Trends in periodontal status: results from the German Oral Health Studies from 2005 to 2023

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Objectives: The objective of this study was twofold: firstly, to provide an overview of trends in periodontal status among younger adults aged 35 to 44 years and younger seniors aged 65 to 74 years between 2005 and 2023, based on data from the German Oral Health Studies (DMS); secondly, to quantify the extent to which observed differences in tooth count variables between consecutive studies can be attributed to differences in characteristics. **Method and materials:** The data from DMS IV (2005), DMS V (2014), and DMS • 6 (2023) were analyzed. The participants completed questionnaires concerning their oral health behaviors, and general and oral health. For this analysis, probing depths (PD) were calculated from three sites on 12 index teeth as a common denominator. The number of teeth, severity, and extent of PD and the Community Periodontal Index (CPI) were reported. Multivariate decomposition was employed to analyze differences by time. **Results:** The proportion of edentate younger seniors notably declined, from 23.2% to 5.4%, between 2005 and 2023. Similarly, the mean number of teeth for dentate younger seniors was 2.4 teeth higher in DMS • 6. While the mean PD remained 2.4 mm for younger adults and 2.8 mm for younger seniors, inconsistent patterns were observed for extent variables. In most cases, a decline of the extent variables was observed between DMS IV and DMS V, with a rebound at DMS • 6 for severe cases in younger seniors (with PD ≥ 6 mm). The proportion of younger adults and seniors with CPI scores of 0 to 2 increased considerably between DMS IV and DMS V, but rebounded at DMS • 6. Overall, the prevalence of these cases increased by approximately 10% points and 5% points, respectively. The majority of the observed reduction in the number of missing teeth (in younger adults) or the prevalence of having less than 20 teeth (in younger seniors) between DMS IV and DMS V and between DMS V and DMS • 6 were explained by an increase in the proportion of highly educated individuals, an increase in the proportion of those who have never smoked (only younger adults), an increase in the proportion of individuals using electric toothbrushes or interdental cleaning devices, and a reduction in the proportion of individuals with lifetime periodontal treatment. **Conclusion:** Over the last two decades, there has been a significant improvement in periodontal health in Germany, with the most notable enhancements occurring between DMS IV and DMS V. The prevalence of periodontal disease has decreased significantly in recent decades, largely due to the implementation of preventive measures. This underscores the importance of integrating preventive measures into dental practice as a public health strategy. *(Quintessence Int 2025;56(Suppl):S48–S58; doi: 10.3290/j.qi.b5981996)*

Keywords: dental care, dentists, DMS 6, multivariate decomposition, number of missing teeth, periodontitis, trend analysis

The German Oral Health Studies (DMS), which have been repeatedly conducted since 1997 and are representative of the population in Germany, have revealed a significant improvement in oral health. Between 1997 (DMS III) and 2014 (DMS V), the prevalence of edentulism in adults and seniors decreased from 1.1% and 24.8% to 0.8% and 12.4%, respectively. The mean number of teeth increased from 23.8 and 10.4 to 25.9 and 16.9, respectively.[1] In addition, the prevalence of periodontitis decreased, as indicated by a reduction in Community Periodontal Index (CPI) score 4 from 9.3% and 10.5% to 3.5% and 9.8%, respectively. This raised the question of whether this improvement would continue in the current 6th German Oral Health Study (DMS • 6) and whether the retention of more teeth would increase the need for periodontal treatment.

Representative, population-wide health surveys can be used to assess the prevalence of diseases and their determinants, and thus to analyze past developments and possibly extrapolate future trends. Health surveys are a prerequisite for sustainable and effective changes or improvements in the structures of a health care system. In addition to the prevalence of diseases, the prevalence of upstream (prevention strategies for the whole community) and downstream (individual treatment) determinants may change over time. An example of an upstream determinant is the restriction on smoking. As a result of legislative measures, fewer and fewer men have taken up smoking in Germany over recent decades, which is reflected in the lower number of lung cancer cases.[2] As an example of a downstream determinant, the increased use of interdental cleaning aids and electric toothbrushes has contributed to an increase in the number of teeth.[3] Only repeated cross-sectional studies can detect changes in the prevalence of a disease and its determinants. If prevalence data are available for both the disease and the risk factors, it is possible to determine whether changes in the prevalence of a risk factor have contributed to changes in the prevalence of the disease.

The aim of the present study was to evaluate trends in periodontal status, the number of teeth, and edentulism using data from three repeated national DMS studies (DMS IV, DMS V, DMS • 6). It was also examined whether changes in the number of missing teeth could be explained by changes in the main determinants of oral health.

Method and materials

Repeated cross-sectional data from 2005 (DMS IV), 2014 (DMS V), and 2023 (DMS • 6) were analyzed separately for younger adults and younger seniors*. The design, sampling, and non-response analyses of DMS IV, V, and 6 have been described in detail elsewhere.[4-7] This analysis included data from 923/1,013, 966/1,019, and 912/740 younger adults/younger seniors from DMS IV, DMS V, and DMS • 6, respectively.

In DMS IV and V, probing depth (PD) was measured at midbuccal, mesiobuccal, and distolingual sites on 12 index teeth (teeth 17, 16, 11, 24, 26, 27, 47, 46, 44, 31, 36, 37, according to FDI notation) using a WHO periodontal probe (PCP 11.5 WHO probe, M+W Dental). In DMS • 6, PD was recorded at six sites on all present teeth except third molars using a 1-mm marked periodontal probe (PCPUNC 15, Zantomed). In order to ensure comparability between the three studies, only measurements from the 12 index teeth with three sites each were used for the current analysis. PD measurements were used to compare periodontal status between waves.

At each DMS wave, an interview was conducted and a selection of demographic, medical, and dental determinants were recorded. When necessary, questions were harmonized across waves to ensure consistency: age, gender, school education (< 10/10/> 10 years), smoking status (never/former/current smoker), body mass index (BMI), diabetes mellitus (yes/no), tooth brushing frequency (at least twice daily, less than twice daily), use of interdental aids (dental floss, toothpicks, interdental brushes, or multiuser [yes/no]), use of an electric toothbrush (yes/no), frequency of dental visits (more than once a year, once a year, rarely), dental service utilization (complaint-oriented, control-oriented), lifetime periodontal treatment (yes/no).

Statistical analysis

Multivariate decomposition[8] was employed to estimate the extent to which differences in the distribution of the dependent variable between two examinations (DMS IV and DMS V; DMS V and DMS • 6) are attributable to differences in distributions of independent variables (ie, differences in characteristics). In particular, the differences in the distribution of the dependent variables between consecutive DMS studies were decomposed into those attributable to differences in the distributions of independent variables (also referred to as "differences in characteristics" or the "explained component" or "characteristics effects") and those resulting from differences in the associations of independent variables and tooth count variables within studies (also referred to as "differences in coefficients" or "unexplained component" or "coefficient effects"). Decompositions were calculated for Poisson (younger adults: "number of missing teeth" as dependent variable) and logistic regression models (younger seniors: "having less than 20 teeth" as dependent variable). The models for differences in characteristics were reported, including beta coefficients and 95% confidence intervals (CIs). The differences in characteristics models assist in determining the extent to which observed changes in the dependent variable can be attributed to changes in the independent variables.

*In DMS IV and V, participants aged 35 to 44 years were referred to as "adults" and those aged 65 to 75 years as "seniors." Here, we are using the terminology of DMS • 6: "younger adults" (35- to 44-year-olds) and "younger seniors" (65- to 74-year-olds).

Table 1 Baseline characteristics of study participants for younger adults (35- to 44-year-olds) and younger seniors (65- to 74-year-olds) in DMS IV, DMS V, and DMS • 6

Variable		DMS IV		DMS V		DMS • 6	
		35- to 44-year-olds	65- to 74-year-olds	35- to 44-year-olds	65- to 74-year-olds	35- to 44-year-olds	65- to 74-year-olds
No. of participants (n)		923	1,013	966	1,019	912	740
Age, years		39.0 ± 2.9	68.8 ± 2.7	39.8 ± 2.9	69.4 ± 3.0	40.1 ± 2.9	69.7 ± 2.8
	Missing	0	0	5	1	1	1
Gender	Male	406 (44.0%)	473 (46.7%)	453 (46.9%)	476 (46.7%)	453 (49.7%)	343 (46.4%)
	Female	517 (56.0%)	540 (53.3%)	513 (53.1%)	543 (53.3%)	458 (50.2%)	397 (53.6%)
	Diverse	NA	NA	NA	NA	1 (0.1%)	0 (0.0%)
	Missing	0	0	0	0	0	0
School education	< 10 years	198 (21.7%)	647 (65.6%)	160 (16.6%)	465 (47.3%)	83 (9.7%)	170 (24.3%)
	10 years	421 (46.1%)	171 (17.3%)	391 (40.6%)	261 (26.5%)	265 (31.1%)	261 (37.3%)
	> 10 years	294 (32.2%)	168 (17.0%)	413 (42.8%)	258 (26.2%)	504 (59.2%)	269 (38.4%)
	Missing	10	27	2	35	60	40
Smoking status	Never smoked	410 (44.8%)	614 (61.8%)	451 (46.8%)	537 (53.0%)	497 (54.8%)	360 (48.9%)
	Former smoker	182 (19.9%)	295 (29.7%)	238 (24.7%)	356 (35.1%)	178 (19.6%)	279 (37.9%)
	Current smoker	323 (35.3%)	84 (8.5%)	274 (28.5%)	121 (11.9%)	232 (25.6%)	97 (13.2%)
	Missing	8	20	3	5	5	4
Body mass index, kg/m^2		25.6 ± 5.3	27.4 ± 4.4	26.0 ± 5.0	27.2 ± 4.5	26.2 ± 5.5	27.3 ± 4.9
	Missing	6	24	10	21	61	46
Diabetes mellitus	No	NA	817 (83.4%)	947 (98.0%)	856 (84.0%)	881 (97.5%)	621 (84.6%)
	Yes	NA	163 (16.6%)	19 (2.0%)	163 (16.0%)	23 (2.5%)	113 (15.4%)
	Missing	NA	33	0	0	8	6
Tooth brushing (frequency)	≥ 2 times daily	780 (85.1%)	797 (80.3%)	800 (83.1%)	855 (84.2%)	743 (81.9%)	579 (83.9%)
	< 2 times daily	137 (14.9%)	196 (19.3%)	163 (16.9%)	160 (15.8%)	164 (18.1%)	111 (16.1%)
	Missing	6	20	3	4	5	50
Interdental cleaning aids (utilization)	No	416 (45.1%)	683 (67.4%)	367 (38.0%)	503 (49.4%)	303 (33.4%)	244 (35.4%)
	Dental floss	291 (31.5%)	85 (8.4%)	338 (35.0%)	120 (11.8%)	381 (42.0%)	110 (15.9%)
	Toothpick	75 (8.1%)	84 (8.3%)	48 (5.0%)	64 (6.3%)	17 (1.9%)	29 (4.2%)
	Interdental brushes	33 (3.6%)	90 (8.9%)	65 (6.7%)	187 (18.4%)	64 (7.1%)	160 (23.2%)
	Multiuser	108 (11.7%)	71 (7.0%)	148 (15.3%)	145 (14.2%)	142 (15.7%)	147 (21.3%)
	Missing	0	0	0	0	5	50
Electric toothbrush (utilization)	No	577 (62.5%)	839 (82.8%)	505 (52.3%)	672 (65.9%)	403 (44.4%)	335 (48.6%)
	Yes	346 (37.5%)	174 (17.2%)	461 (47.7%)	347 (34.1%)	504 (55.6%)	355 (51.4%)
	Missing	0	0	0	0	5	50
Dental visits (frequency)	> once a year	583 (63.7%)	523 (53.0%)	560 (58.4%)	641 (64.3%)	419 (46.5%)	400 (54.8%)
	Once a year	242 (26.4%)	269 (27.3%)	273 (28.5%)	247 (24.8%)	361 (40.0%)	248 (34.0%)
	Rarely	90 (9.8%)	194 (19.7%)	126 (13.1%)	109 (10.9%)	122 (13.5%)	82 (11.2%)
	Missing	8	27	7	22	10	10
Dental service utilization	Complaint-oriented	69 (7.6%)	140 (14.7%)	94 (9.8%)	88 (8.6%)	120 (13.2%)	87 (11.8%)
	Control-oriented	842 (92.4%)	815 (85.3%)	867 (90.2%)	930 (91.4%)	787 (86.8%)	648 (88.2%)
	Missing	12	58	5	1	5	5
Lifetime periodontal treatment (utilization)	Yes	223 (24.3%)	383 (38.9%)	192 (20.1%)	418 (41.7%)	112 (12.4%)	234 (31.9%)
	No	693 (75.7%)	602 (61.1%)	764 (79.9%)	585 (58.3%)	790 (87.6%)	499 (68.1%)
	Missing	7	28	10	16	10	7

Data are presented as numbers (percentages) or mean ± standard deviation based on unweighted data for edentate and dentate participants with complete periodontal findings (partial recording protocol: 12 index teeth with 3 sites).
NA, not available.

Table 2 Trends of prevalence, severity, and extent of periodontitis and the Community Periodontal Index (CPI) in younger adults (35- to 44-year-olds) and younger seniors (65- to 74-year-olds) from DMS IV to DMS • 6

Variable		35- to 44-year-olds			65- to 74-year-olds		
		DMS IV	DMS V	DMS • 6	DMS IV	DMS V	DMS • 6
No. of participants (n)	Including edentates	923	966	912	1,013	1,019	740
	Dentates only	914	962	911	773	902	703
The following data refer to a maximum of 28 teeth							
Edentulism (prevalence)		1.0% (0.5; 1.8)	0.8% (0.3; 1.4)	0.1% (0.0; 0.5)	23.2% (20.7; 25.8)	12.7% (10.7; 14.8)	5.4% (3.9; 7.2)
No. of teeth, including edentates		25.3 (25.0; 25.5)	25.9 (25.7; 26.2)	26.6 (26.5; 26.8)	14.1 (13.5; 14.7)	17.2 (16.7; 17.7)	19.6 (19.0; 20.2)
< 20 teeth, including edentates (prevalence)		5.4% (4.0; 6.9)	3.2% (2.2; 4.5)	2.1% (1.3; 3.2)	59.3% (56.2; 62.3)	45.4% (42.4; 48.5)	36.8% (33.4; 40.4)
< 20 teeth, dentates only (prevalence)		4.4% (3.3; 6.0)	2.5% (1.7; 3.6)	2.1% (1.3; 3.2)	47.0% (43.6; 50.6)	37.5% (34.4; 40.7)	33.2% (29.7; 36.6)
No. of teeth, dentates only		25.5 (25.3; 25.7)	26.1 (26.0; 26.3)	26.6 (26.5; 26.8)	18.3 (17.9; 18.8)	19.7 (19.3; 20.1)	20.7 (20.2; 21.2)
No. of crowned teeth, dentates only		5.0 (4.8; 5.3)	3.8 (3.6; 4.0)	1.5 (1.3; 1.6)	6.7 (6.4; 7.0)	7.6 (7.3; 7.9)	7.1 (6.7; 7.4)
Percentage of crowned teeth, dentates only (%)		21.2 (20.1; 22.3)	15.5 (14.7; 16.4)	5.9 (5.1; 6.8)	42.2 (40.1; 44.3)	43.0 (41.2; 44.6)	38.1 (36.0; 40.1)
No. of interdentally filled teeth, dentates only		6.4 (6.2; 6.7)	5.8 (5.6; 6.1)	3.3 (3.0; 3.5)	4.0 (3.8; 4.3)	4.1 (3.9; 4.3)	3.4 (3.1; 3.6)
Percentage of interdentally filled teeth, dentates only (%)		25.0 (24.1; 25.9)	22.5 (21.6; 26.5)	12.4 (11.6; 13.3)	20.6 (19.6; 21.7)	19.3 (18.5; 20.1)	15.5 (14.4; 16.6)
The following data refer to a maximum of 12 index teeth and 36 sites with periodontal examinations							
No. of periodontally examined index teeth		10.4 (10.3; 10.5)	10.8 (10.7; 10.9)	11.2 (11.1; 11.3)	6.6 (6.4; 6.8)	7.2 (7.0; 7.4)	8.1 (7.8; 8.3)
Mean PD, mm		2.4 (2.3; 2.4)	2.4 (2.3; 2.4)	2.3 (2.3; 2.4)	2.8 (2.8; 2.9)	2.8 (2.8;2.9)	2.8 (2.7; 2.9)
No. of teeth with PD ≤ 3 mm		6.9 (6.7; 7.2)	8.1 (7.9; 8.3)	8.4 (8.2; 8.7)	3.1 (2.9; 3.3)	4.1 (3.9; 4.3)	4.6 (4.4; 4.9)
No. of teeth with PD 4–5 mm		3.0 (2.8; 3.1)	2.4 (2.3; 2.6)	2.5 (2.3; 2.6)	2.7 (2.5; 2.8)	2.6 (2.4; 2.7)	2.7 (2.6; 2.9)
No. of teeth with PD ≥ 6 mm		0.5 (0.4; 0.6)	0.3 (0.2; 0.3)	0.3 (0.2; 0.4)	0.8 (0.7; 0.9)	0.5 (0.4; 0.6)	0.7 (0.6; 0.8)
Percentage of sites with PD ≥ 4 mm (%)		16.0 (14.9; 17.1)	13.0 (11.9; 14.2)	11.8 (10.7; 12.8)	28.1 (26.6; 29.7)	26.4 (24.6; 28.2)	24.2 (22.5; 25.9)
Percentage of sites with PD ≥ 6 mm (%)		2.0 (1.6; 2.3)	1.1 (0.8; 1.4)	1.2 (0.9; 1.5)	5.5 (4.7; 6.3)	3.7 (3.0; 4.3)	4.3 (3.6; 5.0)
Community Periodontal Index	Score 0–2 (equals prevalence of max PD ≤ 3 mm)	23.4% (20.7; 26.2)	40.8% (37.7; 43.9)	33.1% (30.1; 36.2)	10.2% (8.4; 12.1)	21.2% (18.8; 23.8)	14.8% (12.4; 17.5)
	Score 3 (equals prevalence of max PD 4–5 mm)	55.6% (52.4; 58.8)	47.7% (44.6; 50.9)	54.7% (51.4, 57.9)	37.5% (34.5; 40.5)	44.4% (41.4; 47.5)	49.4% (45.8; 53.0)
	Score 4 (equals prevalence of max PD ≥ 6 mm)	20.0% (17.5; 22.7)	10.7% (8.9; 12.8)	12.2% (10.2; 14.5)	29.1% (26.4; 31.9)	21.7% (19.2; 24.3)	30.4% (27.1; 33.7)
	Edentulous	1.0% (0.5; 1.8)	0.8% (0.3; 1.4)	0.1% (0.0; 0.5)	23.2% (20.7; 25.8)	12.7% (10.7; 14.8)	5.4% (3.9; 7.2)
The following data refer to a maximum of 28 teeth in individuals with CPI scores							
No. of teeth (max. 28) for individuals with a CPI score of	0–2	25.9 (25.4; 26.3)	26.6 (26.4; 26.8)	27.1 (26.9; 27.3)	15.6 (14.2; 17.1)	18.3 (17.3; 19.3)	20.0 (18.7; 21.4)
	3	25.6 (25.4; 25.9)	25.8 (25.6; 26.1)	26.5 (26.3; 26.7)	18.2 (17.5; 18.9)	20.1 (19.6; 20.7)	20.8 (20.1; 21.4)
	4	24.7 (24.2; 25.2)	25.7 (25.2; 26.3)	25.9 (25.3; 26.6)	19.5 (18.8; 20.2)	20.2 (19.4; 21.0)	21.0 (20.2; 21.8)

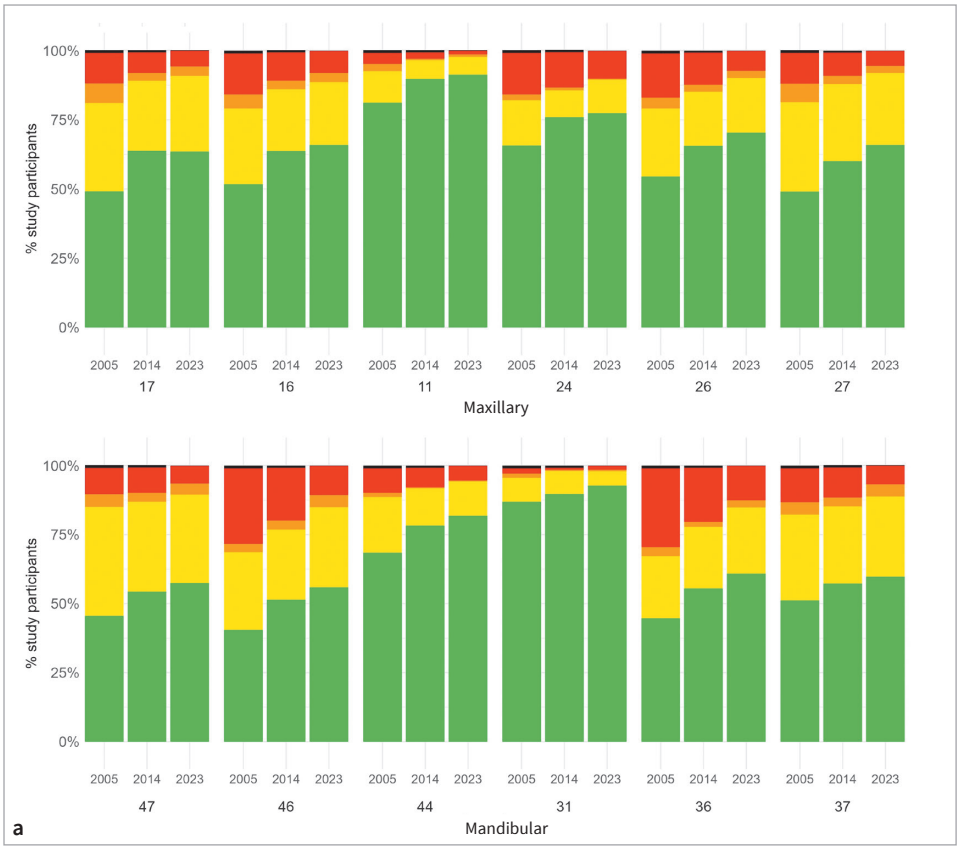
Data are presented as weighted percentages or weighted means (with 95% confidence intervals) for edentate and dentate participants with complete periodontal findings (partial recording protocol: 12 index teeth with 3 sites).
CPI, Community Periodontal Index; PD, probing depth.

All analyses were conducted using Stata/MP 18.0 (StataCorp 2023). *P* values < .05 were considered statistically significant. The recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were applied for reporting.[9]

Data handling and statistical methods, including statistical methods for trend analysis, have been described previously.[10]

Results

The proportion of younger adults and younger seniors with higher school education increased from 32.2% to 59.2% for younger adults and from 17.0% to 38.4% for younger seniors (Table 1). Conversely, the proportion of younger adults with low educational attainment decreased by 12% points, while



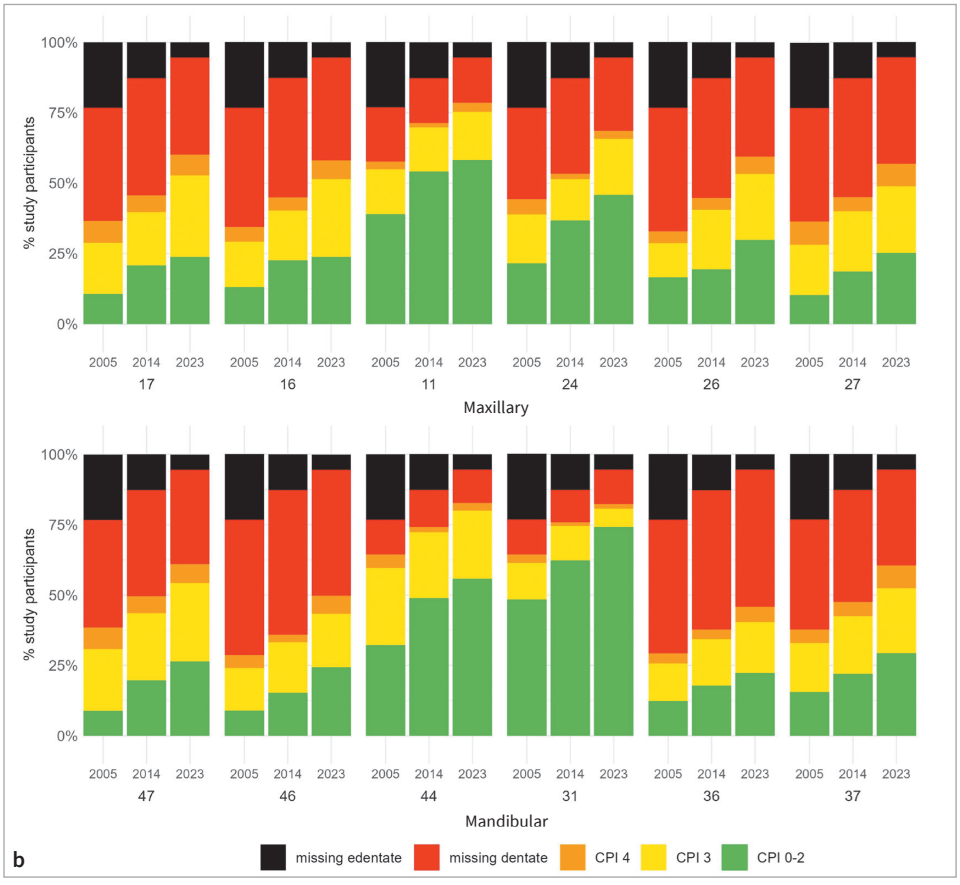


Fig 1a and b Percentage of edentates (black), missing teeth (red), and present teeth with maximum probing depths ≥ 6 mm/CPI 4 (orange), 4–5 mm/CPI 3 (yellow), and 1–3 mm/CPI 0–2 (green) for each index tooth in the maxilla and mandible for younger adults (35- to 44-year-olds) *(a)* and younger seniors (65- to 74-year-olds) *(b)* in DMS IV (2005), DMS V (2014), and DMS • 6 (2023), based on weighted data.

among younger seniors it decreased by approximately 40% points. The proportion of those who have never smoked increased by approximately 10% points among younger adults from DMS IV to DMS • 6, whereas it decreased from 61.8% to 48.9% among younger seniors. Neither the BMI (approximately 26 for younger adults and 27 for younger seniors) nor the percentage of diabetics (2% for younger adults and 16% for younger seniors) exhibited any change across the waves. More than 80% of both younger adults and younger seniors reported brushing their teeth at least twice daily. At DMS IV, 55% of younger adults and 33% of dentate younger seniors utilized an interdental cleaning device, with an upward trend in usage. The utilization of electric toothbrushes demonstrated an upward trajectory from DMS IV to DMS • 6, with an increase from 37.5% to 55.6% among younger adults and 17.2% to 51.4% among younger seniors. Approximately 90% of younger adults and younger seniors reported visiting a dental practitioner at least once a year. There was a notable decline in the proportion of younger adults (from 24.3% to 12.4%) and younger seniors (from 38.9% to 31.9%) who reported lifetime periodontal treatment.

The proportion of edentate participants exhibited a notable decline, from 1.0% to 0.1% for younger adults and 23.2% to 5.4% for younger seniors, between DMS IV and DMS • 6 (Table 2). Consequently, dentate younger adults had on average 1.1 more teeth in DMS • 6 compared to their DMS IV counterparts, while dentate younger seniors had 2.4 more teeth. The mean PD remained largely unchanged across the three waves, with a mean of 2.4 mm for younger adults and 2.8 mm for younger seniors. Although the number of teeth increased in both groups, the average number of teeth with PDs of 4 to 5 mm or ≥ 6 mm decreased markedly from DMS IV to DMS V. This decrease was observed in both younger adults (from 3.5 to 2.7) and younger seniors (from 3.5 to 3.1). No significant changes were observed from DMS V to DMS • 6 in either group. A comparable trend was identified in the number of teeth exhibiting PDs of 6 mm or greater in younger adults. In contrast, among younger seniors, this number demonstrated a decline from DMS IV to DMS V, followed by an increase by DMS • 6. The percentage of participants with CPI scores of 0 to 2 increased between DMS IV and DMS • 6, from 23.4% to 33.1% in younger adults and 10.2% to 14.8% in younger seniors. In younger adults grouped according to categories defined by CPI (Table 2, bottom rows), the total number of teeth exhibited an approximate increase of 1 between DMS IV and DMS • 6. For younger seniors with a CPI of 0 to 2, 3, or 4, the number of teeth demonstrated an increase of 4.4, 2.6, and 1.5 teeth, respectively, between DMS IV and DMS • 6.

Figure 1 shows the distribution of CPI scores and missing teeth in edentate and dentate individuals for each of the 12 index teeth. In younger adults and younger seniors, molars contributed more to the increased number of retained teeth than single-rooted teeth. The percentage of participants with a natural tooth (green, yellow, orange) increased linearly across waves for all age groups and tooth positions, with single-rooted teeth having higher baseline levels than molars. The proportion of younger adults with CPI scores of 0 to 2 increased between DMS IV and DMS V for all tooth positions, whereas the proportion of younger adults with CPI scores of 4 decreased for all tooth positions. The distribution of younger adults according to their CPI scores and tooth loss status for all tooth positions exhibited minimal variation between DMS V and DMS • 6. In all tooth positions, the proportion of younger seniors with CPI scores of 0 to 2 increased across all teeth and all waves. Only for molars did the proportion of younger seniors with CPI scores of 3 to 4 increase from DMS IV to DMS V and from DMS V to DMS • 6.

Finally, observed changes in tooth counts between consecutive DMS studies were decomposed into those attributable to differences in distributions of independent variables (ie, differences in characteristics) and those attributable to differences in associations of independent variables with tooth count variables (ie, differences in coefficients; Table 3). In younger adults, differences in characteristics accounted for 28.1% and 31.2% of the observed study differential in the number of missing teeth between DMS IV and DMS V (−0.786) and between DMS V and DMS • 6 (−0.510), respectively. Most of the observed reduction in the number of missing teeth was explained by an increase in the proportion of highly educated younger adults (beta −0.140 and −0.118) and an increase in the proportion of those who had never smoked (beta −0.016 and −0.069). The increase in the proportion of individuals using electric toothbrushes (beta −0.035 and −0.023) and interdental cleaning devices (beta −0.035 and −0.022) and the reduction in the proportion of individuals with lifetime periodontal treatment (beta −0.045 and −0.026) were also identified as contributing factors. In dentate younger seniors, differences in characteristics accounted for 26.2% and 67.6% of the observed differences in the prevalence of having less than 20 teeth between DMS IV and DMS V (−0.109) and between DMS V and DMS • 6 (−0.076), respectively. Most of this reduction was attributable to an increase in the proportion of highly educated younger seniors (beta −0.007 and −0.014), an increase in the proportion of former smokers (betas −0.004), an increase in the proportion of individuals using electric toothbrushes (beta −0.012 and −0.020) and interdental cleaning devices (beta −0.018 and −0.012), and a reduction in the proportion of individuals with lifetime periodontal treatment (DMS IV to DMS V only; beta −0.018). In dentate and edentate

Table 3a Results from multivariate decomposition models for dentate younger adults (35- to 44-year-olds; dependent variable: "number of missing teeth"; Poisson models)

					Decomposition for "Number of missing teeth"	
					DMS IV to DMS V	DMS V to DMS • 6
Difference					−0.786	−0.510
Due to difference in characteristics					−0.221 (28.1%)	−0.159 (31.2%)
Due to difference in coefficients					−0.566 (71.9%)	−0.351 (68.8%)
		Observed means and percentages*			Model for differences in characteristics	
		DMS IV	DMS V	DMS • 6	Coefficient	Coefficient
Age, years		39.0	39.8	40.1	0.088	0.018
Gender (ref. female)	Male	43.5%	46.7%	49.6%	−0.024	−0.010
School education (ref. < 10 years)	10 years	45.9%	40.5%	31.1%	0.020	0.045
	> 10 years	32.9%	43.6%	59.5%	−0.140	−0.118
Smoking status (ref. current smokers)	Former smokers	19.7%	24.8%	20.1%	−0.030	0.045
	Never smoked	45.3%	47.4%	54.9%	−0.016	−0.069
Body mass index, kg/m²		25.6	25.9	26.2	0.009	0.001
Diabetes mellitus (ref. no)	Yes	NA	1.8%	2.3%	NA	0.001
Tooth brushing frequency (ref. ≥ 2 times daily)	< 2 times daily	14.8%	16.9%	17.4%	−0.003	0.000
Electric toothbrush utilization (ref. no)	Yes	38.2%	48.5%	56.6%	−0.035	−0.023
Interdental cleaning aids utilization (ref. no)	Yes	56.2%	63.1%	68.2%	−0.035	−0.022
Dental visits frequency (ref. rarely)	≥ once a year	90.9%	87.4%	87.9%	−0.009	0.000
Lifetime periodontal treatment (ref. no)	Yes	24.3%	19.7%	13.2%	−0.045	−0.026

*Including only individuals from multivariate decomposition models.
Red text, positive statistically significant beta coefficients; Green text, negative statistically significant beta coefficients.
NA, not available.

Table 3b Results from multivariate decomposition models for dentate younger seniors (65- to 74-year-olds; dependent variable: "having less than 20 teeth"; coded as yes/no; logistic models)

					Decomposition for "Having less than 20 teeth"	
					DMS IV to DMS V	DMS V to DMS • 6
Difference					−0.109	−0.076
Due to difference in characteristics					−0.029 (26.2%)	−0.051 (67.6%)
Due to difference in coefficients					−0.081 (73.8%)	−0.025 (32.4%)
		Observed means and percentages*			Model for differences in characteristics	
		DMS IV	DMS V	DMS • 6	Coefficient	Coefficient
Age, years		68.6	69.3	69.7	0.008	0.004
Gender (ref. female)	Male	48.0%	46.8%	45.5%	0.001	0.001
School education (ref. < 10 years)	10 years	20.1%	28.4%	37.6%	−0.008	0.001
	> 10 years	20.5%	28.7%	40.4%	−0.007	−0.014
Smoking status (ref. current smokers)	Former smokers	31.0%	33.7%	37.7%	−0.004	−0.004
	Never smoked	62.1%	56.0%	50.6%	0.012	0.008
Body mass index, kg/m²		27.3	27.1	27.2	−0.0003	0.001
Diabetes mellitus (ref. no)	Yes	14.2%	14.9%	15.3%	0.001	0.0001
Tooth brushing frequency (ref. ≥ 2 times daily)	< 2 times daily	16.0%	15.5%	16.0%	0.001	0.0001
Electric toothbrush utilization (ref. no)	Yes	21.8%	37.7%	51.5%	−0.012	−0.020
Interdental cleaning aids utilization (ref. no)	Yes	42.2%	56.2%	64.8%	−0.018	−0.012
Dental visits frequency (ref. rarely)	≥ once a year	90.2%	91.8%	90.1%	−0.002	0.002
Lifetime periodontal treatment (ref. no)	Yes	42.2%	41.7%	31.5%	−0.00002	−0.018

*Including only individuals from multivariate decomposition models.
Red text, positive statistically significant beta coefficients; Green text, negative statistically significant beta coefficients.

Table 3c Results from multivariate decomposition models for dentate and edentate younger seniors (65- to 74-year-olds; dependent variable: "having less than 20 teeth"; coded as yes/no; logistic models)

					Decomposition for "Having less than 20 teeth"	
					DMS IV to DMS V	DMS V to DMS • 6
Difference					−0.150	−0.102
Due to difference in characteristics					−0.021 (14.2%)	−0.034 (33.9%)
Due to difference in coefficients					−0.129 (85.8%)	−0.067 (66.1%)
		Observed means and percentages*			Model for differences in characteristics	
		DMS IV	DMS V	DMS • 6	Coefficient	Coefficient
Age, years		68.8	69.3	69.7	0.009	0.006
Gender (ref. female)	Male	47.0%	46.8%	46.1%	0.0003	0.0003
School education (ref. < 10 years)	10 years	17.7%	27.3%	37.2%	−0.013	−0.005
	> 10 years	17.3%	26.7%	39.1%	−0.015	−0.024
Smoking status (ref. current smokers)	Former smokers	29.9%	35.1%	38.1%	−0.009	−0.004
	Never smoked	61.9%	52.9%	48.8%	0.025	0.009
Body mass index, kg/m²		27.4	27.3	27.3	−0.001	−0.0002
Diabetes mellitus (ref. no)	Yes	16.0%	15.9%	15.8%	−0.0001	−0.00001
Dental visits frequency (ref. rarely)	≥ once a year	80.8%	89.5%	89.0%	−0.019	0.001
Lifetime periodontal treatment (ref. no)	Yes	38.7%	41.7%	32.1%	0.0001	−0.016

*Including only individuals from multivariate decomposition models.
Red text, positive statistically significant beta coefficients; Green text, negative statistically significant beta coefficients.

younger seniors, 14.2% and 33.9% of the study differentials were attributed to differences in characteristics, in particular, school education, former and never smoking, and frequency of dental visits. More detailed results from multivariate decomposition models are given as additional material (Appendix 1).

Discussion

The oral health situation in Germany has improved significantly over the past two decades. There has been a notable decline in the number of edentate individuals and an increase in the average number of teeth. On initial examination, the trends in the periodontal status appear to exhibit a perplexing array of inconsistencies, lacking discernible patterns. The proportion of younger adults with CPI scores of 4 halved between DMS IV and DMS V, subsequently stabilizing at 11% to 12%. Conversely, the proportion of younger seniors with CPI scores of 4 decreased from 29.1% to 21.7% and then increased to 30% in DMS • 6. An analysis of the extent of PD ≥ 6 mm at either site or tooth level, as opposed to prevalences, corroborates this finding. It should be noted, however, that the commonly reported CPI scores (ie, scores 3 and 4) do not focus on periodontal health. Indeed, the prevalence of CPI scores 0 to 2 exhibited an increase from 23.4% to 33.1% in younger adults and from 10.2% to 14.8% in younger seniors. Furthermore, there has been a notable increase in the proportion of individuals displaying CPI scores between 0 and 2 for all tooth positions, both in younger adults and younger seniors. This increase has been observed across the transition periods from DMS IV to DMS V and from DMS V to DMS • 6 (Fig 1). Therefore, if the conclusion is based on CPI scores of 0 to 2 rather than CPI scores of 3 or 4, it can be concluded that the periodontal health of the population has improved. If it is based on a CPI score of 4, differentiation between younger adults and younger seniors is needed, and it should be acknowledged that from DMS V to DMS • 6, periodontitis plateaued in younger adults, but worsened in younger seniors.

Another rationale for enhanced periodontal health is the increase in tooth counts observed across all CPI categories. It remains to be seen whether this observation signifies a shift in dental practice, whereby practitioners alter their approach to extraction and opt to treat and retain severely periodontally compromised teeth.[11] A similar result was observed in the Jönköping studies.[12] The improvement in dental health also resulted in a notable increase in the number of teeth in individuals with severe periodontitis. Yet, disparities in the number of teeth across disease categories persisted.

At the tooth level, the molars exhibited a more pronounced degree of improvement than single-rooted teeth. Therefore, the observed improvement may have been overestimated at the subject level due to the overrepresentation of molars among the index teeth. As molars are typically more susceptible to periodontitis, the notable increase in the percentage of periodontally healthy molars indicates a notable decrease in periodontal risk. Furthermore, the rebound in the prevalence of CPI score 4 in younger seniors from DMS V to DMS • 6 may be attributed to more retained molars in comparison to single-rooted teeth.

In response to the question posed by the health authorities regarding the impact of retaining more teeth on the need for treatment (as defined by the presence of PDs ≥ 4 mm), the present findings indicate that in younger adults, the necessity for treatment decreased in both molars and single-rooted teeth. Conversely, in younger seniors, the necessity for treatment increased in molars but decreased in single-rooted teeth. In parallel with the improvement in the periodontal status in both age groups, the proportion of individuals reporting lifetime periodontal treatment decreased from 24% to 12% in younger adults and from 39% to 32% in younger seniors. This decrease might be explained by the increase in the number of periodontally healthy individuals and a reduction in the need for periodontal treatment. Furthermore, more participants in later waves were highly educated, which may have facilitated a more comprehensive understanding of the contents of periodontal treatment. The level of knowledge of the German population regarding periodontal health and treatment used to be low.[13] In earlier waves, participants may have incorrectly identified professional tooth cleaning as periodontal treatment, which could account for the higher prevalence observed in earlier waves. Furthermore, the reduction in the proportion of individuals reporting lifetime periodontal treatment was identified as a contributing factor to the observed decrease in the number of missing teeth across waves (Table 3). This finding aligns with previous research, which demonstrated that tooth loss rates were notably higher in periodontally treated patients than in untreated SHIP-TREND (Study of Health in Pomerania) participants with moderate to severe periodontitis.[14] Higher rates of tooth loss observed during periodontal treatment may be attributable to inadequate oral hygiene instruction or the inefficacy of nonsurgical periodontal treatment. In addition, less effort was made to retain questionable or hopeless teeth during active periodontal therapy in the earlier waves.

Finally, there was no information as to whether participants were enrolled in a structured maintenance program (supportive periodontal care; SPC), which is key to the long-term success of periodontal treatment.[15] SPC was not part of treatment covered by statutory insurance in Germany until July 2021.

The most reliable proxy for lifetime dental problems is edentulism. In all high-income countries, the prevalence of edentulism has been declining and there has been an increase in the number of teeth retained. In numerous epidemiologic studies, edentulism has not been included in the denominator used to calculate the prevalence of periodontitis in a population.[16] In previous DMS publications, the prevalence of periodontitis was only reported for dentate individuals.[7,17,18] However, to accurately estimate the prevalence of periodontitis in the general population, it is essential to consider the data on edentulism. If it is assumed that 40% of the population is edentulous and 18% of dentate individuals have periodontitis, the actual prevalence of periodontitis in the population is 10.8%.

The Jönköping studies revealed that the proportion of individuals with severe periodontitis remained constant over a period of five decades. However, the proportion of edentate individuals decreased to zero.[12] It was hypothesized that a transition from edentulism to severe periodontitis, and from severe to healthy/moderate periodontitis had occurred at comparable rates. Similar observations have been made in other repeated cross-sectional studies (USA, Spain, Japan, New Zealand).[19] Also, in DMS, the decrease in the prevalence of edentulism or in the number of missing teeth in dentate younger seniors led to an increase in the prevalence of the CPI scores of 0 to 3, while the prevalence of CPI scores of 4 remained constant.

As with other high-income countries, Germany has experienced notable shifts in the prevalence of upstream health determinants over the past three decades: the proportion of individuals with higher education has increased, the prevalence of tobacco consumption has declined,[20] and the prevalence of diabetes has increased.[21] With regard to downstream determinants, the present findings indicate a notable increase in the utilization of electric toothbrushes and interdental cleaning aids.[22] From the perspective of health planners, education is considered to be the most important factor with a positive impact on oral health.[22] In addition to education, the increased use of interdental cleaning devices and electric toothbrushes has contributed to the increase in the number of teeth.[3] In the DMS studies, the decline in the number of missing teeth among younger adults and younger seniors between DMS IV and DMS V and between DMS V and DMS • 6 was found to be mainly attributable to an increase in the proportion of individuals with high education status, an increase in the proportion of those who have never smoked (younger adults only), and an increase in the use of electric toothbrushes and interdental

cleaning aids. Thus, population preventive measures were largely responsible, including, for example, smoking bans. In light of these findings, the present authors conclude that the dental community should promote using electric toothbrushes and interdental cleaning aids and encourage patients to quit smoking.

It is important to consider some methodologic issues as a limitation of the present study. Firstly, in DMS IV and DMS V, a WHO periodontal probe with markings at 3.5, 5.5, 8.5, and 11.5 mm was utilized, whereas in DMS • 6 a probe with 1-mm increments was employed. Therefore, an overrepresentation of PD measurements coinciding with probe graduation markings is likely to have occurred in DMS IV and DMS V. This phenomenon is referred to as digit preference.[23] Secondly, as molars are overrepresented among index teeth, the prevalence of periodontitis is probably overestimated. To obtain unbiased full-mouth estimates of periodontitis prevalence in DMS • 6, please refer to Eickholz et al.[24]

Conclusion

Oral health has improved significantly over the past two decades, with the greatest improvements in periodontal health between 2005 and 2014. The reduction in the number of missing teeth was mainly attributed to positive trends in education, smoking, and oral hygiene care. This underscores the importance of preventive measures, which should be repeatedly reinforced in the dental office or through industry advertising as a public health approach.

Disclosure

ARJ, DS, and KK are employed at the National Association of Statutory Health Insurance Dentists (KZBV). The authors declare that there are no conflicts of interest according to the Uniform Requirements for Manuscripts Submitted to Biomedical Journals. The interpretation of data and presentation of information is not influenced by any personal or financial relationship with any individual or organization.

Author contributions

All authors listed in the paper have contributed sufficiently to fulfil the criteria for authorship according to the Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals (ICMJE Recommendations). All authors read and approved the final manuscript. TK is a member of the DMS • 6 scientific advisory board, responsible for developing the clinical examinations, and the author of the manuscript. PE is a member of the DMS • 6 scientific advisory board, responsible for developing the clinical examinations, and a co-author of the manuscript. KK is the deputy principal investigator of the DMS • 6, responsible for the data analysis, and a co-author of the manuscript. ARJ is the principal investigator of the DMS • 6, responsible for developing the clinical examinations, and a co-author of the manuscript. DS and VP were jointly responsible for statistical data preparation and analysis. BH is a scientific advisor for the DMS • 6 and a co-author of the manuscript.

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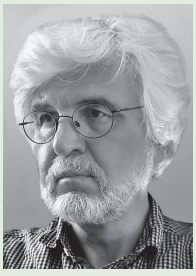

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Appendix 1

Additional data available at: https://www.idz.institute/publikationen/online-journal-zahnmedizin-forschung-und-versorgung/trends-in-periodontal-status-results-from-the-german-oral-health-studies-from-2005-to-2023-online-appendix/.