

## Cross-sectional associations of type 2 diabetes with oral conditions: results of the 6th German Oral Health Study (DMS • 6). Online Appendix

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### ABSTRACT

**Objectives:** This study aimed to investigate the cross-sectional associations between type 2 diabetes (T2D) and periodontitis, dental caries, and tooth loss, according to the glycemic control status, time from T2D diagnosis, and microvascular complications (MVCs) among participants in the 6th German Oral Health Study (DMS • 6).

**Method and Materials:** Cross-sectional data was pooled from participants from the DMS • 6 cross-sectional and cohort components who completed questionnaires regarding their oral and general health behaviors. Information on self-assessed oral health was obtained from interviews. T2D was defined as self-reported diagnosis by a physician. Participants were categorized according to their last self-reported glycosylated hemoglobin (HbA1c) level, time from T2D diagnosis, and presence of MVCs. Probing depth (PD), clinical attachment level (CAL), and presence of coronal and root caries were assessed for all teeth except the third molars, and the number of missing teeth was recorded.

**Results:** T2D was diagnosed in 9.0% of individuals. Severe periodontitis was diagnosed in 16.0% and 5.6% of individuals with and without T2D, respectively. Participants with T2D were more frequently edentulous, had more missing teeth, had higher prevalence of coronal and root caries, and exhibited poorer oral hygiene and dental-care practices. Fully adjusted models revealed that the mean PD and mean CAL were both higher in individuals with T2D than in those without. Compared with participants without T2D, those with T2D were 1.89 times more likely to have worse periodontal status. Among individuals with T2D, HbA1c levels > 7% showed stronger associations with periodontal variables than HbA1c ≤ 7%. Moreover, individuals with poorly controlled T2D had a higher prevalence of root caries than those without T2D. No significant associations were observed between decayed, missing, or filled teeth, percentage of decayed and filled teeth, or self-assessed oral health. Importantly, effect sizes for all outcomes did not differ significantly according to the time from T2D diagnosis.

**Conclusion:** Poorly controlled T2D significantly affects periodontal health. Therefore, future studies should focus on intensified screening for undiagnosed diabetes by the dental workforce and closer communication between various specialists.

**KEYWORDS:** cross-sectional studies, dental care, dental caries, dental health surveys, dentists, diabetes mellitus, DMS 6, epidemiology, Germany, glycemic control, oral health, periodontitis, root caries, tooth loss

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## Appendix 1

Table A1: Characteristics of study participants by age group and presence of type 2 diabetes.

	Younger adults (35- to 44-year-olds)		Older adults (43- to 52-year-olds)		Younger seniors (65- to 74-year-olds)		Older seniors (73- to 82-year-olds)	
	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes
<b>No. of participants (n)</b>	<b>888</b>	<b>19</b>	<b>324</b>	<b>16</b>	<b>631</b>	<b>117</b>	<b>282</b>	<b>58</b>
<b>Age, years</b>	40.1 ± 3.0	42.6 ± 1.7	49.0 ± 2.8	49.3 ± 2.2	69.7 ± 2.8	70.1 ± 2.9	78.3 ± 3.1	76.9 ± 3.0
Missing	1	0			1	0		
<b>Gender</b>								
Male	437 (49%)	14 (74%)	148 (46%)	11 (69%)	286 (45%)	61 (52%)	138 (49%)	26 (45%)
Female	450 (51%)	5 (26%)	176 (54%)	5 (31%)	345 (55%)	56 (48%)	144 (51%)	32 (55%)
Diverse	1 (0.1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
<b>Region</b>								
Old federal states	633 (71%)	13 (68%)	219 (68%)	10 (63%)	443 (70%)	80 (68%)	205 (73%)	36 (62%)
New federal states	255 (29%)	6 (32%)	105 (32%)	6 (38%)	188 (30%)	37 (32%)	77 (27%)	22 (38%)
<b>Education group*</b>								
Low	74 (8.8%)	3 (20%)	20 (6.5%)	2 (13%)	115 (19%)	26 (23%)	79 (30%)	18 (34%)
Medium	391 (47%)	8 (53%)	194 (63%)	13 (87%)	285 (48%)	61 (54%)	117 (44%)	24 (45%)
High	375 (45%)	4 (27%)	93 (30%)	0 (0%)	200 (33%)	27 (24%)	71 (27%)	11 (21%)
Missing	48	4	17	1	31	3	15	5
<b>Monthly net equivalent income, Euro</b>	2,448.6 ± 1,395.6	2,224.4 ± 2,127.0	2,361.1 ± 1,309.8	1,762.8 ± 905.9	2,085.4 ± 1,068.7	1,714.4 ± 906.3	1,961.4 ± 904.5	1,982.1 ± 1,326.4
Missing	116	5	44	3	112	17	57	14
<b>Migration history</b>								
People with migration history	187 (23%)	6 (38%)	36 (12%)	1 (6.7%)	72 (12%)	26 (23%)	22 (8.3%)	5 (9.3%)
People without migration history	643 (77%)	10 (63%)	266 (88%)	14 (93%)	528 (88%)	88 (77%)	244 (92%)	49 (91%)

	Younger adults (35- to 44-year-olds)		Older adults (43- to 52-year-olds)		Younger seniors (65- to 74-year-olds)		Older seniors (73- to 82-year-olds)	
	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes
Missing	58	3	22	1	31	3	16	4
<b>Smoking status</b>								
Never smoked	492 (55%)	4 (21%)	195 (60%)	8 (50%)	315 (50%)	55 (47%)	164 (58%)	35 (60%)
Former smoker	175 (20%)	6 (32%)	73 (23%)	4 (25%)	232 (37%)	46 (39%)	96 (34%)	17 (29%)
Occasional smoker or daily smoker	221 (25%)	9 (47%)	56 (17%)	4 (25%)	84 (13%)	16 (14%)	21 (7%)	6 (10%)
Missing	0	0	0	0	0	0	1	0
<b>Body mass index (kg/m<sup>2</sup>)</b>	26.0 ± 5.2	34.2 ± 9.4	26.3 ± 4.7	34.3 ± 7.5	26.9 ± 4.8	29.6 ± 5.1	26.2 ± 4.9	28.4 ± 6.3
Missing	56	3	21	2	38	4	27	9
<b>Hypertension</b>								
No	804 (91%)	7 (37%)	265 (82%)	7 (44%)	301 (48%)	30 (26%)	98 (35%)	15 (26%)
Yes	79 (8.9%)	12 (63%)	59 (18%)	9 (56%)	327 (52%)	87 (74%)	183 (65%)	43 (74%)
Don't know	5 (0.6%)	0 (0%)	0 (0%)	0 (0%)	3 (0.5%)	0 (0%)	1 (0.4%)	0 (0%)
<b>Elevated blood lipids/ cholesterol levels</b>								
No	798 (90%)	7 (37%)	263 (81%)	9 (56%)	371 (59%)	59 (50%)	170 (60%)	24 (41%)
Yes	75 (8.5%)	11 (58%)	58 (18%)	7 (44%)	239 (38%)	53 (45%)	104 (37%)	30 (52%)
Don't know	14 (1.6%)	1 (5.3%)	3 (0.9%)	0 (0%)	21 (3.3%)	5 (4.3%)	8 (2.8%)	4 (6.9%)
Missing	1	0	0	0	0	0	0	0
<b>Cardiovascular disease**</b>								
No / don't know	852 (96%)	18 (95%)	302 (93%)	14 (88%)	469 (74%)	78 (67%)	166 (59%)	32 (55%)
Yes	36 (4.1%)	1 (5.3%)	22 (6.8%)	2 (13%)	162 (26%)	39 (33%)	116 (41%)	26 (45%)
<b>Current diabetes treatment</b>								
Without insulin	NA	14 (74%)	NA	16 (100%)	NA	96 (82%)	NA	47 (81%)
With insulin	NA	5 (26%)	NA	0 (0%)	NA	21 (18%)	NA	11 (19%)
<b>Self-reported last HbA<sub>1c</sub> (%)</b>	NA	7.0 ± 2.9	NA	7.5 ± 2.1	NA	7.2 ± 2.2	NA	7.3 ± 2.5
≥7%	NA	4 (29%)	NA	6 (50%)	NA	38 (43%)	NA	16 (41%)

	Younger adults (35- to 44-year-olds)		Older adults (43- to 52-year-olds)		Younger seniors (65- to 74-year-olds)		Older seniors (73- to 82-year-olds)	
	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes	No type 2 diabetes	Type 2 diabetes
<7%	NA	10 (71%)	NA	6 (50%)	NA	51 (57%)	NA	23 (59%)
Missing	NA	5	NA	4	NA	28	NA	19
<b>Duration of diabetes</b>								
≤10 years	NA	17 (94%)	NA	14 (88%)	NA	54 (47%)	NA	23 (40%)
>10 years	NA	1 (6%)	NA	2 (12%)	NA	61 (53%)	NA	34 (60%)
Missing	NA	1	NA	0	NA	2	NA	1
<b>Microvascular complications</b>								
No / don't know	NA	16 (84%)	NA	13 (81%)	NA	83 (72%)	NA	33 (57%)
Yes	NA	3 (16%)	NA	3 (19%)	NA	33 (28%)	NA	25 (43%)
Missing	NA	0	NA	0	NA	1	NA	0
<b>Macrovascular complications</b>								
No / don't know	NA	19 (100%)	NA	15 (94%)	NA	97 (83%)	NA	43 (74%)
Yes	NA	0 (0%)	NA	1 (6%)	NA	20 (17%)	NA	15 (26%)

Note: Data are presented as number (percentage) or mean ± standard deviation based on data from dentate participants. \*Education was classified according to the Comparative Analysis of Social Mobility in Industrial Nations (CASMIN) system (1). \*\*includes myocardial infarction, angina pectoris, cardiac insufficiency, cardiac arrhythmias, intermittent claudication and stroke. Abbreviations: HbA<sub>1c</sub>, Haemoglobin A<sub>1c</sub>; NA, not annotated.

## Appendix 2

Table A2.1: Detailed characteristics of dentate participants with type 2 diabetes by metabolic control, duration of type 2 diabetes and presence of microvascular complications (N=210).

Variable	Metabolic control		Duration of type 2 diabetes		Microvascular complications	
	HbA <sub>1c</sub> ≥7%	HbA <sub>1c</sub> <7%	>10 years	≤10 years	Yes	No
<b>No. of participants (n)</b>	64	90	98	108	64	131
<b>Age, years</b>	68.4 ± 10.3	67.1 ± 11.0	72.2 ± 6.1	64.3 ± 12.6	70.6 ± 9.0	66.3 ± 11.7
<b>Gender</b>						
Male	31 (48%)	45 (50%)	50 (51%)	61 (56%)	34 (53%)	71 (54%)
Female	33 (52%)	45 (50%)	48 (49%)	47 (44%)	30 (47%)	60 (46%)
Diverse	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
<b>Region</b>						
Old federal states	36 (56%)	69 (77%)	67 (68%)	68 (63%)	42 (66%)	88 (67%)
New federal states	28 (44%)	21 (23%)	31 (32%)	40 (37%)	22 (34%)	43 (33%)
<b>Education group*</b>						
Low	15 (25%)	16 (19%)	24 (26%)	22 (22%)	18 (29%)	26 (21%)
Medium	30 (51%)	50 (59%)	53 (58%)	52 (51%)	27 (44%)	71 (59%)
High	14 (24%)	19 (22%)	14 (15%)	28 (27%)	17 (27%)	24 (20%)
Missing	5	5	7	6	2	10
<b>Monthly net equivalent income (Euro)</b>	1,747.4 ± 1,204.6	1,994.6 ± 1,027.0	1,782.4 ± 1,078.4	1,884.3 ± 1,247.1	1,957.3 ± 1,390.6	1,762.0 ± 1,067.8
Missing	12	15	21	17	9	25
<b>Migration history</b>						
People with migration history	11 (18%)	17 (20%)	14 (15%)	22 (21%)	12 (19%)	24 (20%)
People without migration history	50 (82%)	68 (80%)	78 (85%)	81 (79%)	50 (81%)	99 (80%)
Missing	3	5	6	5	2	8
<b>Smoking status</b>						
Never smoked	21 (44%)	31 (46%)	27 (42%)	40 (47%)	14 (36%)	49 (48%)
Former smoker	22 (46%)	23 (34%)	26 (41%)	29 (34%)	16 (41%)	36 (35%)
Occasional smoker or daily smoker	5 (10%)	13 (19%)	11 (17%)	16 (19%)	9 (23%)	18 (17%)
Missing	16	23	34	23	25	28
<b>Body mass index (kg/m<sup>2</sup>)</b>	29.8 ± 6.0	29.9 ± 6.7	29.1 ± 6.1	30.7 ± 6.3	30.8 ± 7.0	29.4 ± 5.8
Missing	6	7	10	8	4	11
<b>Hypertension</b>						
No	15 (23%)	30 (33%)	27 (28%)	31 (29%)	15 (23%)	41 (31%)
Yes	49 (77%)	60 (67%)	71 (72%)	77 (71%)	49 (77%)	90 (69%)
Don't know	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
<b>Elevated blood lipids/cholesterol levels</b>						
No	29 (45%)	46 (51%)	47 (48%)	50 (46%)	22 (34%)	71 (54%)

Variable	Metabolic control		Duration of type 2 diabetes		Microvascular complications	
	HbA <sub>1c</sub> ≥7%	HbA <sub>1c</sub> <7%	>10 years	≤10 years	Yes	No
Yes	31 (48%)	40 (44%)	46 (47%)	53 (49%)	38 (59%)	55 (42%)
Don't know	4 (6.3%)	4 (4.4%)	5 (5.1%)	5 (4.6%)	4 (6.3%)	5 (3.8%)
<b>Cardiovascular disease**</b>						
No / don't know	42 (66%)	60 (67%)	60 (61%)	79 (73%)	39 (61%)	93 (71%)
Yes	22 (34%)	30 (33%)	38 (39%)	29 (27%)	25 (39%)	38 (29%)
<b>Self-reported last HbA<sub>1c</sub> (%)</b>						
Missing	0	0	21	32	14	37

Note: Data are presented as number (percentage) or mean ± standard deviation based on data from dentate participants. \* Education was classified according to the Comparative Analysis of Social Mobility in Industrial Nations (CASMIN) system (1). \*\*includes myocardial infarction, angina pectoris, cardiac insufficiency, cardiac arrhythmias, intermittent claudication and stroke. Abbreviations: HbA<sub>1c</sub>, Haemoglobin A<sub>1c</sub>.

**Table A2.2: Dental and oral hygiene characteristics of dentate participants with type 2 diabetes by metabolic control, duration of type 2 diabetes and presence of microvascular complications (N=210).**

Variable	Metabolic control		Duration of type 2 diabetes		Microvascular complications	
	HbA <sub>1c</sub> ≥7%	HbA <sub>1c</sub> <7%	>10 years	≤10 years	Yes	No
<b>No. of participants (n)</b>	64	90	98	108	64	131
<b>Number of missing teeth (base: 28 teeth)</b>	8.5 ± 7.3	7.8 ± 7.8	9.5 ± 7.6	6.3 ± 6.7	8.7 ± 8.0	7.4 ± 6.9
<b>Mean CAL (mm)</b>	3.2 ± 1.8	2.8 ± 1.5	3.1 ± 1.5	2.8 ± 1.7	3.0 ± 1.6	2.8 ± 1.6
Missing	9	14	20	12	12	19
<b>Mean PD (mm)</b>	3.2 ± 1.2	2.9 ± 0.8	3.0 ± 1.0	3.0 ± 0.9	3.1 ± 1.0	2.9 ± 0.9
Missing	6	8	13	7	8	12
<b>Percentage of teeth with PD ≥ 4 mm (%)</b>	31.7 ± 29.2	27.7 ± 23.6	29.7 ± 26.7	28.7 ± 24.2	32.2 ± 26.1	27.6 ± 25.3
Missing	6	8	13	7	8	12
<b>CDC/AAP case definition</b>						
No/ mild periodontitis	15 (26%)	27 (33%)	25 (29%)	31 (31%)	14 (25%)	42 (35%)
Moderate periodontitis	22 (38%)	29 (35%)	26 (31%)	41 (41%)	21 (38%)	40 (34%)
Severe periodontitis	11 (19%)	9 (11%)	16 (19%)	14 (14%)	8 (14%)	20 (17%)
Non-classified	10 (17%)	17 (21%)	18 (21%)	15 (15%)	13 (23%)	17 (14%)
Missing	6	8	13	7	8	12
<b>Community Periodontal Index</b>						
Score 0–2	10 (17%)	7 (8.5%)	11 (13%)	10 (9.9%)	5 (8.9%)	15 (13%)
Score 3	19 (33%)	47 (57%)	37 (44%)	55 (54%)	26 (46%)	58 (49%)
Score 4	29 (50%)	28 (34%)	37 (44%)	36 (36%)	25 (45%)	46 (39%)
Missing	6	8	13	7	8	12
<b>DMFT</b>	16.4 ± 5.0	16.4 ± 6.4	17.1 ± 5.4	15.4 ± 6.1	17.3 ± 5.8	15.5 ± 5.8
<b>Percentage of decayed or filled teeth (%)</b>	41.3 ± 18.8	43.5 ± 24.7	41.2 ± 22.0	42.4 ± 22.8	47.1 ± 23.0	38.2 ± 21.2
<b>DT</b>	0.8 ± 1.8	0.6 ± 1.6	0.7 ± 1.4	0.9 ± 2.7	0.8 ± 1.7	0.6 ± 1.7
<b>FT</b>	7.2 ± 4.5	8.2 ± 5.6	7.1 ± 4.7	8.3 ± 5.4	8.0 ± 5.3	7.5 ± 5.0
<b>ST</b>	11.4 ± 5.0	11.4 ± 6.4	10.7 ± 5.4	12.5 ± 6.2	10.5 ± 5.8	12.4 ± 5.9
<b>DMFS</b>	63.3 ± 27.4	61.6 ± 33.3	67.3 ± 29.0	56.9 ± 30.7	67.2 ± 29.9	58.4 ± 30.1
<b>DS</b>	1.6 ± 4.2	1.1 ± 3.6	1.3 ± 3.0	1.8 ± 6.6	1.4 ± 3.4	1.0 ± 3.4
<b>FS</b>	22.2 ± 16.2	24.4 ± 19.8	21.7 ± 16.9	25.9 ± 19.7	25.9 ± 20.1	22.7 ± 17.5
<b>SS</b>	64.0 ± 27.1	65.5 ± 33.3	59.7 ± 29.1	70.4 ± 30.8	59.5 ± 29.7	69.0 ± 30.4
<b>Root caries experience</b>						
No recession, no root caries	7 (11%)	13 (14%)	12 (12%)	17 (16%)	5 (7.8%)	23 (18%)
Recession, no root caries	14 (22%)	22 (24%)	24 (24%)	26 (24%)	18 (28%)	30 (23%)

Variable	Metabolic control		Duration of type 2 diabetes		Microvascular complications	
	HbA <sub>1c</sub> ≥7%	HbA <sub>1c</sub> <7%	>10 years	≤10 years	Yes	No
Recession, with root caries	43 (67%)	55 (61%)	62 (63%)	65 (60%)	41 (64%)	78 (60%)
<b>Self-assessed oral health</b>						
Good / very good	39 (61%)	51 (57%)	57 (58%)	66 (61%)	35 (55%)	85 (65%)
Very poor / poor / moderate	25 (39%)	39 (43%)	41 (42%)	42 (39%)	29 (45%)	46 (35%)
<b>Dental service utilization</b>						
Control-oriented	52 (81%)	73 (81%)	84 (86%)	86 (80%)	53 (83%)	110 (84%)
Complaint-oriented	12 (19%)	17 (19%)	14 (14%)	22 (20%)	11 (17%)	21 (16%)
<b>Dental visit frequency</b>						
≥ once a year	55 (87%)	75 (83%)	86 (89%)	89 (83%)	57 (90%)	109 (83%)
< once a year	8 (13%)	15 (17%)	11 (11%)	18 (17%)	6 (9.5%)	22 (17%)
Missing	1	0	1	1	1	0
<b>Tooth brushing frequency</b>						
≥ 2 times daily	52 (81%)	62 (69%)	66 (68%)	81 (76%)	45 (70%)	97 (75%)
< 2 times daily	12 (19%)	28 (31%)	31 (32%)	26 (24%)	19 (30%)	32 (25%)
Missing	0	0	1	1	0	2
<b>Interdental cleaning frequency</b>						
≥ once daily	20 (31%)	28 (31%)	30 (31%)	34 (32%)	18 (28%)	45 (35%)
< once daily	44 (69%)	62 (69%)	67 (69%)	73 (68%)	46 (72%)	84 (65%)
Missing	0	0	1	1	0	2
<b>Electric tooth brush utilization</b>						
No	38 (59%)	43 (48%)	54 (56%)	55 (51%)	30 (47%)	76 (59%)
Yes	26 (41%)	47 (52%)	43 (44%)	52 (49%)	34 (53%)	53 (41%)
Missing	0	0	1	1	0	2
<b>Professional tooth cleaning utilization</b>						
No	13 (21%)	21 (23%)	25 (26%)	21 (20%)	15 (24%)	29 (22%)
Yes	49 (79%)	69 (77%)	72 (74%)	85 (80%)	47 (76%)	101 (78%)
Missing	2	0	1	2	2	1
<b>Lifetime periodontal treatment</b>						
No	44 (70%)	67 (75%)	68 (72%)	71 (69%)	41 (67%)	90 (71%)
Yes	19 (30%)	22 (25%)	27 (28%)	32 (31%)	20 (33%)	37 (29%)
Missing	1	1	3	5	3	4

Note: Data are presented as number (percentage) or mean ± standard deviation based on data from dentate participants. Abbreviations: CAL, clinical attachment level; CDC/AAP, Centers for Disease Control/American Academy of Periodontology; HbA<sub>1c</sub>, Haemoglobin A<sub>1c</sub>; PD, probing depth.

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## CITATION

Holtfreter, B., Pitchika, V., Aarabi, G., Zimmermann, F., Kuhr, K., Jordan, A. R., Kocher, T., Rathmann, W.: Cross-sectional associations of type 2 diabetes with oral conditions: results of the 6th German Oral Health Study (DMS • 6). Online Appendix. Zahnmed Forsch Versorg 2026, 6: 10, <http://dx.doi.org/10.23786/2026-6-10>

## PUBLICATION DATE

14.04.2026

# IMPRESSUM

ZAHNMEDIZIN, FORSCHUNG UND VERSORGUNG

Das Online-Journal des Instituts der Deutschen Zahnärzte (IDZ)



## ISSN

0931-9816

## PUBLISHER

Institute of German Dentists,  
Universitätsstraße 73, 50931 Cologne  
Funded by

German Dental Association (Bundeszahnärztekammer – Arbeitsgemeinschaft der deutschen Zahnärztekammern e. V. (BZÄK))  
and National Association of Statutory Health Insurance Dentists (Kassenzahnärztliche Bundesvereinigung K. d. ö. R.)

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