1997 and decreased slightly between 1997 and 2005, whereas the West German DMFT-index steadily decreased between 1989/92 and 2005. In addition, East Germans had consistently more MT in each survey year compared with West Germans, which indicates altogether that East Germany was not able to catch up completely with its Western counterpart.

Acknowledgments

DMS I-IV were funded by the two Federal dental organizations, the Bundeszahnärztekammer/BZÄK and the Kassenzahnärztliche Bundesvereinigung/Cologne. S.S. was supported by the Institut der Deutschen Zahnärzte/IDZ (Institute of German Dentists). B.H. was financed by an unlimited educational grant by GABA, Switzerland.

References

1. Atzpodien K, Bergmann E, Bertz J, Busch M, Eis D, Ellert U *et al*. 20 Jahre nach dem Fall der Mauer: Wie hat sich die Gesundheit in Deutschland entwickelt? In: Robert Koch-Institut, editor. *Beiträge zur Gesundheitsberichterstattung des Bundes*. Berlin: Robert Koch-Institut; 2009. p. 25-137.
2. Bundesagentur für Arbeit. Registered Unemployed, Unemployment Rate by Area Wiesbaden: Statistisches Bundesamt; 2011 [updated 2012 Jan 1; cited 2011 Dec 5]. Available from: https://www.destatis.de/EN/FactsFigures/Indicators/LongTermSeries/LabourMarket/lrarb003.html
3. Arnljot HA, Barmes DE, Cohen LK, Hunter PBV, Ship II. *Oral health care systems. An international collaborative study*. Geneva: World Health Organization; 1985.
4. Marthaler TM. Changes in dental caries 1953–2003. *Caries Res*. 2004;**38**:173-81.
5. Künzel W, Fischer T, Lorenz R, Bruhmann S. Decline of caries prevalence after the cessation of water fluoridation in the former East Germany. *Community Dent Oral Epidemiol*. 2000;**28**:382-9.
6. Künzel W. *Caries decline in Deutschland. Eine Studie zur Entwicklung der Mundgesundheit*. Heidelberg: Hüthig Verlag Heidelberg; 1997.
7. Schuller AA, Holst D. Changes in the oral health of adults from Trondelag, Norway, 1973–1983–1994. *Community Dent Oral Epidemiol*. 1998;**26**:201-8.
8. Micheelis W, Bauch J. *Mundgesundheitszustand und -verhalten in Ostdeutschland*. Institut der Deutschen Zahnärzte (IDZ), editor. Köln: Deutscher Ärzte-Verlag; 1993.

9. Micheelis W, Bauch J. Oral health of representative samples of Germans examined in 1989 and 1992. *Community Dent Oral Epidemiol*. 1996;**24**:62-7.
10. Schiffner U, Hoffmann T, Kerschbaum T, Micheelis W. Oral health in German children, adolescents, adults and senior citizens in 2005. *Community Dent Health*. 2009;**26**:18-22.
11. Einwag J, Keß K, Reich E. *Oral health in Germany: diagnostic criteria and data recording manual. Instructions for examination and documentation of oral health status*. Institut der Deutschen Zahnärzte, editor. Köln: Deutscher-Ärzte-Verlag; 1992.
12. World Health Organization. *Oral health surveys. Basis methods*. 4th ed. Geneva: World Health Organization; 1997.
13. Micheelis W, Reich E. *Dritte Deutsche Mundgesundheitsstudie (DMS III)*. Institut der Deutschen Zahnärzte (IDZ), editor. Köln: Deutscher Ärzte-Verlag; 1999.
14. Hobdell M, Petersen PE, Clarkson J, Johnson N. Global goals for oral health 2020. *Int Dent J*. 2003;**53**:285-8.
15. StataCorp. *Stata statistical software: release 11*. College Station (TX): StataCorp LP; 2009.
16. R Development Core Team. *R: a language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing; 2010.
17. Staatliche Zentralverwaltung für Statistik. Statistisches Jahrbuch 1989 der Deutschen Demokratischen Republik. 34 Jahrgang. 1. Auflage ed. Berlin; 1990.
18. Eberstadt M. Demographic shocks after communism: Eastern Germany, 1989–93. *Popul Dev Rev*. 1994;**20**:137-52.
19. Voigt D, Belitz-Demiriz H, Meck S. Die innerdeutsche Wanderung und der Vereinigungsprozeß. *Dtschl Arch*. 1990;**23**:732-46.
20. Nolte E, Shkolnikov V, McKee M. Changing mortality patterns in East and West Germany and Poland. I: long term trends (1960–1997). *J Epidemiol Community Health*. 2000;**54**: 890-8.
21. Marthaler TM, O'Mullane DM, Vrbic V. The prevalence of dental caries in Europe 1990–1995. ORCA Saturday afternoon symposium 1995. *Caries Res*. 1996;**30**:237-55.
22. Newbrun E. Effectiveness of water fluoridation. *J Public Health Dent*. 1989;**49**(5 Spec No):279-89.
23. Touger-Decker R, van Loveren C. Sugars and dental caries. *Am J Clin Nutr*. 2003;**78**:881S-92S.
24. Splieth C, Meyer G. Factors for changes of caries prevalence among adolescents in Germany. *Eur J Oral Sci*. 1996;**104**(4 Pt 2):444-51.
25. Kramer E. *Prophylaxefibel. Grundlagen der Zahngesundheitsvorsorge*. Köln: Deutscher Zahnärzte Verlag; 2004.
26. Woodward M, Walker AR. Sugar consumption and dental caries: evidence from 90 countries. *Br Dent J*. 1994;**176**: 297-302.
27. Widstrom E, Eaton KA, Borutta A, Dybizbanska E, Broukal Z. Oral healthcare in transition in Eastern Europe. *Br Dent J*. 2001;**190**:580-4.
28. Bardehle D. *Geschichte, Struktur und Kennziffern zur zahnärztlichen Versorgung in der ehemaligen DDR. Eine kommentierte Zusammenstellung verfügbarer Daten von 1949-1989. IDZ-Sonderband*. Köln: Institut der Deutschen Zahnärzte; 1994.
29. Glockmann E, Panzner K-D, Huhn P, Sigusch BW, Glockmann K. *Ursachen des Zahnverlustes in Deutschland. Dokumentation einer bundesweiten Erhebung (2007). IDZ-Information*. Köln: Institut der Deutschen Zahnärzte; 2011.
30. Muller-Nordhorn J, Rossnagel K, Mey W, Willich SN. Regional variation and time trends in mortality from ischaemic heart disease: East and West Germany 10 years after reunification. *J Epidemiol Community Health*. 2004;**58**: 481-5.
31. Heidemann C, Kroll L, Icks A, Lampert T, Scheidt-Nave C. Prevalence of known diabetes in German adults aged 25-69 years: results from national health surveys over 15 years. *Diabet Med*. 2009;**26**:655-8.
32. Micheelis W, Schiffner U. *Vierte Deutsche Mundgesundheitsstudie (DMS IV)*. Institut der Deutschen Zahnärzte (IDZ), editor. Köln: Deutscher Zahnärzte Verlag; 2006.
33. Statistisches Bundesamt. Bevölkerung und Erwerbstätigkeit-Bevölkerungsfortschreibung. In: Statistisches Bundesamt, editor. Fachserie 1 Reihe 13. Wiesbaden; 2012.
34. Kuhnisch J, Heinrich-Weltzien R, Senkel H. [Oral health and use of dental care by 8-year-old immigrants and German students of the Ennepe-Ruhr district]. *Gesundheitswesen*. 1998;**60**:500-4.
35. Max Planck Institute for Demographic Research, Department of Demography at the University of California, Institut national d'études démographiques. The Human Life-Table Database. Rostock, Berkely, Paris; 2007 [updated 2007 Jan 1; cited 2011 Dec 8]. Available from: http://www.lifetable.de/

Supporting information

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

Table S1 Incidence-rate ratios (IRR) from negative binomial regressions, coefficients (B) from multiple linear regressions and odds ratios (OR) from logistic regressions with 95 percent confidence intervals (CI) of dental health variables according to region and survey year. Analyses were weighted. X denotes the interaction term between region and survey year.

Table S2 Incidence-rate ratios (IRR) from negative binomial regressions, coefficients (B) from multiple linear regressions and odds ratios (OR) from logistic regressions with 95 percent confidence intervals (CI) of dental health variables according to region and survey year, adjusting for gender, age, marital status, utilization of dental services, number of snacks, use of dental floss/tooth sticks, and time of the last dental visit. Analyses were weighted. X denotes the interaction term between region and survey year.

Suppl. Table 1: Incidence-rate ratios (IRR) from negative binomial regressions, coefficients (B) from multiple linear regressions and odds ratios (OR) from logistic regressions with 95% confidence intervals (CI) of dental health variables according to region and survey year. Analyses were weighted. X denotes the interaction term between region and survey year.

	Number of MT		Number of FT		Number of DT	
Variable	IRR (95% CI)	p	B (95% CI)	p	IRR (95% CI)	p
Region (ref. West)						
East	1.27 (1.14; 1.40)	<0.001	-3.08 (-3.75; -2.41)	<0.001	0.51 (0.41; 0.63)	<0.001
Survey year (ref. 1989/92)						
1997	1.04 (0.91; 1.18)	0.58	0.92 (0.23; 1.61)	0.01	0.24 (0.18; 0.31)	<0.001
2005	0.65 (0.57; 0.75)	<0.001	0.71 (0.09; 1.34)	0.03	0.22 (0.17; 0.28)	<0.001
Interaction	not significant	0.61	highly significant	<0.001	highly significant	<0.001
East X 1997			1.59 (0.44; 2.74)	0.01	2.63 (1.65; 4.20)	<0.001
East X 2005			2.90 (1.91; 3.90)	<0.001	2.19 (1.41; 3.41)	<0.001

	DMFT-Index		Subjects with ≤20 teeth		Number of ST	
Variable	B (95% CI)	p	OR (95% CI)	P	B (95% CI)	p
Region (ref. West)						
East	-3.27 (-4.01; -2.54)	<0.001	1.26 (0.98; 1.62)	0.07	3.27 (2.54; 4.01)	<0.001
Survey year (ref. 1989/92)						
1997	-0.57 (-1.33; 0.19)	0.14	0.97 (0.72; 1.32)	0.87	0.57 (-0.19; 1.33)	0.14
2005	-2.21 (-2.91; -1.50)	<0.001	0.43 (0.30; 0.60)	<0.001	2.21 (1.50; 2.91)	<0.001
Interaction	highly significant	<0.001	not significant	0.42	highly significant	<0.001
East X 1997	3.36 (2.08; 4.64)	<0.001			-3.36 (-4.64; -2.08)	<0.001
East X 2005	3.78 (2.71; 4.85)	<0.001			-3.78 (-4.85; -2.71)	<0.001

Suppl. Table 2: Incidence-rate ratios (IRR) from negative binomial regressions, coefficients (B) from multiple linear regressions and odds ratios (OR) from logistic regressions with 95% confidence intervals (CI) of dental health variables according to region and survey year, adjusting for gender, age, marital status, utilization of dental services, number of snacks, use of dental floss / tooth sticks and time of the last dental visit. Analyses were weighted. X denotes the interaction term between region and survey year.

	Number of MT		Number of FT		Number of DT	
Variable	IRR (95% CI)	p	B (95% CI)	p	IRR (95% CI)	p
Region (ref. West)						
East	1.36 (1.22; 1.50)	<0.001	-3.39 (-4.04; -2.73)	<0.001	0.46 (0.38; 0.57)	<0.001
Survey year (ref. 1989/92)						
1997	1.08 (0.95; 1.22)	0.23	0.27 (-0.41; 0.96)	0.43	0.21 (0.16; 0.28)	<0.001
2005	0.77 (0.67; 0.88)	<0.001	-0.52 (-1.15; 0.11)	0.11	0.25 (0.19; 0.31)	<0.001
Interaction	not significant	0.74	highly significant	<0.001	highly significant	<0.001
East X 1997			1.86 (0.79; 2.94)	0.001	3.31 (2.13; 5.16)	<0.001
East X 2005			3.15 (2.22; 4.08)	<0.001	2.27 (1.57; 3.29)	<0.001

	DMFT-Index		Subjects with ≤20 teeth		Number of ST	
Variable	B (95% CI)	p	OR (95% CI)	P	B (95% CI)	p
Region (ref. West)						
East	-3.16 (-3.92; -2.39)	<0.001	1.44 (1.07; 1.93)	0.02	3.16 (2.39; 3.92)	<0.001
Survey year (ref. 1989/92)						
1997	-0.93 (-1.71; -0.15)	0.02	1.12 (0.80; 1.57)	0.51	0.93 (0.15; 1.71)	0.02
2005	-2.50 (-3.23; -1.77)	<0.001	0.65 (0.45; 0.96)	0.03	2.50 (1.77; 3.23)	<0.001
Interaction	highly significant	<0.001	not significant	0.34	highly significant	<0.001
East X 1997	3.34 (2.09; 4.59)	<0.001			-3.34 (-4.59; -2.09)	<0.001
East X 2005	3.68 (2.62; 4.74)	<0.001			-3.68 (-4.74; -2.62)	<0.001

J Clin Periodontol 2015; 42: 121–130 doi: 10.1111/jcpe.12352

Journal of Clinical Periodontology

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

Svenja Schützhold[1], Thomas Kocher[1], Reiner Biffar[2], Thomas Hoffmann[3], Carsten O. Schmidt[4], Wolfgang Micheelis[5], Rainer Jordan[5] and Birte Holtfreter[1]

[1]Unit of Periodontology, Department of Restorative Dentistry, Periodontology, and Endodontology, University Medicine, Ernst-Moritz-Arndt-University Greifswald, Greifswald, Germany; [2]Department of Prosthodontics, Gerodontology, and Biomaterials, Centre of Oral Health, Greifswald University, Greifswald, Germany; [3]Department of Periodontology, Medical Faculty Carl Gustav Carus, Dresden, Germany; [4]Institute for Community Medicine, University Medicine of Greifswald, Greifswald, Germany; [5]Institute of German Dentists, Köln, Germany

Schützhold S, Kocher T, Biffar R, Hoffmann T, Schmidt CO, Micheelis W, Jordan R, Holtfreter B. Changes in prevalence of periodontitis in two German population-based studies. J Clin Periodontol 2015; 42: 121–130. doi: 10.1111/jcpe.12352.

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

Accepted for publication 2 December 2014

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.

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

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 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

	Age (years)	SHIP-0, 1997–2001 (n = 3551)			SHIP-Trend, 2008–2012 (n = 3431)		
AL		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)*

			DMS III, 1997 (n = 1009/445 #)			DMS IV, 2005 (n = 1115/553 #)		
	AL	Age (years)	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.

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%

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)

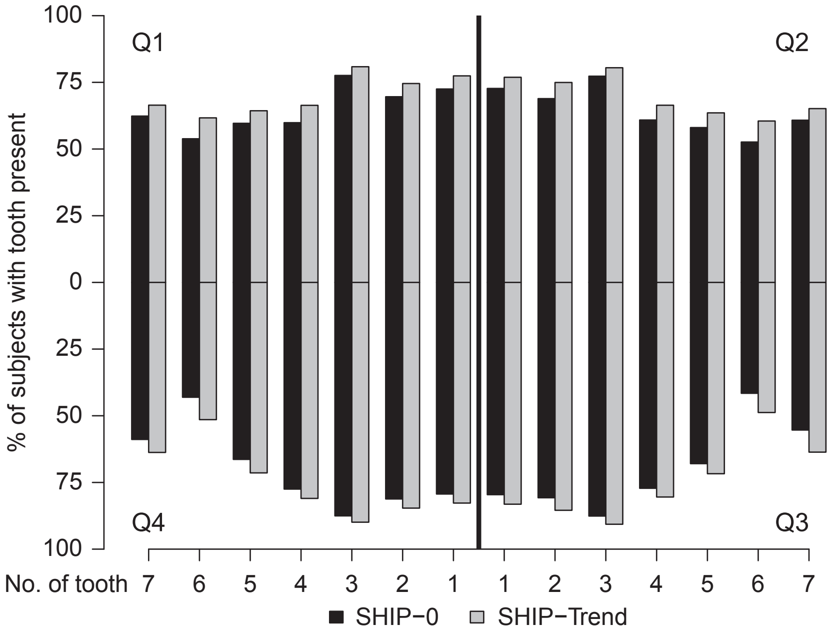

Fig. 1. Percentage of subjects with the respective tooth present at each specific position for all teeth in all quadrants in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend). Analyses were weighted.

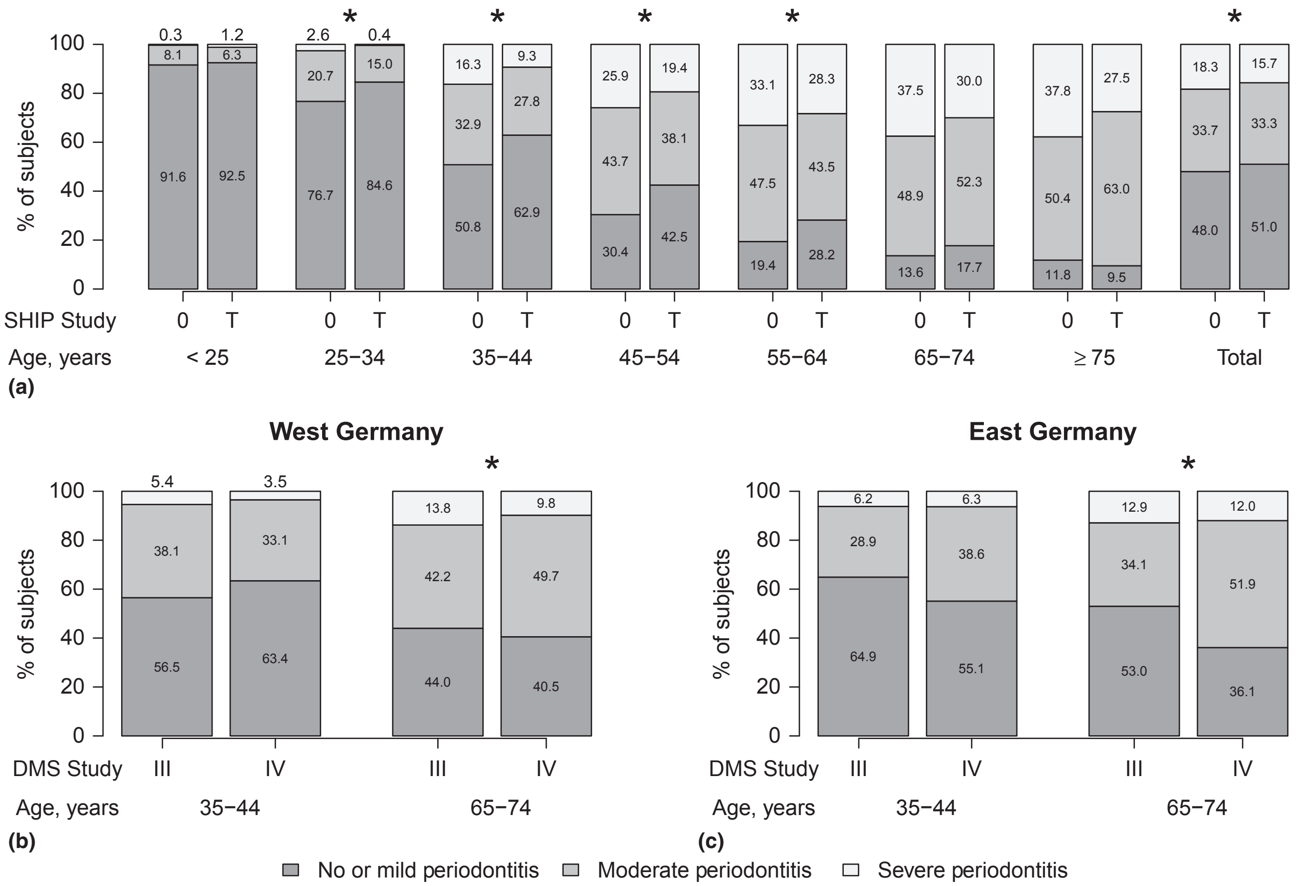

Fig. 2. Percentage distribution of subjects classified according to the CDC-AAP classification (Page & Eke 2007) and according to age in (a) the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV, separately reported for (b) West and (c) East Germany). 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

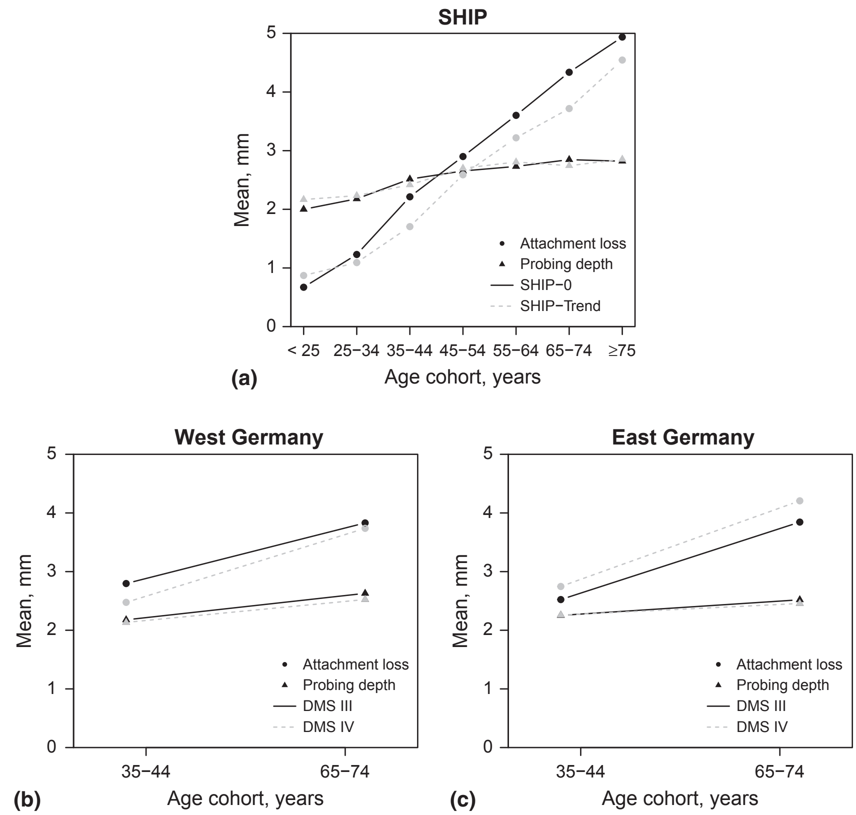

Fig. 3. Changes in mean attachment loss and mean probing depth according to age in (a) the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend) and the German Oral Health Studies (DMS III and IV, separately reported for (b) West and (c) East Germany). Analyses were weighted.

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.

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.

References

Atzpodien, K., Bergmann, E., Bertz, J., Busch, M., Eis, D., Ellert, U., Fuchs, J., Gaber, E., Gutsche, J., Haberland, J., Hagen, C., Hapke, U., Heidemann, C., Helm, D., Hintzpeter, B., Jordan, S., Knopf, H., Kraywinkel, K., Kroll, L. E., Kurth, B.-M., Lampert, T., Langen, U., Laußmann, D., List, S. M., Mensink, G. B. M., Neuhauser, H., Nowossadeck, E., Poethko-Müller, C., Ryl, L., Saß, A.-C., Scheidt-Nave, C., Schlaud, M., Schmitz, R., Starker, A., Thelen, J., Wolf, U., Ziese, T., Hoffmann, W., Kilian, H., Orth, B. & Völzke, H. (2009) 20 Jahre nach dem Fall der Mauer: Wie hat sich die Gesundheit in Deutschland entwickelt? [20 years after reunification: How did health develop in Germany?]. In: Robert Koch-Institut. (eds). *Beiträge zur Gesundheitsberichterstattung des Bundes*, pp. 71–144. Berlin: R. K. Institut.

Baelum, V. & Lopez, R. (2013) Periodontal disease epidemiology - learned and unlearned? *Periodontology 2000* **62**, 37–58.

Baelum, V., Manji, F., Fejerskov, O. & Wanzala, P. (1993) Validity of CPITN's assumptions of hierarchical occurrence of periodontal conditions in a Kenyan population aged 15-65 years. *Community Dentistry and Oral Epidemiology* **21**, 347–353.

Dye, B. A., Tan, S., Smith, V., Lewis, B. G., Barker, L. K., Thornton-Evans, G., Eke, P. I., Beltran-Aguilar, E. D., Horowitz, A. M. & Li, C. H. (2007) Trends in oral health status: United States, 1988–1994 and 1999–2004. *Vital and Health Statistics. Series 11: Data from the National Health Survey*, **00**, 1–92.

Gjermo, P. E. (2005) Impact of periodontal preventive programmes on the data from epidemiologic studies. *Journal of Clinical Periodontology* **32** (Suppl 6), 294–300.

Gjermo, P., Rosing, C. K., Susin, C. & Oppermann, R. (2002) Periodontal diseases in Central and South America. *Periodontology 2000* **29**, 70–78.

Haisman-Welsh, R. J. & Thomson, W. M. (2012) Changes in periodontitis prevalence over two decades in New Zealand: evidence from the 1988 and 2009 national surveys. *New Zealand Dental Journal* **108**, 134–138.

Hensel, E., Gesch, D., Biffar, R., Bernhardt, O., Kocher, T., Splieth, C., Born, G. & John, U. (2003) Study of Health in Pomerania (SHIP): a health survey in an East German region. Objectives and design of the oral health section. *Quintessence International* **34**, 370–378.

Hirotomi, T., Kocher, T., Yoshihara, A., Biffar, R., Micheelis, W., Hoffmann, T., Miyazaki, H. & Holtfreter, B. (2014) Comparison of periodontal conditions among three elderly populations in Japan and Germany. *Journal of Clinical Periodontology* **41**, 633–642.

Holst, D. & Schuller, A. A. (2011) Equality in adults' oral health in Norway. Cohort and cross-sectional results over 33 years. *Community Dentistry and Oral Epidemiology* **39**, 488–497.

Holtfreter, B., Alte, D., Schwahn, C., Desvarieux, M. & Kocher, T. (2012a) Effects of different manual periodontal probes on periodontal measurements. *Journal of Clinical Periodontology* **39**, 1032–1041.

Holtfreter, B., Demmer, R. T., Bernhardt, O., Papapanou, P. N., Schwahn, C., Kocher, T. & Desvarieux, M. (2012b) A comparison of periodontal status in the two regional, population-based studies of SHIP and INVEST. *Journal of Clinical Periodontology* **39**, 1115–1124.

Holtfreter, B., Kocher, T., Hoffmann, T., Desvarieux, M. & Micheelis, W. (2010) Prevalence of periodontal disease and treatment demands based on a German dental survey (DMS IV). *Journal of Clinical Periodontology* **37**, 211–219.

Holtfreter, B., Schwahn, C., Biffar, R. & Kocher, T. (2009) Epidemiology of periodontal diseases in the Study of Health in Pomerania. *Journal of Clinical Periodontology* **36**, 114–123.

Houshmand, M., Holtfreter, B., Berg, M. H., Schwahn, C., Meisel, P., Biffar, R., Kindler, S.

& Kocher, T. (2012) Refining definitions of periodontal disease and caries for prediction models of incident tooth loss. *Journal of Clinical Periodontology* **39**, 635–644.
Hugoson, A., Sjodin, B. & Norderyd, O. (2008) Trends over 30 years, 1973–2003, in the prevalence and severity of periodontal disease. *Journal of Clinical Periodontology* **35**, 405–414.
John, U., Greiner, B., Hensel, E., Ludemann, J., Piek, M., Sauer, S., Adam, C., Born, G., Alte, D., Greiser, E., Haertel, U., Hense, H. W., Haerting, J., Willich, S. & Kessler, C. (2001) Study of Health In Pomerania (SHIP): a health examination survey in an east German region: objectives and design. *Sozial- und Praventivmedizin* **46**, 186–194.
Kalsbeek, H., Truin, G. J., Poorterman, J. H., van Rossum, G. M., van Rijkom, H. M. & Verrips, G. H. (2000) Trends in periodontal status and oral hygiene habits in Dutch adults between 1983 and 1995. *Community Dentistry and Oral Epidemiology* **28**, 112–118.
Kalsbeek, H., Truin, G. J., van Rossum, G. M., van Rijkom, H. M., Poorterman, J. H. & Verrips, G. H. (1998) Trends in caries prevalence in Dutch adults between 1983 and 1995. *Caries Research* **32**, 160–165.
Keil, U., Stieber, J., Doring, A., Chambless, L., Hartel, U., Filipiak, B., Hense, H. W., Tietze, M. & Gostomzyk, J. G. (1988) The cardiovascular risk factor profile in the study area Augsburg. Results from the first MONICA survey 1984/85. *Acta Medica Scandinavica. Supplementum* **728**, 119–128.
Kingman, A. & Albandar, J. M. (2002) Methodological aspects of epidemiological studies of periodontal diseases. *Periodontology 2000* **29**, 11–30.
Konig, 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. *European Journal of Dental Education* **14** (Suppl 1), 4–24.
Micheelis, W. & Reich, E. (1999) *Dritte Deutsche Mundgesundheitsstudie (DMS III). Ergebnisse, Trends und Problemanalysen auf der Grundlage bevölkerungsrepräsentativer Stichproben in Deutschland 1997*. Köln: Deutscher Zahnärzte Verlag.
Micheelis, W. & Schiffner, U. (2006) *Vierte Deutsche Mundgesundheitsstudie (DMS IV)*. Köln: Deutscher Zahnärzte Verlag.
Owens, J. D., Dowsett, S. A., Eckert, G. J., Zero, D. T. & Kowolik, M. J. (2003) Partial-mouth assessment of periodontal disease in an adult population of the United States. *Journal of Periodontology* **74**, 1206–1213.
Page, R. C. & Eke, P. I. (2007) Case definitions for use in population-based surveillance of periodontitis. *Journal of Periodontology* **78**, 1387–1399.
R Core Team (2013) *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.
Rothlisberger, B., Kuonen, P., Salvi, G. E., Gerber, J., Pjetursson, B. E., Attstrom, R., Joss, A. & Lang, N. P. (2007) Periodontal conditions in Swiss army recruits: a comparative study between the years 1985, 1996 and 2006. *Journal of Clinical Periodontology* **34**, 860–866.
Savage, A., Eaton, K. A., Moles, D. R. & Needleman, I. (2009) A systematic review of definitions of periodontitis and methods that have been used to identify this disease. *Journal of Clinical Periodontology* **36**, 458–467.
Schmidt, C. O., Alte, D., Volzke, H., Sauer, S., Friedrich, N. & Valliant, R. (2011) Partial misspecification of survey design features sufficed to severely bias estimates of health-related outcomes. *Journal of Clinical Epidemiology* **64**, 416–423.
Schutzhold, S., Holtfreter, B., Hoffmann, T., Kocher, T. & Micheelis, W. (2013) Trends in dental health of 35- to 44-year-olds in West and East Germany after reunification. *Jour al of Public Health Dentistry* **73**, 65–73.
Skudutyte-Rysstad, R. & Eriksen, H. M. (2007) Changes in caries experience among 35-year-old Oslo citizens, 1973–2003. *Acta Odontologica Scandinavica* **65**, 72–77.
Skudutyte-Rysstad, R., Eriksen, H. M. & Hansen, B. F. (2007) Trends in periodontal health among 35-year-olds in Oslo, 1973–2003. *Journal of Clinical Periodontology* **34**, 867–872.
StataCorp (2009) *Stata Statistical Software: Release 11*. College Station, TX: StataCorp LP.
Susin, C., Kingman, A. & Albandar, J. M. (2005) Effect of partial recording protocols on estimates of prevalence of periodontal disease. *Journal of Periodontology* **76**, 262–267.
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. *International Journal of Epidemiology* **40**, 294–307.
White, D., Pitts, N., Steele, J., Sadler, K. & Chadwick, B. (2011) 2: Disease and related disorders – a report from the Adult Dental Health Survey 2009. In: Sullivan, I. O. (ed.). pp. 20–50. The Information Centre for Health and Social Care.

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).

Address:
Svenja Schützhold
Unit of Periodontology
Department of Restorative Dentistry, Periodontology, and Endodontology
University Medicine
Ernst-Moritz-Arndt University Greifswald
Rotgerberstr. 8, 17475 Greifswald
Germany
E-mail: svenja.schuetzhold@uni-greifswald.de

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.

Supplement Table 1: Demographics of the study samples for subjects with probing depth data in the Studies of Health in Pomerania (SHIP-0 and SHIP-Trend). Data are presented as numbers with percentages.

	SHIP-0, 1997-2001 (n=3736)			SHIP-Trend, 2008-2012 (n=3620)		
Age (years)	Total No.	Males No. (%)	Females No. (%)	Total No.	Males No. (%)	Females No. (%)
20-29	589	273 (46.3%)	316 (53.7%)	355	176 (49.6%)	179 (50.4%)
30-39	752	352 (46.8%)	400 (53.2%)	619	283 (45.7%)	336 (54.3%)
40-49	735	345 (46.9%)	390 (53.1%)	801	382 (47.7%)	419 (52.3%)
50-59	736	346 (47.0%)	390 (53.0%)	788	385 (48.9%)	403 (51.1%)
60-69	601	322 (53.6%)	279 (46.4%)	666	320 (48.1%)	346 (51.9%)
70-81/84[#]	323	179 (55.4%)	144 (44.6%)	391	218 (55.7%)	173 (44.3%)
Total	3736	1817 (48.6%)	1919 (51.4%)	3620	1764 (48.7%)	1856 (51.3%)

SHIP, Study of Health in Pomerania; No., Number; %, percentage; [#]SHIP-0: 70-81, SHIP-Trend: 70-84

Supplement 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). Analyses were weighted.

		SHIP-0, 1997-2001 (n=3551)			SHIP-Trend, 2008-2012 (n=3431)		
AL	Age (years)	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	20-29	63.4 (2.2)	2.6 (0.1)	21.9 (1.2)	49.1 (2.8)*	2.0 (0.2)*	15.3 (1.3)*
	30-39	90.1 (1.2)	5.2 (0.1)	50.2 (1.1)	75.7 (1.8)*	3.4 (0.1)*	30.1 (1.3)*
	40-49	96.7 (0.7)	6.5 (0.1)	72.3 (1.3)	92.6 (0.9)*	5.5 (0.1)*	56.4 (1.2)*
	50-59	98.3 (0.5)	6.5 (0.1)	82.6 (1.0)	96.4 (0.7)*	5.9 (0.1)*	73.0 (1.1)*
	60-69	100 (0)	5.7 (0.1)	91.3 (0.7)	99.1 (0.4)*	5.9 (0.1)	84.4 (1.0)*
	70-81/84[#]	100 (0)	4.4 (0.2)	95.7 (0.9)	99.6 (0.4)	5.0 (0.2)*	89.9 (1.2)*
	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	20-29	11.2 (1.3)	0.2 (0.03)	1.6 (0.2)	6.2 (1.3)*	0.2 (0.05)*	1.3 (0.4)*
	30-39	35.8 (1.9)	0.9 (0.1)	9.9 (0.8)	19.3 (1.6)*	0.5 (0.1)*	4.7 (0.5)*
	40-49	64.0 (1.9)	2.4 (0.1)	29.8 (1.3)	48.1 (1.8)*	1.6 (0.1)*	17.7 (1.0)*
	50-59	78.8 (1.7)	3.0 (0.1)	42.3 (1.4)	66.9 (1.7)*	2.5 (0.1)*	33.4 (1.3)*
	60-69	87.1 (1.5)	3.1 (0.1)	56.1 (1.6)	77.8 (1.7)*	2.9 (0.1)*	45.5 (1.6)*
	70-81/84[#]	90.3 (1.9)	2.9 (0.1)	69.4 (2.5)	86.4 (1.9)	3.0 (0.1)	59.6 (2.2)*
	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)*

SHIP, Study of Health in Pomerania; No., Number; %, percentage; SE, standard error; AL, attachment loss

* $p<0.05$, Mann-Whitney U test or chi-square test, as appropriate, to detect differences between SHIP-0 and SHIP-Trend;

[#]SHIP-0: 70-81, SHIP-Trend: 70-84

Supplement 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). Analyses were weighted.

		SHIP-0, 1997-2001 (n=3736)			SHIP-Trend, 2008-2012 (n=3620)		
PD	Age (years)	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	20-29	43.6 (2.0)	1.3 (0.1)	10.2 (0.7)	49.0 (2.7)	1.5 (0.1)	11.6 (1.0)
	30-39	63.1 (1.8)	2.3 (0.1)	20.6 (1.0)	60.1 (2.1)	2.5 (0.1)	20.0 (1.1)
	40-49	82.6 (1.4)	3.5 (0.1)	36.8 (1.1)	73.3 (1.6)*	3.5 (0.1)	31.0 (1.2)*
	50-59	81.3 (1.5)	3.2 (0.1)	39.2 (1.4)	81.6 (1.4)	3.8 (0.1)*	40.7 (1.3)
	60-69	78.5 (1.8)	2.7 (0.1)	41.7 (1.4)	81.1 (1.6)	3.4 (0.1)*	42.2 (1.4)
	70-81/84[#]	71.2 (2.6)	1.9 (0.1)	43.1 (2.3)	74.5 (2.3)	2.7 (0.1)*	41.9 (1.9)
	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	20-29	5.6 (1.0)	0.1 (0.02)	0.6 (0.1)	4.2 (1.1)	0.1 (0.04)	0.8 (0.3)
	30-39	16.2 (1.4)	0.4 (0.05)	3.7 (0.4)	10.2 (1.2)*	0.2 (0.04)*	1.8 (0.3)*
	40-49	33.9 (1.7)	0.9 (0.1)	10.4 (0.9)	25.9 (1.6)*	0.6 (0.1)*	6.1 (0.6)*
	50-59	38.7 (1.9)	0.9 (0.1)	12.7 (1.0)	29.7 (1.6)*	0.9 (0.1)*	10.0 (0.7)*
	60-69	34.4 (1.9)	0.7 (0.1)	13.4 (1.0)	32.6 (1.9)	0.7 (0.1)	9.7 (0.8)
	70-81/84[#]	31.4 (2.7)	0.5 (0.1)	14.2 (1.6)	24.4 (2.2)	0.5 (0.1)	8.7 (1.0)*
	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)*

SHIP, Study of Health in Pomerania; No., Number; %, percentage; SE, standard error; PD, probing depth

* p<0.05, Mann-Whitney U test or chi-square test, as appropriate, to detect differences between SHIP-0 and SHIP-Trend;

[#]SHIP-0: 70-81, SHIP-Trend: 70-84

Supplement 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). Analyses were weighted.

	SHIP-0, 1997-2001 (n=4288)		SHIP-Trend, 2008-2012 (n=4321)	
Age (years)	Edentulism % (SE)	No. of teeth of dentates mean (SE)	Edentulism % (SE)	No. of teeth of dentates mean (SE)
20-29	0 (0)	26.3 (0.1)	0 (0)	27.2 (0.1)*
30-39	0.5 (0.5)	23.8 (0.1)	0 (0)	26.0 (0.1)*
40-49	1.1 (0.4)	21.2 (0.2)	0.5 (0.2)	23.7 (0.2)*
50-59	5.1 (0.8)	18.7 (0.3)	5.3 (0.7)	20.1 (0.2)*
60-69	21.8 (1.5)	14.4 (0.3)	10.2 (1.1)*	17.5 (0.3)*
70-81/84#	43.5 (2.2)	9.7 (0.4)	21.2 (1.7)*	13.5 (0.3)*
Total	8.7 (0.4)	20.7 (0.1)	6.1 (0.4)*	21.6 (0.1)*

SHIP, Study of Health in Pomerania; No., Number; %, percentage; SE, standard error

* p<0.05, Mann-Whitney U test or chi-square test, as appropriate, to detect differences between SHIP-0 and SHIP-Trend; #SHIP-0: 70-81, SHIP-Trend: 70-84

Supplement Table 5: 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). Analyses were weighted.

	SHIP-0, 1997-2001 (n=4288)			SHIP-Trend, 2008-2012 (n=3347)		
Age (years)	No or mild (%)	Moderate (%)	Severe (%)	No or mild (%)	Moderate (%)	Severe (%)
20-29	87.9	11.2	0.9	89.2	10.1	0.7
30-39	66.1	26.6	7.3	75.5	21.1	3.4*
40-49	36.2	41.3	22.5	51.7	34.7	13.6*
50-59	24.2	44.3	31.5	35.6	38.7	25.7*
60-69	15.9	48.2	35.9	20.2	50.4	29.4
70-81/84[#]	11.0	53.3	35.7	13.6	57.1	29.3
Total	48.0	33.7	18.3	51.0	33.3	15.7*

SHIP, Study of Health in Pomerania; %, percentage

* p<0.05, Mann-Whitney U test or chi-square test, as appropriate, to detect differences between SHIP-0 and SHIP-Trend; [#]SHIP-0: 70-81, SHIP-Trend: 70-84