Relationship between smoking and oral health: results of the 6th German Oral Health Study (DMS • 6)

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Objectives: Smoking is the most significant individual health risk and the leading cause of premature mortality in industrialized nations. International studies demonstrate that smoking also affects oral health adversely. This study aimed to investigate the association between smoking and oral health using population-representative data for Germany. **Method and materials:** The data source was the 6th German Oral Health Study (DMS • 6), conducted between 2021 and 2023. Data from a total of 2,135 individuals were included in the analyses. The distribution of sociodemographic characteristics (gender, age, education status), oral health behaviors (frequency of toothbrushing, interdental cleaning, and dental visits), and oral health-related parameters (self-assessed oral health, oral health-related quality of life, root caries, periodontitis, oral mucosal changes, and the number of teeth present) were reported separately for smoking status (daily smokers, former smokers, and never smoked). To estimate the associations between smoking status and oral health outcomes, mixed-effects regression models were employed. **Results:** Daily smokers exhibited worse outcomes in both self-assessed oral health parameters and clinical oral health measures compared to individuals who had never smoked. These associations persisted even after adjusting for sociodemographic factors and oral health behaviors. Similar trends were observed for former smokers compared to never smokers. **Conclusion:** Smoking is a well-established risk factor for poorer oral health. The findings of DMS • 6 confirm this association and are consistent with those of other national and international studies. Given the strong impact of smoking on oral health, comprehensive measures to curb smoking are essential. Evidence-based behavioral and structural preventive interventions exist to reduce tobacco consumption and promote smoking cessation. Dental offices can also contribute to tobacco prevention and cessation by providing brief counseling on the risks of smoking for both oral and general health. *(Quintessence Int 2025;56(Suppl):S96–S103; doi: 10.3290/j.qi.b5982019)*

Keywords: dental care, dentists, DMS 6, mouth diseases, periodontitis, quality of life, smoking cessation, tobacco use

Smoking remains prevalent among adults in the population in Germany, despite a general decline in the proportion of smokers.[1,2] According to the German Health Update study (GEDA 2023) conducted by the Robert Koch Institute (RKI), the smoking rate among adults in Germany is 29%.[3]

Smoking is the most significant single health risk in industrialized nations and a leading cause of premature mortality. Diseases more commonly found among smokers include cardiovascular, respiratory, and cancer-related conditions. For example, nearly one-fifth of all cancer diagnoses in Germany are attributed to smoking,[4] and in 2021, approximately 99,000 people in Germany died from tobacco-related causes.[5] Furthermore, smoking negatively impacts the immune system, metabolism, skeletal structure, eyes, fertility, and oral health.[6]

Smoking harms oral health in various ways: it is a risk factor for the development of oral precursor lesions and subsequent oral cavity tumors, oral mucosal lesions, root caries, periodontal disease, and gingival recession.[7,8] Moreover, smokers exhibit impaired healing following periodontal treatment. Smoking cessation reduces the risk of oral diseases and associated impairments. Some oral mucosal lesions may regress after quitting smoking.[7,9]

The present study aimed to analyze the association between smoking and oral health using recent data from the 6th German Oral Health Study (DMS • 6). A distinction is made between daily smokers, former smokers, and never smokers. Both self-assessed parameters, such as self-rated oral health and oral health-related quality of life, and clinical parameters, including root caries, periodontitis, oral mucosal changes, and the number of teeth present, were examined. The analyses were statistically controlled for sociodemographic factors and characteristics of oral health behavior. To date, such a comprehensive analysis of the association between smoking and oral health has not been conducted for Germany. This article therefore fills a research gap.

Method and materials

The DMS • 6 (2021 to 2023) is a nationally representative oral epidemiologic and social science survey. It aligns directly with the five previous German Oral Health Studies conducted by the Institute of German Dentists (Institut der Deutschen Zahnärzte, IDZ) since 1989.[10-14] The main objective of these studies has been to provide health reporting on oral diseases in Germany. The DMS • 6 is a combined cross-sectional and cohort study, and thus classified as an observational study. Details on the general methodology of the study are presented in separate articles.[15,16] The 6th German Oral Health Study (DMS • 6) has been approved by the Institutional Review Board (IRB) of the Witten/Herdecke University, Witten, Germany (registration number S-249/2021). This study is registered at the German Clinical Trials Register (registration number DRKS00028701).

Sample

The analysis included study participants from the following age groups of the DMS • 6: older adolescents (20-year-olds, DMS • 6 cohort), younger adults (35- to 44-year-olds, DMS • 6 cross-section), older adults (43- to 52-year-olds, DMS • 6 cohort), and younger seniors (65- to 74-year-olds, DMS • 6 cross-section). Participants were included in the analyses if they met the inclusion criteria of the DMS • 6 analysis set (complete dental and caries examination, periodontal examination conducted on at least two quadrants) and provided valid information on smoking status. Occasional smokers (n = 112) and edentulous individuals (n = 38) were excluded from the analyses, as well as 12 participants with missing smoking status. Overall, data from 2,276 individuals were included in the descriptive analyses. Additionally, 141 participants were excluded from the regression analyses due to missing covariate data (11 of 333 older adolescents, 59 of 867 younger adults, 18 of 332 older adults, and 53 of 744 younger seniors). Finally, data from 2,135 participants were included in the models.

Variables

Smoking

Participants were asked whether they smoke. Response options included: "Yes, daily," "Yes, occasionally," "No, not anymore," and "I have never smoked." Individuals reporting daily smoking were subsequently asked about the number of cigarettes smoked per day and the age at which they started smoking. Former smokers were additionally asked about the age at which they started and stopped smoking.

Self-reported oral health parameters

The following self-assessed oral health parameters were used in the statistical analyses:

- self-assessment of oral health status (dichotomized response categories: "very good/good" vs "moderate/poor/very poor")
- oral health-related quality of life (OHIP-5,[17] dichotomized response categories: "never/rarely" vs "occasionally/often/always").

Dental-clinical parameters

Additionally, variables from the clinical examination were included in the analyses:

- root caries (yes/no)
- mean clinical attachment level (CAL, mm; < 3 mm/ ≥ 3 mm), partial-mouth protocol
- mean probing depth (PD, mm), partial-mouth protocol: index teeth with three measurement sites
- bleeding on probing (BOP, % of sites), partial-mouth protocol
- oral mucosal changes (yes/no; defined as the presence of at least one of the following suspected diagnoses: carcinoma, leukoplakia, oral lichen planus, smoker's keratosis)
- number of teeth (< 20 teeth/ ≥ 20 teeth).

Detailed definitions of these variables are described in other publications.[18-24]

Statistical analysis

Descriptive analyses of sociodemographic characteristics (gender, age, education status) and oral health behavior as well as

Table 1 Baseline characteristics of study participants by smoking status

Variable			Smoking status			
			Daily	Former	Never smoked	Total
No. of participants (n)			369	559	1,348	2,276
Sociodemographic characteristics	Gender	Female	166 (45.0%)	269 (48.1%)	745 (55.3%)	1,180 (51.8%)
		Male	202 (54.7%)	290 (51.9%)	602 (44.7%)	1,094 (48.1%)
		Diverse	1 (0.3%)	0 (0.0%)	1 (0.1%)	2 (0.1%)
		Missing	0	0	0	0
	Age, years		45.8 ± 15.2	55.8 ± 15.0	45.9 ± 17.6	48.3 ± 17.1
		Missing	0	1	1	2
	Age group	20-year-olds	48 (13.0%)	16 (2.9%)	269 (20.0%)	333 (14.6%)
		35- to 44-year-olds	182 (49.3%)	182 (32.6%)	503 (37.3%)	867 (38.1%)
		43-to 52-year-olds	50 (13.6%)	78 (14.0%)	204 (15.1%)	332 (14.6%)
		65- to 74-year-olds	89 (24.1%)	283 (50.6%)	372 (27.6%)	744 (32.7%)
		Missing	0	0	0	0
	Education group	Low	71 (20.4%)	77 (14.3%)	111 (8.7%)	259 (12.0%)
		Medium	215 (61.8%)	295 (54.6%)	718 (56.3%)	1,228 (56.8%)
		High	62 (17.8%)	168 (31.1%)	446 (35.0%)	676 (31.3%)
		Missing	21	19	73	113
Oral hygiene behavior	Tooth brushing (frequency)	≥ 2 times daily	263 (72.7%)	476 (85.9%)	1,158 (86.1%)	1,897 (83.9%)
		< 2 times daily	99 (27.3%)	78 (14.1%)	187 (13.9%)	364 (16.1%)
		Missing	7	5	3	15
	Interdental cleaning (frequency)	≥ once daily	78 (21.5%)	185 (33.4%)	376 (28.0%)	639 (28.3%)
		< once daily	284 (78.5%)	369 (66.6%)	969 (72.0%)	1,622 (71.7%)
		Missing	7	5	3	15
	Dental visits (frequency)	≥ once a year	293 (79.8%)	500 (89.8%)	1,208 (90.1%)	2,001 (88.4%)
		< once a year	74 (20.2%)	57 (10.2%)	132 (9.9%)	263 (11.6%)
		Missing	2	2	8	12

Data are presented as numbers (percentages) or means ± standard deviation based on unweighted data for dentate participants with valid information on smoking status; edentate individuals and occasional smokers were excluded.

oral health-related parameters were stratified by smoking status (daily, former, never smoked).

Mixed-effects regression models were employed to estimate the associations between smoking status (exposure; reference category: never smoked) and oral health-related outcomes. Depending on the distribution of the outcome variables, generalized linear models with a gamma distribution, Poisson regressions with robust standard errors, or fractional probit regressions were used. The models incorporated sociodemographic characteristics and oral health behaviors as fixed effects, and a composite regional variable as a random effect. All models were adjusted in a stepwise manner (see Table 3):

- Step 1: Unadjusted baseline models to assess the association between smoking status (exposure) and oral health-related outcomes.
- Step 2: Adjustment for gender (measured as gender identity), age (continuous), and education status (CASMIN classification; Comparative Analysis of Social Mobility in Industrial Nations; categorized into low, medium, and high education group[25]) to account for sociodemographic differences.

Table 2 Oral health-related characteristics by smoking status

Variable		Smoking status			
		Daily	Former	Never smoked	Total
Self-assessment of oral health status	Very good/good	210 (57.1%)	376 (67.3%)	1,050 (78.1%)	1,636 (72.0%)
	Moderate/poor/very poor	158 (42.9%)	183 (32.7%)	295 (21.9%)	636 (28.0%)
	Missing	1	0	3	4
Impaired OHRQoL	Never/rarely	208 (59.9%)	381 (70.7%)	976 (76.9%)	1,565 (72.6%)
	Occasionally/often/always	139 (40.1%)	158 (29.3%)	294 (23.1%)	591 (27.4%)
	Missing	22	20	78	120
Root caries*	Yes	131 (40.8%)	223 (41.1%)	353 (32.7%)	707 (36.4%)
	No	190 (59.2%)	320 (58.9%)	726 (67.3%)	1,236 (63.6%)
	Missing	0	0	0	0
Mean CAL, mm†		2.0 ± 1.5	2.0 ± 1.4	1.4 ± 1.1	1.7 ± 1.3
	CAL ≥ 3 mm	273 (80.8%)	415 (81.1%)	853 (65.4%)	1,541 (71.5%)
	CAL < 3 mm	65 (19.2%)	97 (18.9%)	451 (34.6%)	613 (28.5%)
	Missing	31	47	44	122
Mean PD, mm†		2.6 ± 0.8	2.6 ± 0.7	2.3 ± 0.5	2.4 ± 0.7
	Missing	20	24	29	73
BOP (% sites)†		18.9 ± 21.0	18.9 ± 21.2	15.8 ± 18.4	17.1 ± 19.6
	Missing	20	24	29	73
No. of teeth‡	< 20 teeth	51 (57.3%)	95 (33.6%)	101 (27.2%)	247 (33.2%)
	≥ 20 teeth	38 (42.7%)	188 (66.4%)	271 (72.8%)	497 (66.8%)
	Missing	0	0	0	0
Oral mucosa changes‡§	Yes	11 (12.4%)	13 (4.6%)	14 (3.8%)	38 (5.1%)
	No	78 (87.6%)	270 (95.4%)	358 (96.2%)	706 (94.9%)
	Missing	0	0	0	0

Data are presented as numbers (%) or means ± standard deviation based on unweighted data for dentate participants with valid information on smoking status; edentate individuals and occasional smokers were excluded.
BOP, bleeding on probing; CAL, clinical attachment level; OHRQoL, oral health-related quality of life; PD, probing depth.
*Not recorded in the age group of 20-year-olds.
†Partial-mouth protocol: index teeth with 3 measurement sites.
‡Only for the age group of 65- to 74-year-olds.
§Oral mucosa changes (≥ 1): suspected carcinoma, leukoplakia, oral lichen planus, or smoker's keratosis.

- Step 3: Additional adjustment for the frequency of toothbrushing (at least twice daily), interdental cleaning (at least once daily), and dental visits (at least once per year) to account for differences in oral health behavior.

Regression coefficients or prevalence ratios (PR) with corresponding 95% confidence intervals (CIs) and *P* values were reported.

Age groups were combined for the analyses, and unweighted cross-sectional data were used. For descriptive analyses, all available cases were included (available case analysis), while regression analyses were limited to cases with valid data for all relevant variables (complete case analysis). Gender-diverse individuals were not included in the regression analyses due to the small number of cases. Detailed information on data handling and statistical methods is described previously.[16]

Results

Table 1 illustrates the smoking status of the study population (daily, former, never smoked) stratified by sociodemographic character-

Table 3 Association analyses between smoking status (reference: never smoked) and oral health-related characteristics

		Step 1: crude estimate				Step 2: adjusted for sociodemographic characteristics**				Step 3: adjusted for sociodemographic characteristics** and characteristics of oral health behavior††			
		Daily		Former		Daily		Former		Daily		Former	
Dependent variable		Estimate (95% CI)	*P* value	Estimate (95% CI)	*P* value	Estimate (95% CI)	*P* value	Estimate (95% CI)	*P* value	Estimate (95% CI)	*P* value	Estimate (95% CI)	*P* value
Self-assessment of oral health status (ref. very good/good)*	Moderate/poor/ very poor	PR = 2.01 (1.70; 2.37)	< .001	PR = 1.50 (1.27; 1.78)	< .001	PR = 1.94 (1.61; 2.34)	< .001	PR = 1.29 (1.09; 1.54)	.003	PR = 1.80 (1.46; 2.23)	< .001	PR = 1.29 (1.09; 1.53)	.002
Impaired OHRQoL (ref. never/rarely)*	Occasionally/often/ always	PR = 1.72 (1.43; 2.07)	< .001	PR = 1.26 (1.10; 1.44)	.001	PR = 1.67 (1.36; 2.05)	< .001	PR = 1.22 (1.05; 1.41)	.010	PR = 1.59 (1.29; 1.95)	< .001	PR = 1.22 (1.05; 1.41)	.010
Root caries (ref. no)*§	Yes	PR = 1.21 (1.04; 1.41)	.015	PR = 1.20 (1.00; 1.43)	.052	PR = 1.39 (1.23; 1.56)	< .001	PR = 1.00 (0.85; 1.18)	.962	PR = 1.40 (1.25; 1.57)	< .001	PR = 1.00 (0.85; 1.18)	.990
Mean CAL, mm†‖		b = 0.32 (0.22; 0.43)	< .001	b = 0.32 (0.23; 0.41)	< .001	b = 0.34 (0.25; 0.44)	< .001	b = 0.09 (0.07; 0.17)	.033	b = 0.31 (0.22; 0.41)	< .001	b = 0.09 (0.01; 0.17)	.028
Mean CAL (ref. < 3 mm)*‖	≥ 3 mm	PR = 1.23 (1.14; 1.32)	< .001	PR = 1.25 (1.17; 1.33)	< .001	PR = 1.26 (1.17; 1.35)	< .001	PR = 1.07 (1.01; 1.13)	.029	PR = 1.26 (1.16; 1.36)	< .001	PR = 1.07 (1.01; 1.13)	.033
Mean PD, mm†‖		b = 0.15 (0.12; 0.18)	< .001	b = 0.13 (0.10; 0.15)	< .001	b = 0.13 (0.10; 0.16)	< .001	b = 0.06 (0.04; 0.08)	< .001	b = 0.11 (0.09; 0.14)	< .001	b = 0.06 (0.04; 0.08)	< .001
BOP (% sites)‡‖		b = 0.01 (−0.16; 0.19)	.864	b = 0.05 (−0.09; 0.20)	.464	b = −0.05 (−0.23; 0.12)	.562	b = −0.04 (−0.19; 0.11)	.627	b = −0.09 (−0.26; 0.09)	.342	b = −0.03 (−0.19; 0.12)	.662
Number of teeth (ref. ≥ 20)*#	< 20	PR = 2.11 (1.74; 2.56)	< .001	PR = 1.29 (0.97; 1.72)	.080	PR = 2.15 (1.77; 2.63)	< .001	PR = 1.29 (0.99; 1.68)	.057	PR = 2.04 (1.66; 2.51)	< .001	PR = 1.29 (1.00; 1.68)	.054

For each combination of exposure and oral health-related dependent variable, 3 separate models were calculated. The estimates refer to the exposure = smoking status (former smokers; current smokers vs never smoked [reference]). The unweighted dataset includes study participants with valid information on smoking status, age, gender, education, frequency of dental visits, frequency of tooth brushing, and frequency of interdental cleaning; two gender-diverse individuals were excluded from the association analyses.

b, regression coefficient; BOP, bleeding on probing; CAL, clinical attachment level; CI, confidence interval; OHRQoL, oral health-related quality of life; PD, probing depth; PR, prevalence ratio.

*Model specification: generalized linear model with mixed effects, family (Poisson), link function (logarithm).

†Model specification: generalized linear model with mixed effects, family (Gamma), link function (logarithm).

‡Model specification: fractional probit regression.

§Participants without gingival recession were excluded, feature not recorded in the age group of 20-year-olds.

‖Partial-mouth protocol: index teeth with 3 measurement sites.

#Only for the age group of 65- to 74-year-olds.

**Gender, age, education.

††Frequency of tooth brushing, frequency of interdental cleaning, frequency of dental visits.

istics and oral health behavior. The proportion of daily smokers was 16.2%. About one-quarter of the participants reported having quit smoking, while nearly 60% indicated they had never smoked. Women were significantly more likely than men to report never having smoked, whereas the proportion of daily smokers was notably higher among men. The group of daily smokers had a mean age of 45 years, similar to that of never smokers. The mean age of former smokers was significantly higher, at 55 years. Regarding education status, approximately one-third of former and never smokers belonged to the high education group, compared to only about one-sixth of daily smokers. In terms of oral health behavior, the proportion of individuals brushing their teeth twice a day, cleaning interdental spaces daily, and visiting a dental practitioner at least once a year was similar among former and never smokers but noticeably higher than among daily smokers.

An examination of smoking behavior revealed that daily smokers reported smoking for an average of 29 years, with a mean of 13 cigarettes per day. Among former smokers, the average duration of smoking exposure was approximately 18 years (results not shown).

Table 2 presents the oral health-related parameters descriptively by smoking status, while Table 3 shows the regression analysis results for these parameters. Both former and daily smokers more frequently reported moderate to very poor self-assessed oral health compared to never smokers. A similar trend was observed for impairments in oral health-related quality of life. The prevalence of a CAL of 3 mm or more, as well as the mean PD, was higher among both former and daily smokers compared to never smokers. These findings were corroborated in the regression analyses, where these associations remained

significant even after adjustment for sociodemographic characteristics and oral health behaviors. Compared to never smokers, daily smokers also had a higher prevalence of root caries and were more likely to have fewer than 20 teeth, even after adjustments for sociodemographic characteristics and oral health behaviors. No association was observed between smoking status and BOP, either for former or daily smokers. Regarding documented oral mucosal changes, daily smokers exhibited more lesions compared to the other subgroups (Table 2).

Discussion

The present analyses of the DMS • 6 data demonstrate that individuals who smoke daily have poorer outcomes in both self-assessed oral health parameters and dental-clinical parameters compared to those who have never smoked. These associations remained significant even after adjusting for sociodemographic characteristics and oral health behaviors. This trend is also largely observed among former smokers when compared to never smokers.

International studies support the association between smoking and oral health.[7,8,26-30] However, for a more direct comparison with the findings of the DMS • 6, other nationwide surveys conducted in Germany may be more suitable. The RKI in Berlin collects survey data on smoking behavior and self-reported oral health, among other things, within its nationwide health monitoring, including several waves of the GEDA study.[31-34] According to GEDA 2019/2020-EHIS, individuals reporting moderate to very poor self-assessed oral health were more likely to report daily smoking than those who assessed their oral health as very good or good.[31,34] Additionally, the same dataset revealed that individuals experiencing difficulties with chewing and biting were more likely to report daily smoking compared to those without such impairments.[32,33] Data from GEDA 2023 further showed that individuals who smoke are less likely to attend regular dental check-ups than non-smokers.[34] Moreover, the Survey of Health in Pomerania (SHIP) has explored the relationship between smoking and oral health,[35] demonstrating an association between tooth loss and smoking. Furthermore, a clear dose–response relationship has been established between smoking behavior and the severity of periodontal disease, including attachment loss and tooth loss.[36]

Conclusion

Given the strong impact that smoking has on oral health, comprehensive measures to curb smoking are essential.[7] Evidence-based behavioral and structural preventive measures exist to reduce tobacco use in the population and to increase smoking cessation.[37] These measures include regular increases in tobacco taxes, comprehensive bans on tobacco advertising, promotion, and sponsorship, warnings about the dangers of tobacco use, protection from passive smoking, and support for smoking cessation. Despite successes in tobacco prevention, there is still room for improvement in Germany in implementing internationally recommended measures, as reflected in the European Tobacco Control Scale for 2021, which compares the efforts of 37 countries regarding effective tobacco prevention and control.[38] Germany ranks second to last in this comparison.

However, studies indicate that dental offices can contribute to tobacco prevention and cessation efforts.[7] The present results show that a large proportion of the smoking population visits a dental practitioner at least once a year (79.8%, Table 1), presenting an opportunity for brief counseling on the risks of smoking and the benefits of smoking cessation for both oral and general health. There are various approaches to structuring such brief counseling, as outlined in the S3 guideline "Smoking and tobacco addiction: screening, diagnosis, and treatment."[39] Cochrane analyses show that brief counseling by physicians and smoking cessation interventions offered by dental practitioners can help smokers to quit more effectively.[40,41]

Therefore, success in improving oral health and reducing smoking requires a policy mix that involves diverse stakeholders and combines both structural and behavioral preventive measures.

Disclosure

ARJ and KK are employed by 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 fulfill the criteria for authorship according to Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals (ICMJE Recommendations). All authors read and approved the final manuscript. LK is a member of the DMS • 6 scientific advisory board and the author

of the manuscript. AS is a co-author of the manuscript. KH is a member of the DMS • 6 scientific advisory board, responsible for developing the clinical examinations, and a co-author of the manuscript. NFB is the former deputy study director, responsible for the social science study design, and a co-author of the manuscript. VP is a scientific advisor for the DMS • 6, jointly responsible for the statistical analyses, 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. KK is the deputy principal investigator of the DMS • 6, responsible for the data analysis, and a co-author of the manuscript.

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