6th German Oral Health Study (DMS • 6): data processing and statistical methods

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Objectives: The 6th German Oral Health Study (DMS • 6) is a combined cross-sectional and cohort study with the main objective of reporting oral diseases in Germany. Based on cross-sectional data, current prevalence estimates and trend analyses on the development of oral health and care status in Germany were conducted using representative data. Associations between oral health and further participant characteristics were examined. The aim of this article is to provide details on data handling and statistical analysis of the cross-sectional data. **Sample weighting:** Weighting factors were used as part of the statistical analysis to correct for deviations between the analysis set and the population structure in Germany. The objective was to make nationwide representative statements for the age groups examined in the cross-sectional component of the DMS • 6. Different types of weights were calculated: design, non-response, and calibration weights. **Processing of quantitative variables:** The indices and transformed variables required for data analysis were defined based on variables collected in clinical examinations and social science interviews. Dental characteristics were aggregated at the participant level. **Statistical methods:** For epidemiologic description, prevalence rates and means with associated 95% confidence intervals were calculated. Regression models were adjusted to estimate the strength of associations between participant characteristics of interest and oral health-related outcomes. To describe trends in the temporal development of oral health and dental care status in Germany, epidemiologic descriptions from DMS • 6 and previous studies were compared. *(Quintessence Int 2025;56 (Suppl):S22–S29; doi: 10.3290/j.qi.b5981988)*

Keywords: cross-sectional studies, data analysis, data management, dental care, dentists, DMS 6, epidemiologic studies

The 6th German Oral Health Study (DMS • 6) is an oral epidemiologic and social science survey conducted on a nationally representative level. It aligns directly with the five preceding oral health studies the Institut der Deutschen Zahnärzte (IDZ) conducted since 1989.[1-5] The 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, as such, is an observational study. Like its predecessors, it includes cross-sectional surveys representative of Germany for selected age groups (DMS • 6 cross-section). The age groups were defined according to the World Health Organization (WHO) recommendations for oral epidemiologic studies.[6] These included 12-year-olds, representing younger adolescents; 35- to 44-year-olds, representing younger adults; and 65- to 74-year-olds, representing younger seniors (referred to as WHO age groups hereafter). Additionally, a group of 8- and 9-year-old younger children was included in the study to obtain information on oral health during mixed dentition, alongside questions on dental and jaw malocclusions. Three other age groups were examined as part of the first follow-up survey of the DMS V (DMS • 6 cohort). For the 20-year-olds (older adolescents), 43- to 52-year-olds (older adults), and 73- to 82-year-olds (older seniors), newly collected data were linked on an individual basis with DMS V data, enabling longitudinal analyses for the first time within the framework of the German Oral Health Studies.

The cross-sectional component of DMS • 6 enabled current prevalence estimates and trend analyses of oral health and care status development in Germany based on representative data. Cross-sectional data facilitated the examination of associations between oral health and additional participant characteristics. The individually linkable longitudinal data from the DMS • 6 cohort further provide an opportunity to analyze

changes in oral diseases over the life course, as well as their protective and risk factors.

This article aims to detail the processing steps from the collected raw data through data handling and statistical analysis methods to the reporting of study results. It describes specifics on sample weighting, processing of quantitative variables, and statistical methodologies relevant to the overall study evaluation. Additionally, more specific information can be found in individual result articles on various dental and social science topics. The following sections report on the processing of cross-sectional data. Details on the processing of longitudinal data will be published at a later date (2026). The examination of 8- and 9-year-olds was conducted in a preliminary field phase; details on weighting, data handling, and statistical methodology have been described elsewhere and are not part of this article.[7,8]

The 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 weighting

Weighting factors were applied as part of the statistical analysis to correct deviations between the analysis set and the population structure in Germany. The objective was to enable nationwide representative statements for the age groups examined in the cross-sectional component of the DMS • 6.

In the following, the estimation of weighting factors for the three WHO age groups is described. Each age group was treated as a separate sample to be weighted. Different types of weights were calculated: design weights, non-response weights, and calibration weights.

Design weights were calculated as the inverse of the study participant selection probability. The sample design was considered at this step, as the sampling design of DMS • 6 was set up disproportionately across the German federal states.[9] Additionally, variations in the sizes of sample points were accounted for.

Non-response weighting aimed to align the net sample (study participants) with the originally drawn gross sample. For this purpose, meta-data available from the gross sample was used. Responses from the non-response survey were not included, as the discrepancies between the net sample of the main study and the net sample of the non-response survey were marginal.[10] To calculate the weighting factors, multivariable logistic regression models were used, estimating the probability of study participation based on explanatory variables such as federal state, gender, age, BIK municipality size class, and nationality. Non-response weighting was the second step after design weighting and provided the basis for a modified design weight, calculated as the product of the non-response weight and the design weight. This weighting adjusts for unequal selection probabilities due to the sample design and, simultaneously, for varying participation probabilities.

After applying the first two weighting steps, calibration weighting was performed to further align with known population characteristics. The calibration weight was based on the modified design weight. As a reference for population totals, data from official statistics (official population projections as of 31 December 2022, Microcensus 2022) were used.[11,12] Calculation of the weighting factors was conducted through an iterative marginal calibration procedure, considering key characteristics such as federal state, gender, age, BIK municipality size class, nationality, household size, and education. The calibration weight factors were restricted to a range between 0.2 and 5.0. Finally, normalization to the number of study participants was performed.

Processing of quantitative variables

The clinical examination program included assessments of dental findings, periodontal findings, caries, root caries, molar-incisor hypomineralization (MIH), erosions, dentures, oral mucosa findings, plaque, and oral functional capacity. The clinical examinations were conducted according to a standardized manual. Most quantitative variables were recorded not at the participant level but at the tooth level, tooth surface level, or jaw level, for example. For data analysis, these variables were appropriately aggregated to the participant level, such as by the number or proportion of affected teeth, the presence of a finding (prevalence), or as the arithmetic mean across all surfaces examined. During data aggregation, all available values were used, with no requirement for complete data. Unless otherwise specified, variable calculations were based on data for 28 teeth, excluding third molars (exception: edentulism). An overview of variables from the clinical examinations is provided in Table 1.

The social science surveys collected information on topics including sociodemographics (eg, age, gender, education status, income, migration history), oral hygiene behavior (eg, toothbrushing frequency, interdental cleaning frequency), dental service utilization (eg, dental visits, professional tooth cleaning), general health (eg, diabetes mellitus, cardiovascular diseases), oral health-related quality of life, smoking behavior,

Table 1 Overview of variables from the clinical examinations

Topic	Variable	
Dental findings	Full dentition (yes | no)	
	Edentulism (based on 32 teeth; yes | no)*	
	Number of teeth	
	Number of missing teeth total / replaced / not replaced	
	Restorations	Fillings (yes | no)
		Partial crowns/inlays (yes | no)
		Full crowns (yes | no)
Caries	Coronal caries	Number of decayed, missing, filled surfaces (DMFS, DS, MS, FS)
		Number of decayed, missing, filled teeth (DMFT, DT, MT, FT)
		Number of filled and sound teeth (FST, ST)
		(dynamic) Significant Caries Index (SiC, dSiC)
		Caries experience (DMFT > 0; yes | no)
		Caries-free (DMFT = 0; yes | no)
		Number of teeth with active initial lesions
		Fissure sealing (yes | no)
		Number of sealed teeth
	Root caries	Root Caries Index (RCI; %)
		Root caries (yes | no | edentulous)
		Number of teeth with active root or secondary lesions
		Number of teeth with filled root surfaces
Periodontal findings	Bleeding on probing (BOP)	BOP (% sites)
	Probing depth (PD)†	Mean PD (mm)
		PD ≥ 4 mm / ≥ 6 mm (yes | no)
		Number of teeth with PD ≥ 4 mm / ≥ 6 mm
		Percentage of sites with PD ≥ 4 mm / ≥ 6 mm (%)
	Clinical attachment level (CAL)†	Mean CAL (mm)
		CAL ≥ 3 mm / ≥ 5 mm (yes | no)
		Number of teeth with CAL ≥ 3 mm / ≥ 5 mm
		Percentage of sites with CAL ≥ 3 mm / ≥ 5 mm (%)
	EFP/AAP classification	Periodontitis status and stage (periodontal health | gingivitis | periodontitis case: stage I / II / III / IV | edentulous | non-classified)
		Periodontitis grade (grade A | grade B | grade C)
	CDC/AAP case definition (no or mild periodontitis | moderate periodontitis | severe periodontitis | edentulous | non-classified)	
	Community Periodontal Index (CPI; score 0, 1, or 2 | score 3 | score 4 | edentulous)†	
Plaque	Modified Marginal Plaque Index (mMPI; % segments with plaque)	
Molar-incisor hypomineralization (MIH)	MIH (yes | no)	
	Maximum degree of expression (no MIH | demarcated opacity | posteruptive enamel breakdown, circumscribed | posteruptive enamel breakdown, extensive | atypical restoration | extraction due to MIH)	
	Number of MIH teeth	
Erosions (BEWE)	Erosions (yes | no)	
	Maximum BEWE score (no erosion | initial loss of surface structures | clinically manifest defect, loss of tissue < 50% of the most severely affected tooth surface | clinically manifest defect, loss of tissue ≥ 50% of the most severely affected tooth surface)	
	Risk level classification (no increased risk level | slightly increased risk level | medium risk level | high risk level)	
Oral mucosa findings	Suspected:	Carcinoma (yes | no)
		Leukoplakia (yes | no)
		Oral lichen planus (yes | no)
		Smoker's keratosis (yes | no)
		Candida (yes | no)
		Prothesis-related changes (yes | no)
		Other (yes | no)
Dentures	Fixed dentures	Bridges (yes | no)
		Implants (yes | no)
		Number of implants*
	Removable dentures	Removable dentures* (yes | no; n)
		Acrylic partial dentures (yes | no; n)
		Cast framework partial dentures (yes | no; n)
		Combined fixed-removable dentures (yes | no; n)
		Hybrid dentures (yes | no; n)
		Complete dentures (yes | no; n)
	Wearing behavior (dentures are worn | dentures are not worn or only worn sporadically)	
	Removable denture quality (no deficiencies, very good quality | acceptable condition, good quality | moderate deficiencies, moderate quality | major deficiencies, poor quality)	
	Primary prosthetic treatment (fully dentate [no gaps, no dentures] | ≥ 1 untreated gap, no dentures | ≥ 1 one crown restoration | ≥ 1 fixed denture (ie, bridge/implant) | ≥ 1 removable partial denture | ≥ 1 complete denture)*	
Oral functional capacity	Resilience capacity level (normal | slightly reduced | greatly reduced | no resilience)	
	Therapeutic capability (normal | slightly reduced | greatly reduced | none)	
	Oral hygiene ability (normal | slightly reduced | greatly reduced | none)	
	Self-responsibility (normal | reduced | none)	

BEWE, Basic Erosive Wear Examination; CDC/AAP, Centers for Disease Control/American Academy of Periodontology; EFP/AAP, European Federation of Periodontology/American Academy of Periodontology.
*Variables calculated for the entire dentition and separately for the maxilla and mandible.
†Variables calculated for both full-mouth recording (28 teeth with 6 measurement sites each) and partial-mouth recording (12 index teeth with 3 measurement sites each).

and sugar consumption. Based on the quantitative variables collected, indices and transformed variables needed for data analysis were defined. An overview of the social science variables is provided in Tables 2 and 3.

The manual for the clinical examination, the social science questionnaires, and the documentation on the definition of transformed variables with details on processing quantitative variables are published elsewhere.[13] As a quality assurance measure, variable transformations were validated internally and externally. Data processing was conducted using SPSS Statistics for Windows, Version 26 (IBM) and R Version 4.4.1 (R Core Team).

Statistical methods

Study participants were included in the analysis set if they met all defined inclusion criteria:

- complete recording of dental findings
- complete recording of caries findings
- recording of periodontal findings in at least two quadrants.

In the 12-year-old age group, only the first two criteria were relevant. Missing information on the social science survey did not lead to exclusion from the analysis set. Depending on the research question, data analysis accounted for weighting factors, with primary use of modified design weights. Analyses were performed using SPSS Statistics for Windows, Version 26, R Version 4.4.1, and Stata/MP 18.0 (StataCorp).

Missing data

All three survey components – clinical examination, computer-assisted personal interview (CAPI), and paper and pencil interview (PAPI) – were completed by 95.2% of participants.

At least one interview was missing for 4.8% of cases (PAPI 4.7%, CAPI 0.7%). Additional missing data due to refusals or non-recordable data, lack of responses, or implausible entries varied between 0% and 12% across variables (item "missingness"). Missing data was uncommon for variables assessed during the clinical examination or CAPI (generally 0% to 1%). Variables captured through PAPI had the highest rates of missing data (2% to 12%). This corresponds to the request for sensitive personal information such as income in this survey mode. Missing values were not imputed. For epidemiologic description, available case analysis was used; for regression analyses, only cases with complete data on all variables considered were included (complete case analysis).

Characteristics of study participants

Descriptive analyses of social science variables were conducted to characterize study participants. For continuous variables, mean and standard deviation were given, and for categorical variables, absolute (n) and relative frequencies (in %) were provided. These analyses were based on unweighted data, the results were presented separately by age group.

Epidemiologic description

The epidemiologic description aimed to answer the first research question of DMS • 6: What are the current prevalence rates of oral diseases?

Prevalences and means with corresponding 95% confidence intervals (CIs) were calculated using a weighted dataset. Edentulous participants were included in the prevalence calculations to obtain population-representative prevalence data. Results were presented separately by age group for participants in the DMS • 6 cross-sectional component. Within age groups, further subgroup analysis was conducted based on variables of interest, such as self-reported gender (male/female), education group (low/medium/high), migration history (yes/no), and the presence of at least one cardiovascular disease (yes/no).

Association analyses

The association analyses sought to answer the second research question of DMS • 6: What associations exist between oral health and other participant characteristics?

Associations between oral health and various participant characteristics, such as education, migration history, smoking status, oral hygiene behavior, chronic diseases, and diet, were initially explored descriptively using cross-tabulations and bar charts (for two categorical variables), comparisons of measures of central tendency and dispersion along with box plots (for one categorical and one continuous variable), or correlation coefficients and scatter plots (for two continuous variables).

Mixed-effects regression models were fitted to estimate the extent of associations between explanatory variables of interest (exposures) and oral health-related outcomes. Generalized linear models with Gaussian or gamma distribution and Poisson regression with robust standard errors were used. Beginning with univariable models for the exposure variable, covariates such as age, gender, and education status were incorporated stepwise as fixed effects, while a composite regional variable was included as a random effect. The composite re-

Table 2 Overview of social science variables from the paper and pencil interview

Topic	Variable
Sociodemographics	Age (years)
	Gender (male | female | diverse)
	Body mass index (kg/m²)
Socioeconomic status (SES)	SES-index (SES total score, SES sub-score Education, SES sub-score Occupation, SES sub-score Income)
	SES-group (low | medium | high)
	Education group (low | medium | high)
	School education (< 10 years | 10 years | > 10 years)
	Monthly net equivalent income (Euro)
	Subjective social status (low | medium | high)
Health economics	Health insurance status (statutory health insurance | statutory health insurance + supplementary health insurance | private health insurance | other | no health insurance)
	Need for dental or orthodontic examination or treatment in the last 12 months (yes | no)
	Refusal of dental examination or treatment due to cost in the last 12 months (yes | no)
	Refusal of orthodontic examination or treatment due to cost in the last 12 months (yes | no)
	Utilization of dental or orthodontic treatment in the last 12 months (yes | no)
	Out-of-pocket amount for dental or orthodontic treatment in the last 12 months (Euro)
Migration	Migration history (people with migration history | people without migration history)
	Immigration generation (1st generation: immigrated to Germany themselves | 2nd generation: both parents born outside Germany)
	Length of stay (years)
	Age at arrival (years)
	Language spoken at home (German | other | German + other)
	Self-assessment of German language skills (very good | good | moderate | limited | none)
	Residence status (German citizenship | permanent residence | temporary residence)
	Region of origin (Germany | Western Europe | Eastern Europe | North America, Australia, New Zealand | Central and South America | Asia | Africa | Turkey | Arab states)
Disability and need for care	Home care service utilization in the last 12 months (yes | no)
	Receipt of nursing care (yes | no)
	Level of care (level of care 1 | 2 | 3 | 4 | 5)
	Officially recognized disability (degree of disability < 50% | severe disability: degree of disability ≥ 50% | no)
Oral health-related quality of life (OHRQoL)	Oral Health Impact Profile (OHIP-G5 sum score)
Fluoride prophylaxis	Fluoride toothpaste use (yes | no)
	Fluoridated salt use (usually no | occasionally | usually yes)
Sugar consumption	Short form of the Marburg Sugar Index (MSI-S total score)
Dental anxiety	Modified Dental Anxiety Scale (mDAS sum score)

gional variable combined information on the region (North/East/South/West Germany) and community size (rural, urban, metropolitan area), which was used as a random effect in the models instead of study centers because the number of centers (n = 90) was too large for model estimation. The results from the models were presented as regression coefficients (b) for generalized linear models or prevalence ratios (PR) for Poisson regressions along with 95% CIs and *P* values.

For association analyses, unweighted data from all age groups, both from the DMS • 6 cross-sectional and DMS • 6 cohort components, were utilized. Age groups were pooled as appropriate based on the research question.

Table 3 Overview of social science variables from the computer-assisted personal interview

Topic	Variable		
Utilization of preventive dental services	Dental service utilization (control-oriented | complaint-oriented)		
	Dental visit frequency (only in case of problems | < once a year | ≥ once a year | ≥ once every 6 months)		
	Professional tooth cleaning utilization (yes | no | don't know)		
	Professional tooth cleaning frequency (never | usually no PTC | < once a year | ≥ once a year | ≥ once every 6 months)		
	Dental office loyalty (office switching almost every visit | occasional office switching | usually no office switching)		
	Use of bonus booklet (yes | no)		
Oral hygiene behavior	Type of toothbrush used (electric | manual | both | none)		
	Interdental cleaning (yes | no)		
	Interdental cleaning aids (dental floss | tooth sticks | interdental brushes | multiple | none)		
	Tooth brushing frequency (< once daily | once daily | 2 times daily | > 2 times daily)		
	Interdental cleaning frequency (never | < once a week | ≥ once a week | ≥ once daily)		
Medical geography	Means of transport to the dental office	On foot (mentioned | not mentioned)	
		By bicycle (mentioned | not mentioned)	
		By public transport (mentioned | not mentioned)	
		By private vehicle (mentioned | not mentioned)	
		Other (mentioned | not mentioned)	
	Duration to reach the dental office (≤ 10 min | ≤ 30 min | ≤ 60 min | ≤ 90 min | > 90 min)		
Cardiometabolic diseases[‡]	Diabetes mellitus	Diabetes mellitus (Type 1 diabetes | Type 2 diabetes | gestational diabetes | no diabetes)	
		Age of onset of diabetes (years)	
		Duration of diabetes (years)	
		Controlled diabetes (HbA1c < 7% | HbA1c ≥ 7%)	
		Diabetes treatment at first manifestation / currently (insulin only | oral medication or GLP-1 analogs only | combinations: insulin and oral medication | diet or other treatment or no treatment)	
		Complications of diabetes mellitus	Retinopathy (yes | no | don't know)
			Blindness (yes | no | don't know)
			Protein in urine (yes | no | don't know)
			Kidney failure (yes | no | don't know)
			Dialysis (yes | no | don't know)
			Neuropathy (yes | no | don't know)
			Amputation (yes | no | don't know)
			Diabetic foot (yes | no | don't know)
	Cardiovascular diseases	Myocardial infarction (yes | no | don't know)	
		Angina pectoris (yes | no | don't know)	
		Cardiac insufficiency (yes | no | don't know)	
		Cardiac arrhythmias (yes | no | don't know)	
		Intermittent claudication (yes | no | don't know)	
		Stroke (yes | no | don't know)	
		Hypertension (yes | no | don't know)	
		Elevated blood lipids/cholesterol levels (yes | no | don't know)	
Dental treatments	Lifetime periodontal treatment (yes | no | don't know)		
	Orthodontic treatment utilization (yes | no)		
Self-assessment of health status and health literacy	Self-assessment of general health status / oral health status (very poor | poor | moderate | good | very good)		
	Locus of control* (very much | much | some | little | none)		
	Health literacy[†] (never | rarely | sometimes | often | always)		
Health services research	Dental office located close enough to home (yes | no)		
	Scheduling difficulties with the dentist in the last 12 months (yes | no)		
Smoking behavior	Smoking status (daily smoker | occasional smoker | former smoker | never smoked)		
	Duration of smoking exposure (years)		
	Number of cigarettes smoked per day / per week		

HbA1c, glycated hemoglobin; PTC, professional tooth cleaning.
*How much can you do yourself to maintain or improve your dental health?
[†]How often do you need help from someone when reading instructions, patient information leaflets, or other written materials from your doctor or pharmacist?
[‡]Self-report on medical diagnoses.

Trend analyses

Trend analyses aimed to answer the third research question of DMS • 6: How has the oral health and care status in Germany developed from 1989 to 2023?

Based on the DMS • 6 cross-sectional component, as well as the previous studies DMS I/II to DMS V, a trend analysis was conducted to describe the temporal development of the oral health and care status in Germany. This included a comparative presentation of epidemiologic descriptions and the care of oral diseases. The results were presented separately by age groups. Trend analyses beyond those mentioned here are described in detail in the respective result articles. In analyzing and presenting the results, one focus was the methodologic differences among the studies, and these were thoroughly discussed. For instance, the examinations conducted as part of DMS I and II took place in dental practices, whereas, since DMS III, participants have been invited to mobile examination centers. Moreover, both the clinical examination protocols and social science surveys have been updated over the years to align with new scientific standards.

Sensitivity analyses

For the epidemiologic description, the modified design weight was primarily used to weight the dataset. As part of sensitivity analyses, the evaluations were repeated using the calibration weight. The analyses revealed no substantively relevant deviations in the estimation results. Any additional sensitivity analyses conducted are described in the respective results articles.

Conclusion

This article presents details of data handling and statistical analysis of the cross-sectional data from DMS • 6. Based on cross-sectional data, current prevalence estimates and trend analyses on the development of oral health and care status in Germany were conducted using representative data. Associations between oral health and further participant characteristics could thereby be examined.

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Disclosure

KK, DS, FZ, CO, and ARJ 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. KK is the deputy principal investigator of the DMS • 6, responsible for the data analysis, and the author of the manuscript. DS is jointly responsible for statistical data preparation and analysis. NFB is the former deputy principal investigator and responsible for the social science study setting. VP is the scientific advisor of DMS • 6, jointly responsible for statistical analyses, and a co-author of the manuscript. FZ is responsible for the social science analysis and a co-author of the manuscript. CO is project manager of the DMS • 6. ARJ is the principal investigator of the DMS • 6, responsible for developing the clinical examinations, and a co-author of the manuscript.

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