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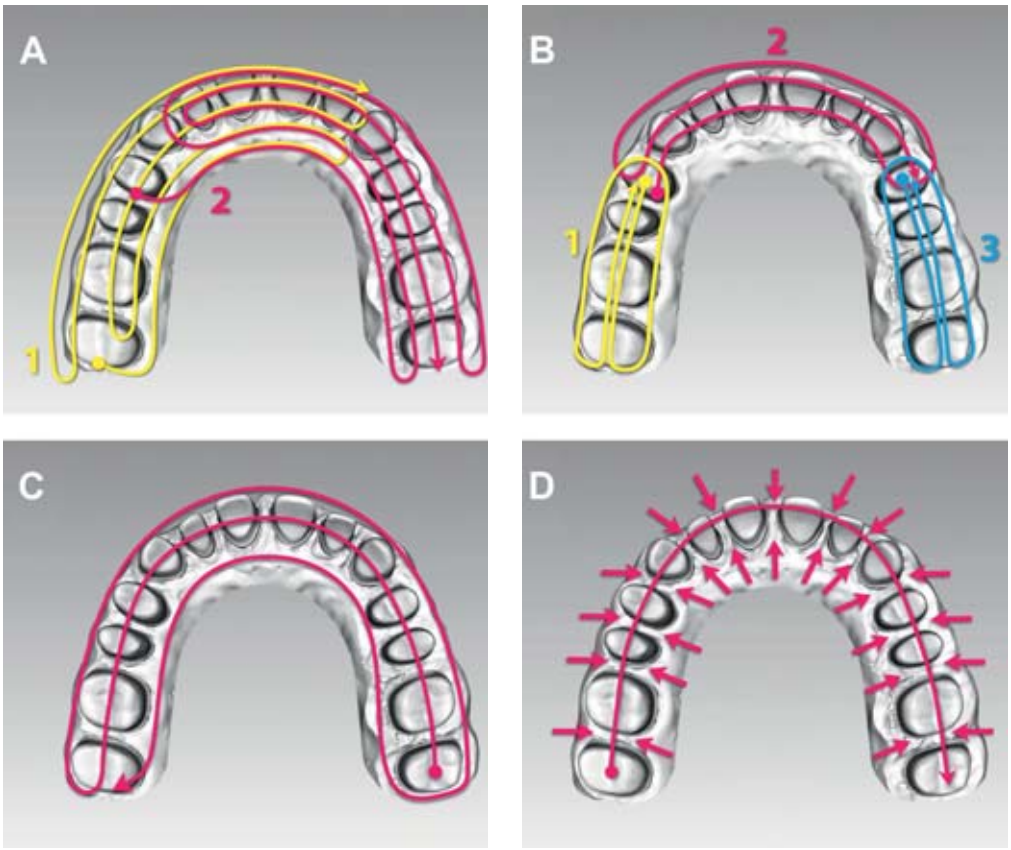

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RESEARCH

ORIGINAL ARTICLES

Title picture: From original article by Prott, Kohal, Vach, Hack, Patzelt: Accuracy of computerized optical impression making: the influence of different scan paths, p. 185–195. Fig. 1: Different scan paths. (LS Prott)
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Accuracy of computerized optical impression making: the influence of different scan paths

Introduction: The aim of this in vitro study was to investigate the influence of different scan paths on the accuracy of digital full arch impressions obtained by 3 scanning systems.

Materials and methods: A maxillary model with 14 prepared teeth was digitized with a reference scanner (ATOS III Triple Scan) and 3 test scanners (CS 3500, CEREC Omnicam and True Definition) using 7 different scan paths. In test path 1 and 2, the manufacturers' suggested scan paths were investigated. In test path 3, 4, and 5 shorter scan paths were utilized. For comparison, a randomly selected scan path was performed in test path 6. Test path 7 was a repetition of scan path 1 to investigate whether there was a learning effect. The scans were digitally superimposed (Geomagic Control), values for trueness and precision were evaluated and statistical analyses performed.

Results: Path 4 (trueness: 32.7 ± 10.3 µm, precision: 23.8 ± 9.5 µm) and path 5 (trueness: 35.1 ± 10.7 µm, precision: 24.2 ± 10 µm) revealed the highest accuracy. For trueness measurements of Omnicam, no statistically significant differences were found between individual scan paths. Overall, path 7 showed a higher accuracy than path 1, however, the differences were not statistically significant.

Conclusion: Ideally, the selected scan path should be as short as possible, and long-distance scans should be avoided. The accuracy of Omnicam appeared not to be dependent on a specific scan path. For all three scanners, the accuracy was clinically acceptable, however, the scan of a prepared full arch with a point-and-click system (CS 3500) cannot be recommended.

Keywords: computerized optical impression making; digital impression; optical impression; scan path; scan pattern

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Scanner / Path	CS 3500		Omnicam		True Definition	
	Mean	SD	Mean	SD	Mean	SD
1	71.6	7.7	28.2	8.5	45.2	13.0
2	52.6	8.9	31.0	8.7	45.8	8.1
3	45.0	5.7	23.7	6,0	50.0	11.1
4	44.1	4.6	22.3	2.1	31.6	7.3
5	43.2	9.8	27.2	7.4	34.8	8.6
6	52.0	11.8	28.0	9.8	43.8	11.0
7	64.0	9.2	26.1	4.3	39.7	6.6

Table 1 Mean deviations and standard deviations (SD) for trueness of all test groups in µm.

1. Introduction

To produce high-quality dental restorations, it is necessary to make an impression of the prepared teeth which ideally should be as accurate and detailed as possible. For intraoral scanning, the accuracy is specified in terms of trueness and precision (ISO 5725-1) [14]. Trueness describes the extent of deviation between test and reference measurements, whereas precision is defined as the consistency among the test measurements obtained by a comparison of the repeated intraoral scans [35]. Only trueness and precision together may describe the accuracy of a digital impression [7]. However, the quality of a restoration corresponds to the sum of errors of each individual step in a digital workflow [25]. Errors that occur during the impression making process can usually not be compensated for in the subsequent steps [43]. The main advantages of computerized optical impression making are the increased patient comfort, the savings of working time and the elimination of errors caused by the conventional impression material or during the production of the stone model [33, 43, 51]. In previous studies, full arch digital impressions revealed an equal or higher accuracy than that achieved with conventional impression materials [6, 32, 46]. Nevertheless, in 2021 only half of the American dentists used an intraoral scanner in their practice [38]. 66 % of the nonusers mentioned the high level of financial investment as the main reason. Against this, digital devices, such as intraoral scanners and milling machines, are already well established in dental technology [1]. Even in other fields of dentistry, like orthodontics or maxillofacial surgery, digital technologies are already an integral part of treatment for the calculation of indices, treatment follow-ups and the simulation of treatment plans in advance [10, 22].

The accuracy of digital impressions is affected by the extension of the area to be scanned [9, 46, 53]. During optical data acquisition, 3D single images are stitched together by overlaying and merging the edge areas of the point clouds of 2 single images [25]. Thereby, any inaccuracies sum up to larger errors in the resulting 3-dimensional dataset. Previous in vitro studies examining the acquisition of full arches demonstrated that most scanning systems are able of capturing a full arch with sufficient accuracy, however, there is a need for improvement to achieve the level of conventional impression making [7–9, 15]. Moreover, there is a lack of studies investigating the accuracy of full arch impressions in patients [6, 17, 20, 23, 42].

To reduce measurement errors in larger scan areas, it seems to be necessary to find a process where the individual images are not lined-up along the dental arch, but rather are stitched together in such a way that errors due to superimposition are kept to a minimum. This may be achieved, for example, by additional lateral images or by crossing the occlusal surface [54]. The influence of scan paths on the accuracy of full arch impressions has been demonstrated in previous studies [5, 8, 24, 28, 30, 45]. However, these studies used dentate models with no preparation or with a maximum of 2 prepared teeth. To represent a more complex situation, the present study contains a model with 14 prepared teeth. Moreover, there is still no consensus in literature which scan path is the most appropriate one, especially for using different scanning systems. Since the evidence whether the manufacturer's scan path is really superior to others is lacking, the present study compared different shorter scan paths to the more complex scan paths of the manufacturers.

Previous studies reported that the learning curve was highest for low-experienced operators [19, 37, 49], however, the learning curve of an experienced operator may still be steep when using another intraoral scanner [52]. Moreover, it is reported that the accuracy of newer scanning systems is less likely be influenced by the user's experience [22]. To analyze this learning effect, the second objective of the study was to investigate if there is an effect of increasing experience due to the large number of scans performed. The tested null hypotheses were that (I) the 7 different scan paths and (II) the user's experience do not affect the accuracy of digital impressions obtained by 3 different scanning systems.

2. Materials and methods

A maxillary dental model (Prosthetic Restauration Jaw Model (PRO2001-UL-SP-FEM-32), Nissin Dental Products INC., Kyoto, Japan) with screwable typodont teeth (Simple Root Tooth Model (A5A-200), Nissin Dental Products INC.) was used in the present study. The model was duplicated and an acrylic replica (Self-curing denture, Lang Dental, Wheeling, IL, USA) was fabricated. The typo-

dont teeth 17–27 were embedded into the acrylic model and were prepared with a shoulder to accept all-ceramic crowns. In order to create a reference data set, the model was firstly digitized with a highly accurate industrial scanner (ATOS III Triple Scan, GOM GmbH, Braunschweig, Germany). Subsequently, the reference model was scanned with 3 intraoral scanning systems: CS 3500 (Carestream Health, Rochester, NY, USA), CEREC AC Omnicam (Dentsply Sirona GmbH, Bensheim, Germany), and True Definition (3M ESPE, Seefeld, Germany). The following software versions were used: CS 3500 (Dental Imaging Software, Version 1.2.6.50), Omnicam (Version SW 4.4.0.122433), True Definition (Version 5.0.2-production-eu).

Overall, 7 different scan paths were tested and each scan path was performed 5 times [31, 32, 34]. For the scan of a full arch, Dentsply Sirona [4] and 3M ESPE recommended a specific scan path. Carestream Health did not provide any information about a full arch scan for the CS 3500. Therefore, the manufacturer's scan path of the Omnicam was used. For True Definition, the recommended manufacturer's scan path as well as video instructions for powdering and camera positioning were available on the computer interface. In test path 1, the scan path recommended by the manufacturer was investigated. In path 2, the manufacturer's scan path of the other tested scanner was used. In path 3, 4, and 5 shorter scan paths were investigated, which were previously tested in a study by Ender and Mehl [8]. For comparison, a randomly selected scan path was chosen in path 6. In path 7, the manufacturer's scan path used in path 1 was repeated in order to investigate if there is a learning effect due to the large number of scans. All scan strategies are displayed in a representative illustration (Figure 1). In this present study, the completeness of the datasets was mandatory. After the implementation of the respective scan path scanning was continued until relevant missing areas above the preparation margins were sufficiently captured. The overall scanning time was recorded.

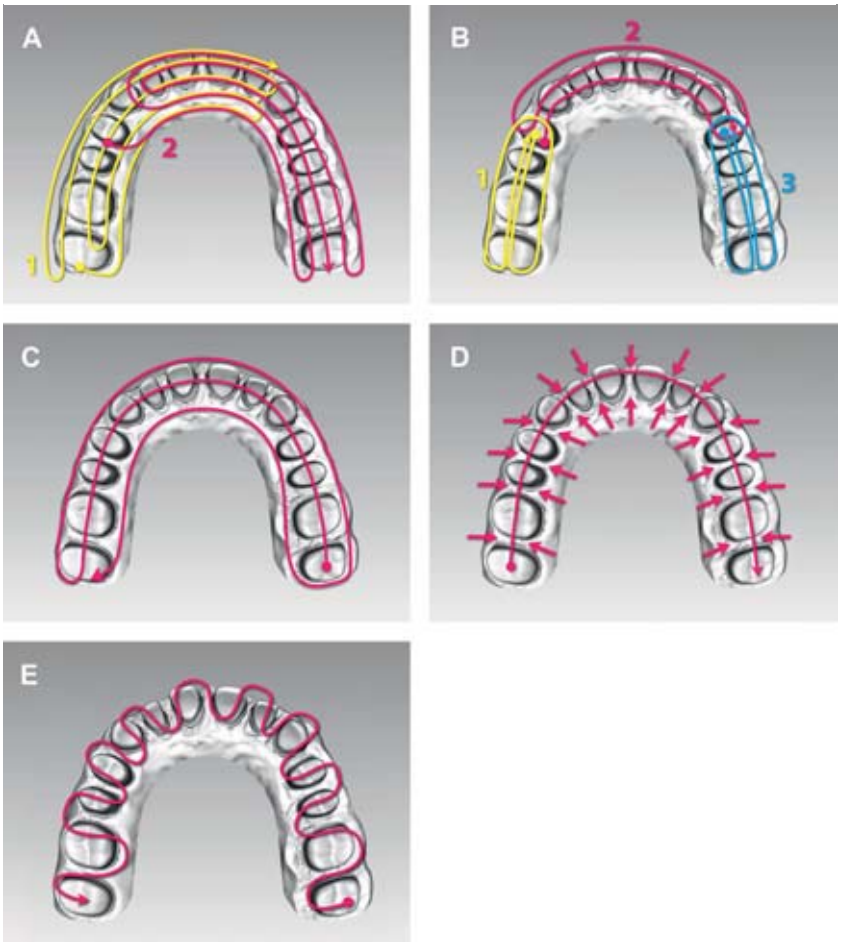

Figure 1: L.S. Prott

Figure 1
A) Manufacturer's recommended scan path of the Omnicam:
First half of arch: Starting occlusally at tooth 17 (1, yellow), the camera was tilted at a 45° angle to the palatal and guided anteriorly to tooth 22, where it was rotated another 45° and then returned to tooth 17, now at a 90° angle. From there, it was directed back to the occlusal surface of tooth 17 and then moved anteriorly back to tooth 22, where the camera was rotated 45° to the buccal and then guided posteriorly back to tooth 17. Buccally on tooth 17, the camera was rotated another 45° and then moved back anteriorly at a 90° angle. Second half of arch: Starting occlusally at tooth 14 (2, red), from where the camera was rotated at a 90° angle to the palatal and guided along the dental arch to tooth 27. There, the camera was tilted back to a 45° angle and then guided to tooth 12, where it was panned over and then guided buccally at a 45° angle to tooth 27. It was tilted again at a 90° angle and moved back to 12. The camera was rotated occlusally and finally returned to 27.

B) Manufacturer's scan path of the True Definition: Starting from tooth 14 occlusally to the distal surface of 17, the camera was moved back palatally to 14. Then panned buccally and returned to tooth 17. Subsequently it was directed occlusally back to 14 (1, yellow). Secondly, the camera was guided palatally from 14 to 24 in a vertical position. It was then panned over 24 and directed labially back to 14. Starting from 14, the incisal surface was scanned back to 24 (2, red). Started occlusally at tooth 24 and the camera was guided from there distally to 27. Then palatally back to 24 and then buccally to 27. The scan path ended occlusally (3, blue).

C) Scan path 3 (Straight): Starting occlusally at tooth 27, the camera was guided along the dental arch to tooth 17. Then the buccal and finally the oral surfaces were scanned.

D) Scan path 4 (Panned): The scan started occlusally at tooth 17 and the camera was guided along the dental arch to tooth 27. Subsequently it was panned at an angle of approximately 30° from oral, then from buccal.

E) Scan path 5 (Cross): The scan started occlusally at 27 and the camera was moved along the dental arch in slow zigzag movements from oral to buccal to tooth 17 (tooth numbers are noted according to the FDI World Dental Federation notation system).

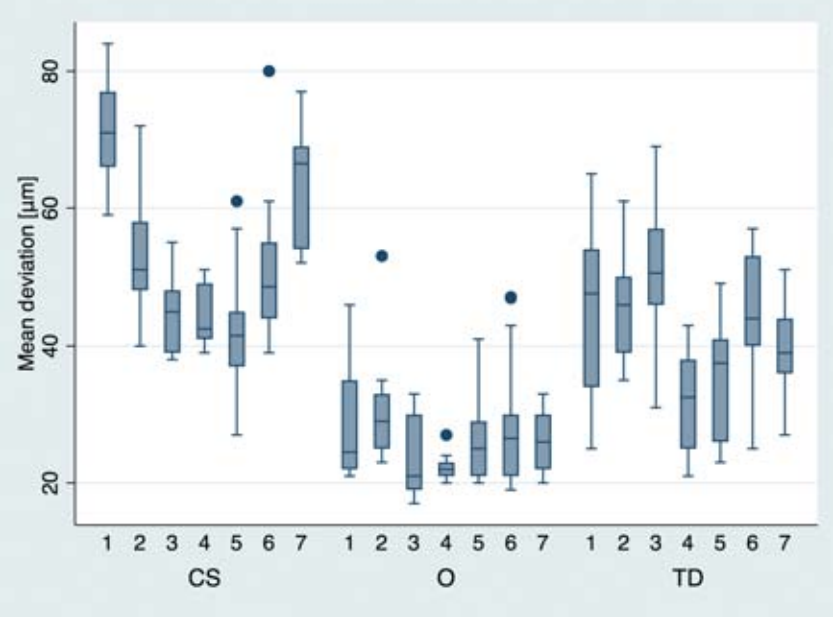

Figure 2: K. Vach

Figure 2 Mean deviations of all test groups for the trueness measurements (CS = CS 3500, O = Omnicam, TD = True Definition).

For CS 3500, datasets could be exported directly to open STL files. Against this, the files of Omnicam had to be exported as encrypted dxd files, since the CEREC workflow was still a closed system at the time of this study. The conversion into open STL files was carried out with the Sirona Connect software (Version SW 4.4.1.132174) and InLab (Version SW 15.1.0.135929). For True Definition, the datasets had to be sent to a proprietary cloud platform (3M Connection Center) for conversion and were downloaded as open STL files. Before scanning, the model was pretreated with dusting powder (3M High Resolution Scanning Spray, 3M ESPE, Saint Paul, MN, USA). The CS 3500 and the Omnicam scanner did not need any powdering.

All scans were performed by a dental student (L.P.) on several consecutive days. On these days, the humidity was at 21 ± 12 % and the room temperature at 24 ± 3 °C. The student trained herself to perform the scans for a week beforehand, performing 30 practice scans with each scanner.

For evaluation, the STL files of the reference scanner and the test scanners were loaded into a 3D analysis software (Geomagic Control 2014, 3DSystems, Rock Hill, SC,USA). Using Geomagic's initial alignment and the best-fit algorithm, the datasets were superimposed by determining the minimal distance between 2 closest surface points of the test and reference file. Subsequently, 3D comparisons were performed and mean values as well as positive and negative mean deviations were calculated. The deviations between the datasets of the test scanners and the reference scan (trueness) and the deviations of the data sets within a test group (precision) were determined. For trueness, a total number of 35 comparisons were performed (5 comparisons per test group, 7 test groups). For precision the number of comparisons was 70 (10 comparisons per test group, 7 test groups). Color-coded images were exported for visual evaluations.

For descriptive statistical analysis means, medians and standard deviations (SD) were computed. Linear mixed models were fitted with random intercepts for each scan strategy to evaluate device effects on response variables. The method of Scheffe was applied to address the multiple testing problem due to several pairwise comparisons. The calculations were performed with a statistical software (STATA 14.2, StataCorp LP, College Station, TX, USA). The level of statistical significance was set to $p \leq 0.05$.

3. Results

The results for trueness of all test groups are shown in Table 1 and are graphically displayed in Figure 2. The comparisons between the individual scan paths are given in Table 2. For the CS 3500, the datasets in path 4 (44.1 ± 4.6 µm) and in path 5 (43.2 ± 9.8 µm) deviated the least from the reference scan. There were statistically significant differences between path 1 and 2 (19 ± 3.6 µm, p = 0.000), 1 and 3 (26.6 ± 3,6 µm, p = 0.000), 1 and 4 (27.5 ± 3.6 µm, p = 0.000), 1 and 5 (28.4 ± 3.6 µm, p = 0.000), 1 and 6 (19.6 ± 3.6 µm, p = 0.000), 3 and 7 (19 ± 3.6 µm, p = 0.000), 4 and 7 (19.9 ± 3.6 µm, p = 0.000) and 5 and 7 (20.8 ± 3.6 µm, p = 0.000). The visual analysis showed high deviations above 100 µm especially in the molar regions (Figure 3). The trueness measurements of the Omnicam were best in path 3 (23.7 ± 6 µm) and 4 (22.3 ± 2.1 µm). There were no statistically significant differences between the individual scan paths. In the higher deviating test paths of the manufacturers' scan paths, datasets with positive deviations occlusally and buccally with simultaneously occurring negative deviations on the oral surfaces were frequently found (Figure 4). The True Definition datasets deviated least from the reference scan in path 4 (31.6 ± 7.3 µm) and path 5 (34.8 ± 8.6 µm). Statistically significant differences were found between path 2 and 4 (14.2 ± 3.9 µm, p = 0.038), 3 and 4 (18.4 ± 3.9 µm, p = 0.001) and 3 and 5 (15.2 ± 3.9 µm, p = 0.018). All scan paths of the True Definition showed a wavy deviation pattern from occlusal. Orally, negative deviations occurred, while buccally, especially in the posterior regions, there were high positive deviations more frequently (Figure 5).

The precision results are given in Table 3. Figure 6 displays graphs of the mean deviations, and the comparisons between the individual scan paths are given in Table 4. The precision of the CS 3500 was lowest in path 1 (25.5 ± 5.7 µm). Statistically significant differences were found between the paths 1 and 2 (16.3 ± 3 µm, p = 0.000), 1 and 6 (14.7 ±

Scanner / Path	CS 3500			Omnicam			True Definition		
	Mean	SEM	p-value	Mean	SEM	p-value	Mean	SEM	p-value
1 vs. 2	19.0	3.6	**0.000**	2.8	3.0	0.990	0.6	3.9	1.000
1 vs. 3	26.6	3.6	**0.000**	4.5	3.0	0.899	4.8	3.9	0.958
1 vs. 4	27.5	3.6	**0.000**	5.9	3.0	0.704	13.6	3.9	0.058
1 vs. 5	28.4	3.6	**0.000**	1.0	3.0	1.000	10.4	3.9	0.308
1 vs. 6	19.6	3,6	**0.000**	0.2	3.0	1.000	1.4	3.9	1.000
1 vs. 7	7.6	3.6	0.609	2.1	3.0	0.998	5.5	3.9	0.920
2 vs. 3	7.6	3.6	0.609	7.3	3.0	0.444	4.2	3.9	0.979
2 vs. 4	8.5	3.6	0.466	8.7	3.0	0.220	14.2	3.9	**0.038**
2 vs. 5	9.4	3.6	0.332	3.8	3.0	0.954	11.0	3.9	0.239
2 vs. 6	0.6	3.6	1.000	3.0	3.0	0.986	2.0	3.9	1.000
2 vs. 7	11.4	3.6	0.119	4.9	3.0	0.855	6.1	3.9	0.873
3 vs. 4	0.9	3.6	1.000	1.4	3.0	1.000	18.4	3.9	**0.001**
3 vs. 5	1.8	3.6	1.000	3.5	3.0	0.970	15.2	3.9	**0.018**
3 vs. 6	7.0	3.6	0.701	4.3	3.0	0.918	6.2	3.9	0.864
3 vs. 7	19.0	3.6	**0.000**	2.4	3.0	0.996	10.3	3.9	0.321
4 vs. 5	0.9	3.6	1.000	4.9	3.0	0.855	3.2	3.9	0.995
4 vs. 6	7.9	3.6	0.562	5.7	3.0	0.738	12.2	3.9	0.132
4 vs. 7	19.9	3.6	**0.000**	3.8	3.0	0.954	8.1	3.9	0.632
5 vs. 6	8.8	3.6	0.419	0.8	3.0	1.000	9.0	3.9	0.500
5 vs. 7	20.8	3.6	**0.000**	1.1	3.0	1.000	4.9	3.9	0.954
6 vs. 7	12.0	3.6	0.082	1.9	3.0	0.999	4.1	3.9	0.981

Table 2 Mean deviations with standard errors of the mean (SEM) and p-values for the trueness comparisons of the individual scan paths in µm. Significant differences ($p \leq 0.05$) are highlighted.

3 µm, p = 0.001), and 2 and 5 (11.7 ± 3 µm, p = 0.021). For the Omnicam, the datasets in path 7 (15.1 ± 4.3 µm) deviated least. There were statistically significant differences between paths 1 and 2 (8.4 ± 2.1 µm, p = 0.014), 1 and 4 (8.9 ± 2.1 µm, p = 0.006), 1 and 7 (9.2 ± 2.1 µm, p = 0.004), and 6 and 7 (7.6 ± 2.1 µm, p = 0.042). For the True Definition, the lowest deviation was found in path 2 (19.9 ± 5.6 µm). There were statistically significant differences between paths 1 and 6 (13.6 ± 3.3 µm, p = 0.012), 2 and 3 (18.8 ± 3.3 µm, p = 0.000), 2 and 6 (24.9 ± 3.3 µm, p = 0.000), 2 and 7 (15.7 ± 3.3 µm, p = 0.001), 3 and 4 (13.9 ± 3.3 µm, p = 0.009), 3 and 5 (15.1 ± 3.3 µm, p = 0.003), 4 and 6 (20 ± 3.3 µm, p = 0.000), 5 and 6 (21.2 ± 3.3 µm, p = 0.000),

Scanner / Path	CS 3500		Omnicam		True Definition	
	Mean	SD	Mean	SD	Mean	SD
1	25.5	5.7	24.3	10.9	31.2	10.6
2	41.8	13.3	15.9	2.6	19.9	5.6
3	33.2	8.3	17.4	5.8	38.7	12.7
4	31.3	8.5	15.4	3.8	24.8	7.6
5	30.2	9.0	18.9	6.9	23.6	10.8
6	40.2	12.1	22.6	9.3	44.8	15.5
7	35.0	9.7	15.1	4.3	35.6	13.3

Table 3 Mean deviations and standard deviations (± SD) for precision of all test groups in µm.

and 5 and 7 (12 ± 3.3 µm, p = 0.047). Regarding the precision of all scanners, the highest deviations were found primarily in the molar regions.

The scanning times result from the execution of the scan path, the rescanning and the processing of the dataset. The average scanning time (+ SD) for the CS 3500 was 34 ± 3.4 minutes and 17 ± 5.7 minutes for the Omnicam. For the True Definition, a maximum scanning time of 7 minutes was default by the scanner. After the practice scans, it was reliably possible to capture the whole model in these 7 minutes, however, for all True Definition scans the maximum scan time of 7 ± 0 minutes was applied.

Regarding a learning effect, path 7 showed a higher accuracy than path 1, however, these differences were only statistically significant for the precision of Omnicam. The learning curve can therefore be regarded as minor.

4. Discussion

The aim of this in vitro study was to examine the effect of seven different scan paths on the accuracy of 3 commercially available intraoral scanners. For a dataset to be considered accurate, both parameters, trueness and precision, must be within an acceptable range. Deviations across the full arch of less than 100 µm are accepted since deviations of 100 µm and above may cause an non-acceptable fit of the produced restorations [7]. Based on the present results, the null hypothesis (I) was rejected as the applied scan paths affected the accuracy of digital impressions. However, for trueness measurements of the Omnicam, no statistically significant differences were found between the individual scan paths. Also Passos et al. [30] reported previously, that there was no dominant strategy for trueness and precision measurements with the Omnicam.

Overall, path 4 (Panned) and 5 (Cross) achieved the highest accuracy. In path 4, the camera was first moved occlusally along the dental arch and then panned at a 30° angle from oral and buccal. In path 5, the dental arch was scanned in slow zigzag movements. In a study by Ender and Mehl [8], the panned scanpath also reached the lowest deviation, while Cross was statistically significant worse. In contrast, Van der Meer et al. [48] found the lowest measurement errors with the zigzag scan path. Ender and Mehl [8] suspected that these deviations could have been due to the different analysis procedures as they superimposed the scans in a 3D evaluation software, while Van der Meer et al. [48] measured the inclinations and distances between 3 cylinders. However, it should be mentioned that in the study by Van der Meer et al. [48] only the Lava C.O.S. used a specific scanning protocol. Furthermore, all scanners used a different principle of acquisition and differed in the use/not-use of powder. Medina-Sotomayor et al. [26] also achieved the best results with a zigzag scan path. Keul and Güth [16] found a scan path, that performed a zigzag scan of both quadrants, with an additional overlapping in the anterior region, most suitable. Likewise, other authors concluded that the accuracy can be increased by additional angled images and crossing over the occlusal surface [11, 21, 27]. This might be an advantage, because more data could be acquired in the hard-to-reach approximal regions during execution of the scan path. Additionally, more information might be obtained by taking additional overlapping angled images, especially in the more inclined and less structured anterior areas [27]. A recent study reported significant differences in measurements made within a quadrant compared to intermolar or inter-canine distances [23], which were traced back to greater errors occurring in the incisor region. Consequently, the selection of an appropriate scan path seems to be particularly important to minimize stitching errors in the anterior region, simultaneously, this leads to a reduction of the high deviations frequently found in the molar regions.

In the present study, all tested scanners achieved greater accuracy utilizing shorter scan paths than with the more complex scan paths suggested by the manufacturers. For trueness of the CS 3500, no statistically significant differences between the shorter paths 3, 4 and 5 and the manufacturers' scan paths 1 and 7 were found. In contrast, regarding trueness of Omnicam, there were no statistically significant differences between the individual scan paths. However, also for Omnicam, the trueness values were identified to be most accurate in path 4 (Panned), while the deviation of the manufacturers' scan paths in path 1 and 2 was highest. A possible explanation might be that the more complex manufac-

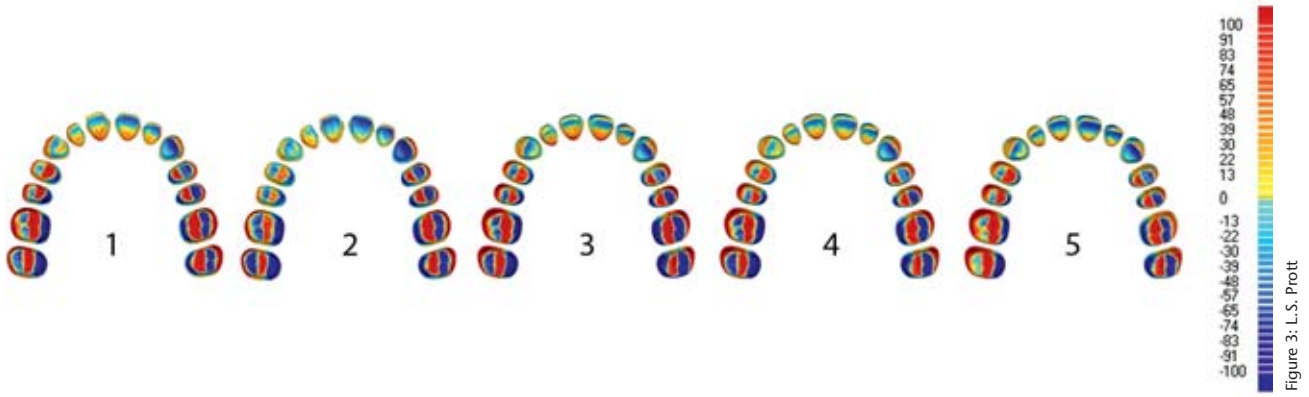

Figure 3 Superimposed datasets of the reference scanner and CS 3500 (dark blue ≤ –100 µm, dark red ≥ +100 µm deviation).

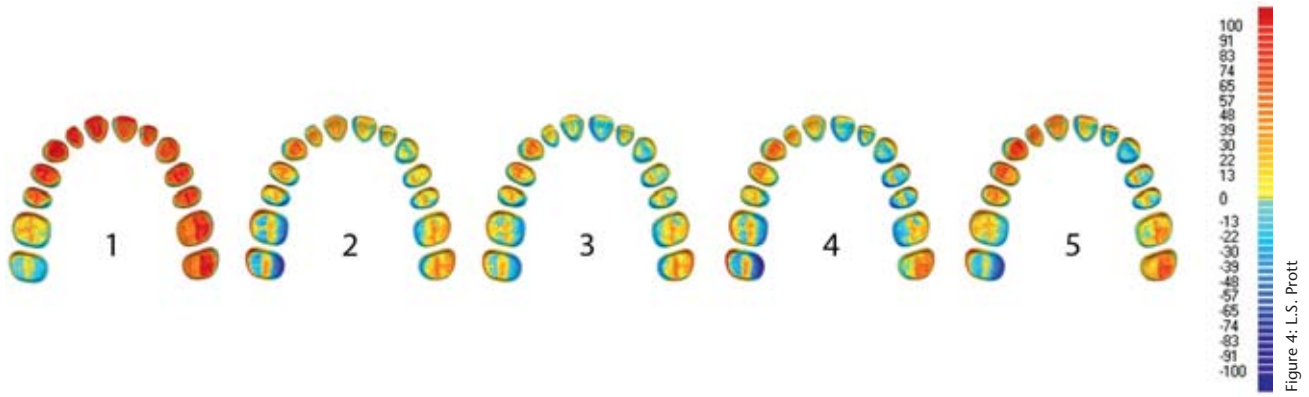

Figure 4 Superimposed datasets of the reference scanner and the Omnicam (dark blue ≤ –100 µm, dark red ≥ +100 µm deviation).

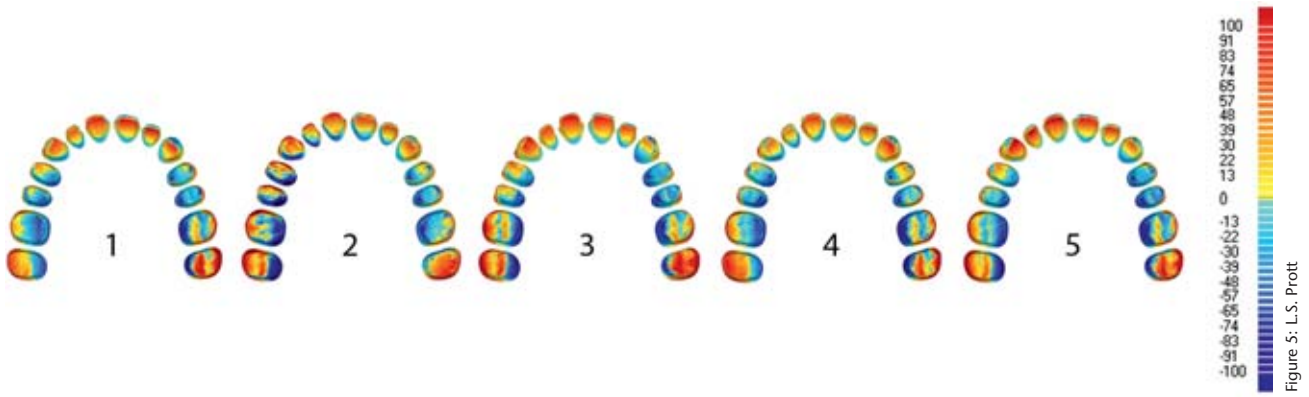

Figure 5 Superimposed datasets of the reference scanner and the True Definition (dark blue ≤ –100 µm, dark red ≥ +100 µm deviation).

turers' scan paths had a higher number of errors due to the large number of individual images that needed to be stitched together. Overall, trueness and precision values of the Omnicam were better than those achieved with the CS 3500. The higher deviations of the CS 3500 may be due to technological differences (point-and-click system) as well as different matching algorithms, filters, lower resolution or interpolation errors [43, 44, 50]. The Omnicam and CS 3500 use the same scanning technology (active triangulation), but they differ in their stitching mechanisms. While the Omnicam is a video-based system, the CS 3500 is a point-and-click system. As mentioned in previous studies, the video-based technology seems to be beneficial for a highly accurate image acquisition [12, 26]. Furthermore, the current literature shows that software versions have a significant influence on the accuracy of intraoral scanners [9, 13], and the ongoing improvements in soft- and hardware will continuously increase the scanning technology [42].

The trueness of the True Definition was highest in path 4 (Panned) and path 5 (Cross) with statistically significant differences to path 3 (Straight). The results obtained with the Omnicam and CS 3500 were not significantly worse in path 3, but issues were observed during the stitching process of the CS 3500 when

Scanner / Path	CS 3500			Omnicam			True Definition		
	Mean	SEM	p-value	Mean	SEM	p-value	Mean	SEM	p-value
1 vs. 2	16.3	3.0	**0.000**	8.4	2.1	**0.014**	11.4	3.3	0.074
1 vs. 3	7.7	3.0	0.370	6.9	2.1	0.091	7.5	3.3	0.549
1 vs. 4	5.8	3.0	0.728	8.9	2.1	**0.006**	6.4	3.3	0.723
1 vs. 5	4.7	3.0	0,883	5.4	2.1	0.364	7.6	3.3	0.523
1 vs. 6	14.7	3.0	**0.001**	1.7	2.1	0.996	13.6	3.3	**0.012**
1 vs. 7	9.5	3.0	0.129	9.2	2.1	**0.004**	4.4	3.3	0.946
2 vs. 3	8.6	3.0	0.231	1.5	2.1	0.998	18.8	3.3	**0.000**
2 vs. 4	10.6	3.0	0.058	0.6	2.1	1.000	5.0	3.3	0.901
2 vs. 5	11.7	3.0	**0.021**	3.0	2.1	0.914	3.8	3.3	0.974
2 vs. 6	1.6	3,0	1.000	6.7	2.1	0.113	24.9	3.3	**0.000**
2 vs. 7	6.8	3.0	0.535	0.9	2.1	1.000	15.7	3.3	**0.001**
3 vs. 4	2.0	3.0	0.999	2.0	2.1	0.989	13.9	3.3	**0.009**
3 vs. 5	3.1	3.0	0.985	1.6	2.1	0.997	15.1	3.3	**0.003**
3 vs. 6	7.0	3.0	0.498	5.3	2.1	0.389	6.1	3.3	0.767
3 vs. 7	1.8	3.0	0.999	2.3	2.1	0.976	3.1	3.3	0.990
4 vs. 5	1.1	3.0	1.000	3.6	2.1	0.823	1.2	3.3	1.000
4 vs. 6	9.0	3.0	0.187	7.3	2.1	0.061	20.0	3.3	**0.000**
4 vs. 7	3.8	3.0	0.957	0.3	2.1	1.000	10.8	3.3	0.112
5 vs. 6	10.1	3.0	0.086	3.7	2.1	0.791	21.2	3.3	**0.000**
5 vs. 7	4.9	3.0	0.860	3.9	2.1	0.758	12.0	3.3	**0.047**
6 vs. 7	5.2	3.0	0.814	7.6	2.1	**0.042**	9.2	3.3	0.272

Table 4 Mean deviations with standard errors (SEM) and p-values for the precision comparisons of the individual scan paths in µm. Significant differences ($p \leq 0.05$) are highlighted.

scanning longer distances along the buccal and labial surfaces (in path 3). Visible stitching errors already occurred during the execution of the scan path. For the CS 3500 and True Definition the scan path 3 appeared to be rather unsuitable. It seems that scanning in sextants (manufacturer scan path True Definition) had no advantage. However, the deviations could also have been caused by the vertical scan in the anterior region. The authors of a recent study recommend to avoid a rotation of the scan wand, attributing the inferior accuracy to an interruption of the image-stitching process due to the change of direction [29].

Overall, regarding precision, deviations were very high in path 6 (Randomly selected scan path). This demonstrates that precision increases when a scan path is used. The Omnicam's precision values were most ac-

curate by utilizing the manufacturers' suggested scan path. This differs from the trueness values, where the manufacturers' scan paths were often statistically significant worse than the shorter scan paths. The overlapping scan in the less structured anterior region may have had a positive effect on the precision measurements.

In the present study, the scanning time was higher than in other studies [36, 47, 51]. Allegedly, this was due to the prepared study model that was utilized. Other in vitro studies have used an unprepared model or a model with a maximum of 2 prepared teeth so that it was sufficient to move the wand along the approximal space only once. For unprepared teeth a high mesh density is not as relevant as for prepared teeth, where a large number of triangles are necessary to represent the preparation margin precisely [39]. After the scan path was carried out, the datasets of the prepared full arch model showed data gaps in almost all approximal spaces. These gaps were subsequently closed by additional angled images. Because the results of the present study were better than those of Treesh et al. [47] (trueness of Omnicam: 48.8 µm and CS 3500: 84.6 µm) and Renne et al. [36] (trueness of Omnicam: 95.4 ± 10.7 µm and CS 3500: 77 ± 6.5 µm), it can be assumed that the rescanning at least did not have a negative effect on the accuracy of the scans. Due to the different study designs, it is not possible to compare the studies directly. However, with a scanning time of 34 ± 3.4 minutes (including processing and rescanning), the CS 3500 appears clinically unsuitable for the acquisition of a prepared full arch.

Some previous studies used the scanning time for evaluating the learning effect of intraoral scanning [40, 49, 52]. Additionally, the learning curve was determined by measuring deviations or image numbers [35, 37]. As expected, the learning curve was highest for low-experienced operators [19, 37, 49]. Resende et al. [37] found that low experienced operators obtained larger scanning times and the highest number of images compared to more experienced operators. Likewise, Radeke et al.[35]

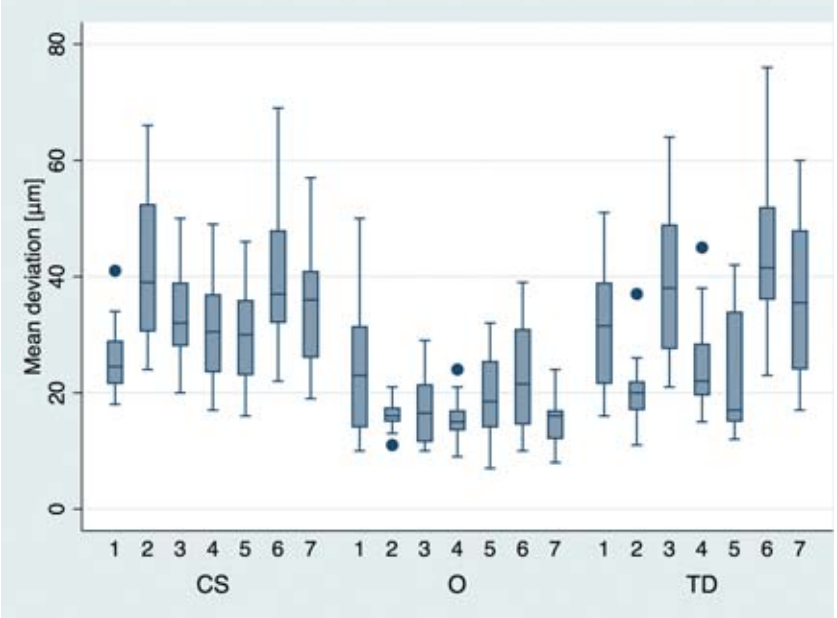

Figure 6: K. Vach

Figure 6 Mean deviations of all test groups for the precision measurements (CS = CS 3500, O = Omnicam, TD = True Definition).

reported that the experience, not the graduation, effected the accuracy. In the present study, the learning effect was evaluated by comparing the accuracy of the same manufacturers' scan paths in group 1 and 7. Overall, path 7 delivered a better result than path 1, but the difference was generally not statistically significant. The learning curve was regarded as minor. In accordance with previous evidence, the authors suspected that the learning effect was probably higher during the exercise scans and subsequently increased only minimally. Thereby, the second null hypothesis that the user's experience does not affect the scan accuracy could be partly rejected.

Like in other in vitro studies, clinical conditions like the influence of saliva and blood, limited space, patient movement and different refractive surfaces of tooth substrates and restorations were not considered [3, 41]. Another limitation is the performance of the scans on several consecutive days. Ideally, the study should have been carried out on one day in order to ensure similar conditions. Temperature, humidity and lighting conditions might have affected the present results [2, 18]. Moreover, the used intraoral scanning systems were based on different technology (active triangulation and active wavefront sampling) and differed in their acquisition mode (video sequencing and image acquisition) and the need for powdering. The influence of these system-specific factors is unknown, however, since each scanning system has different characteristics these factors cannot been excluded. Finally, a best-fit algorithm was used for the superimposition of the datasets. For large full-arch datasets the error caused by the point-to-point measurements of the superimposition itself sum up and it remains unknown if and how far the results were influenced by these superimposition errors. However, the superimposition of digitized models is referred to as the standard procedure for 3D surface comparisons [9]. Further research should be undertaken to detect how different scan paths influence the accuracy of full-arch scans in vivo and additional studies with prepared full arch models in vitro would be advisable.

5. Conclusion

Within the limitations of the present study, it can be concluded that there is an effect on the accuracy related to different scan paths when scanning prepared full arches, however, some devices are less sensitive to different scan paths than others. In general, for all tested scanners, the scan path

should be as short as possible and long-distance scans should be avoided. In addition, there is a learning curve, however, it can be considered as minor and scanning of prepared full arches with a point-and-click system cannot be recommended.

Conflict of interest

The authors declare that they do not have any conflicts of interest related to the subject matter of this study.

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Instruction on interdental cleaning – a survey among dental professionals

Introduction: Instruction on interdental cleaning at home (IC) is daily routine in the dental practice and mostly performed by dental professionals (DP). Recently published S3-guidelines (AWMF: 083–022/083–043) describe, among other things, the need and extent of patient-specific instructions on IC. However, since little evidence is available up to date regarding the DP's recommendations to patients on IC or data on the level of knowledge of German DPs about IC, an exploratory survey study was initiated.

Methods: At 2 evaluation time points in 2018 and 2021 (during and after the publication of guideline AWMF: 083–022/083–043), dental professionals with (DP+) and without (DP–) certified education in dental hygiene were surveyed at 3 German dental training institutes using an anonymized and validated online questionnaire (unipark.com, Tivian XI GmbH, Cologne, Germany). The probands answered 11 questions regarding personal details (including age, professional degree/experience, personal IC habits), the recommendations according to IC (including devices such as interdental brush/floss and additional use of toothpaste or interdental gel together with the IC devices), and the basis for their recommendations. The results were analyzed mainly descriptively.

Results: In total, 89 DPs participated in 2018 (DP–/DP+: 68/21) and 109 DPs in 2021 (DP–/DP+: 59/50), 2021 with a higher DP+ rate (p = 0.006). At both evaluation times, DP+ were more likely (2018/2021: 62 %/64 %) to report following scientific recommendations than DP– (2018/2021: 27 %/41 %). At the first evaluation date, 78 % of all DPs (2021: 73 %) reported recommending IC devices they themselves perceived as effective. Patient preferences were considered by DP+ 24 % in 2018 and 36 % in 2021. DP– considered patient preferences in 54 % (2018) and 39 % (2021). DPs predominantly reported to use interdental brushes (2018/2021: 75 %/77 %) and floss (2018/2021: 78 %/84 %) as their personal IC devices. A majority of DPs also recommended both devices in 2018/2021 with 99 %/95 % for interdental brushes and 75 %/78 % for floss.

Discussion: Despite the small number and special selection of DPs, the results of the exploratory survey study suggest that a basic knowledge of IC is present in all groups of DPs. The DPs surveyed were more likely to consider the self-perceived efficacy of IC devices than patient preferences or evidence-based recommendations, regardless of their level of certification.

Conclusion: The results suggest that there is a need for more intensive coaching of DPs regarding evidence-based and patient-specific instruction on IC at home.

Keywords: dental hygienist; dental professional; instruction; interdental cleaning at home

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Introduction

The Fifth German Oral Health Survey (DMS V) shows that awareness of one's own teeth and oral hygiene has evolved among younger adults (35- to 44-year-olds) and younger seniors (65- to 74-year-olds), and the use of home oral hygiene products has steadily increased since 1997 [9]. On the other hand, half (52%) of younger adults and 65% of younger seniors have periodontal diseases. Based on scientific studies, it can be suspected that especially interdental tooth surfaces are predisposed to caries and periodontitis and are not adequately cleaned by the single use of a toothbrush [11]. Therefore, various complementary aids and techniques have been described in addition to brushing teeth with a toothbrush alone, ranging from simple toothpicks with a triangular cross-section to complex oral irrigators with a pulsating cleaning jet [13]. According to a systematic research, dental floss and various forms of interdental brushes (IDB) have the highest prevalence worldwide [11]. In contrast, national DMS V data show that younger adults are predominantly using floss (48.7%) and only 16.5% are using IDBs. In the younger senior age group, 29.1% are more likely to use ID brushes than floss (23.1%) [9]. Based on this difference in the usage behavior of the 2 age groups, it can already be seen that the instruction of the interdental cleaning devices must be individualized to the patient [5]. Generalizations, as occasionally seen in advertisements, and unscientific claims about the cleaning effect of interdental cleaning devices lead to uncertainty among all parties involved. Particularly with regard to the aspect of cleaning effectiveness, however, the often necessary reference to a lack of evidence must not be equated with a lack of effectiveness of the products. In general, the treatment of patients should not only be individualized but also evidence-based, taking into account the following three principles: (1.) the experience of the practitioner (internal evidence), (2.) patient preferences, and (3.) the current state of clinical research (external evidence). According to current guidelines, methods and interdental cleaning devices should always be selected according to the patient's skills and preferences, which is the only way to ensure patient acceptance of long-term use [14]. Consequently, a patient-specific optimal solution does not always have to be in accordance with general scientific findings, such as those found in systematic reviews. Since interdental cleaning (IC) involves additional effort for patients, explaining the need for IC is also a key aspect that must be communicated during patient instruction. In addition, each patient-specific decision should be adjustable. For an optimal cleaning result and to avoid trauma due to improper use of the interdental cleaning devices, individual instructions and adaptations to the respective situation must be provided on an ongoing basis. This requires qualified and empathetic dental professionals who select and adapt the appropriate oral cleaning devices together with the patients [5]. Both S3-guidelines "Home mechanical biofilm management in the prevention and treatment of gingivitis" (AWMF: 083-022) and "The treatment of periodontitis stage I–III" (AWMF: 083-043) contain scientifically based recommendations for the specific selection and use of devices for IC. However, the authors are not aware of any studies addressing the knowledge and familiarity of the above-mentioned guidelines as well as the understanding of the specific recommendations of the instructing dental professionals ((DP) qualified as: dental assistant (DA), dental prophylaxis assistant (DPA) and dental hygienist (DH)) in Germany. Therefore, the aim of this questionnaire-based study is to elicit the recommendation behavior of this group of persons regarding IC.

Material and methods

The present scientific survey was conducted at 3 German dental training institutes, in Kiel, Bremen, and Karlsruhe, in 2018 (1. EV) from March to September, with the implementation of the S3-guideline (AWMF: 083-022), and in 2021 (2. EV) from July to December, with the amendment of the S3-guideline (AWMF: 083-022) and the publication of the S3-guideline "The treatment of periodontitis stage I–III" (AWMF: 083-043). DPs with and without certified education in dental hygiene were surveyed. Participants were made aware of the survey by notices with QR codes (linked questionnaires) in the training institutes. The inclusion criteria were 1. completed professional training as a dental assistant in Germany, 2. minimum age of 18 years, 3. understanding of the German language, and 4. own internet-enabled device to access the online questionnaire. Participants were excluded if they did not fulfill one or more of the above-mentioned 4 items.

To answer the question about the extent to which DPs' continuing education influences recommendations and use of IC devices, participants were divided into DPs who had completed certified prophylaxis continuing education (DP+), which includes DPAs and DHs, and DPs without such continuing education (DP–).

A written consent in compliance with the actual German General Data Protection Regulation was required to participate. A positive vote of the ethics committee of the medical faculty of Kiel University was available for the questionnaire-based study (FN: D 411/18).

Questionnaire

The online survey and documentation of responses were performed using Unipark software (unipark.com, Tivian XI GmbH, Cologne, Germany). 21 DPs, employed at the Clinic for Dental Conservation and Periodontology at the University Hospital Schleswig-Holstein, Campus Kiel, validated the digital questionnaire in the period from January to February 2018.

The participants were able to open the questionnaire with a computer or mobile device via QR code or URL in the web browser and answer it anonymously. In total, the questionnaire consists of 11 items. The first 3 items refer to the subjects' professional background (highest certified advanced/further education), age, and work experience. The other items refer to the personal IC, the basis for recommending specific home IC devices, and the recommendations to patients regarding their home IC, such as the criteria for selecting a specific IC device or regarding additional application of toothpaste or interdental gel

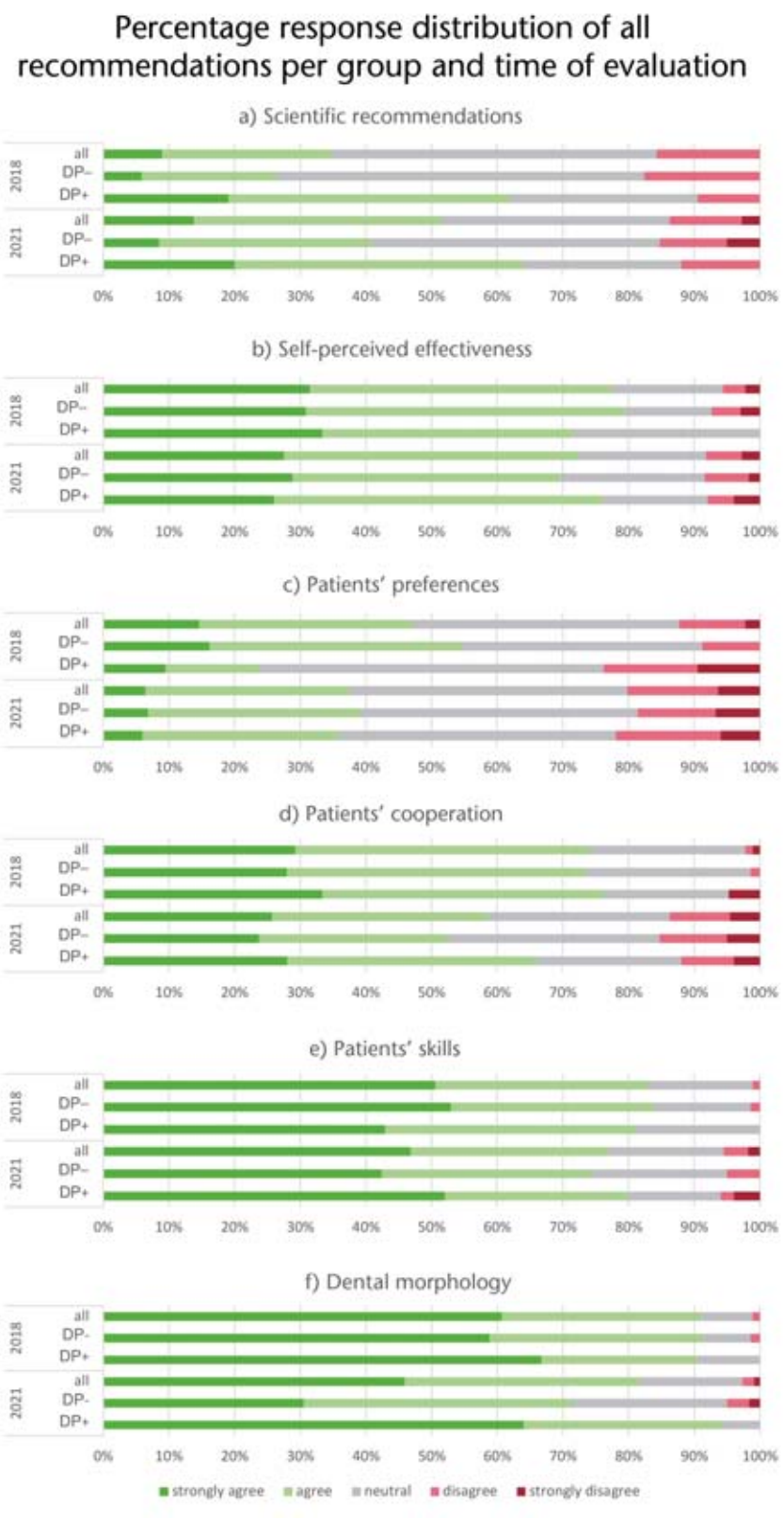

Fig 1: C. Graetz

Figure 1 Percentage response distribution of all recommendations per group and time of evaluation.

Percentage distribution of the subjects in relation to the recommendation basis (Likert items) (a) scientific recommendations, (b) self-perceived effectiveness of the interdental cleaning devices, (c) patients' preferences, (d) patients' cooperation, (e) patients' skills, and (f) dental morphology, divided according to the evaluation in 2018 and 2021 and education in dental hygiene (DP+: dental professionals with certified education in dental hygiene; DP–: dental professionals without certified education in dental hygiene).

to the IC devices. The use and recommendation of IC devices was recorded dichotomously (0/1), whereas the basis for recommendations was recorded using Likert items (1–5: strongly agree to strongly disagree).

Statistics

Data analysis was performed using IBM SPSS Statistics version 28.0.1.1 (14) statistical software. In addition to a primarily descriptive analysis, a comparison was made between the 2 evaluation time points and groups of DPs using the nonparametric Mann-Whitney U test. When more than 2 groups were compared, the Kruskall-Wallis test was used. Correlations between participant-specific variables and between recommendations or bases for recommendations were tested using the Kendall-Tau correlation and Phi correlation. All tests were 2-sided with a significance level of $p < 0.05$, correcting for multiple responses using the Bonferroni method.

Results

A total of 361 participants took part, with a response rate of 45.9 % (89/194) in 2018 and 65.3 % (109/167) in 2021 with complete responses to all questions (Table 1).

Demographic results

There were 18 out of the 89 participants in 2018 who reported DPA and 3 who reported DH as their certification. In 2021, of 109 DPs, 35 indicated DPA and 15 indicated DH as their certification. There were significant differences between the DP+ and DP– divided both by evaluation time point and between evaluation time points (Table 1). Similarly, there was a statistically significant younger mean age of all participants for 2018 than 2021 ($p = 0.022$), although the reported work experience at both evaluation times (2018 and 2021) was not statistically significantly different ($p = 0.332$). In 2018, the age structure of DP– and DP+ was the same, but at the second evaluation, DP– were younger than DP+ (2018/2021: $p = 0.145$/$p = 0.029$). Work experience data in 2018 were identical ($p = 0.476$), whereas DP+ noted longer work experience than DP– for 2021 ($p = 0.005$) (Tab. 1).

Personal interdental cleaning of dental professionals surveyed

The majority of participants reported to use dental floss (78%; DP–/DP+: 79%/71%) and IDB (75%; DP–/DP+: 75%/76%) in 2018. As shown in Table 2, 55% used them daily (DP–/DP+: 54%/57%), mostly in the evening (85%; DP–/DP+: 90%/71%), and mostly without additional toothpaste or interdental gel (76%; DP–/DP+: 75%/81%). In 2021, using dental floss was also reported for personal IC by 84% (DP–/DP+: 86%/80%) and for IDB by 77% (DP–/DP+: 76%/78%). Again, 62% used them daily (DP–/DP+: 58%/68%), mostly in the evening (83%; DP–/DP+: 85%/80%), and mostly without additional toothpaste or interdental gel (79%; DP–/DP+: 78%/80%). Using IC devices together with toothpaste was reported by 16% (DP–/DP+: 15%/19%) of all DPs in 2018 and 17% (DP–/DP+: 17%/16%) in 2021.

Dental professionals' bases of recommendation for interdental care

As shown in Figure 1a), DP+ were significantly more likely than DP– (27%/41%) to report the following scientific recommendations at both evaluation time points (2018/2021) (p = 0.003/p = 0.016).

The number of DPs who based their IC devices selection on dental morphology (2018 vs. 2021 DP/DP–/DP+: 91%/91%/91% vs. 82%/71%/94%), patient's skills (2018 vs. 2021 DP/DP–/DP+: 83%/84%/81% vs. 77%/75%/80%) and patient's cooperation (2018 vs. 2021 DP/DP–/DP+: 74%/74%/ 76% vs. 59%/53%/66%) decreased between both evaluation time points. At the first evaluation time point (2018), slightly more participants reported using the self-perceived effectiveness of IC devices on their own teeth as a basis for recommendation, with 78% of all DPs vs. 73% in 2021 (2018 vs. 2021 DP–/DP+: 79%/71% vs. 70%/76%) (Fig. 1). A correlation shows a significant relationship between the statement to recommend a specific IC device based on patients' cooperation and advanced training to become a certified DH (r = –0.136; p = 0.038). No significant difference was found between the DP– and DP+ groups when considering patients' preferences in recommendation behavior (p = 0.098). Figure 2 shows the percentage distribution of the participants with respect to individual recommendation bases.

Evaluation time point	2018 (1. EV)	2021 (2. EV)	p-value
Participants	**100 % [89]**	**100 % [109]**	
Highest professional degree in the dental sector/highest certified further education			
DP–	76.4 % [68]	54.1 % [59]	0.018*
DP+	23.6 % [21]	45.9 % [50]	0.006*
p-value	0.006*	0.006*	
Age			
MW ± SD [range] in years	31.49 ± 9.12 [21–56]	34.76 ± 10,30 [18–62]	0.022
DP–	29.99 ± 7.64 [21–51]	32.25 ± 9,712 [18–62]	1.000*
DP+	36.38 ± 11.71 [21–56]	37.72 ± 10,28 [23–59]	1.000*
p-value	0.145*	0.029*	
Work experience			
MW ± SD [range] in years	13.28 ± 8.95 [3–40]	15.10 ± 10.55 [2–46]	0.332
DP–	11.93 ± 7.52 [4–36]	12.36 ± 9.58 [2–46]	1.000*
DP+	17.67 ± 11.71 [3–40]	18.34 ± 10.89 [4–43]	1.000*
p-value	0.476*	0.005*	

Table 1 Demographic data per evaluation time point in 2018 versus 2021 (number [N], mean ± standard deviation [range]).
MW: mean; SD: standard deviation; 1. EV: first evaluation time point; 2. EV: second evaluation time point; DP+: dental professionals with certified education in dental hygiene; DP–: dental professionals without certified education in dental hygiene

Specific recommendations on interdental care by dental professionals

At both evaluation time points, the most frequent answers to which IC devices participants recommend were dental floss with 75%/78% (2018 vs. 2021 DP–/DP+: 77%/71% vs. 85%/70%) and IDB even with 99%/95% (2018 vs. 2021 DP–/DP+: 99%/100% vs. 93%/98%). The rubber interdental bristles were recommended by 25% of all participants. Applying toothpaste to the IC device was mentioned slightly less frequently as a recommendation in 2021 (22%; DP–/DP+ 24%/20%) than in 2018 (26%; DP–/DP+: 28%/19%). Of all participants who recommended this combination, less than 10% (2018 vs. 2021 DP/DP–/DP+: 9%/9%/10% vs. 9%/7%/10%) reported following scientific recommendations at both evaluation time points. In the DP+ group, there was a significant correlation between using and recommending dental floss (2018/2021: r = 0.533; p = 0.015/r = 0.546; p < 0.001). Moreover, in both groups, DP– and DP+, at both evaluation time points, there was a significant correlation between personal use of IC devices to-

gether with toothpaste and recommending it to patients (2018 DP–: r = 0.547; p < 0.001, 2018 DP+: r = 1.000; p < 0.001, 2021 DP–: r = 0.704; p < 0.001, 2021 DP+: r = 0.736; p < 0.001).

Discussion

The present results show that a majority of the surveyed DPs, with or without certified further education and training in dental prophylaxis, have basic knowledge of various IC devices and their applications. In addition, it seems that the personal usage of IC devices of the surveyed DPs, despite further education, is the basis for the IC recommendations. Patient-specific factors or scientific evidence were given secondary consideration. Regardless of the evaluation time point, only 47 % of DP– and 32 % of DP+ considered patients' preferences when making recommendations (DP– vs. DP+: p = 0.098), which can influence patients' cooperation. However, the results of this study show that there is a significant relationship between specialization to DH and participants' decision to consider patients' cooperation as a basis for recommendations. Individualized recommendations are crucial when the prevention of oral diseases such as caries, gingivitis, and periodontitis is the focus. Only if the motivation and instruction of the patients is individually adapted to multiple parameters (e.g. age, periodontal health status) and needs (e.g. limited motor skills, fixed orthodontic appliances) of the patients, a long-term acceptance for regular home IC can be expected. The basic prerequisite for this is patient loyalty and education on the causes of periodontal diseases and caries as well as the various options for therapy and prevention, which must be individually adapted to the patients' understanding [8, 12], for example, supported by illustrations or videos. If, during the evaluation, it becomes clinically apparent that the home IC is not performed adequately or the patients report a lack of or difficulty in using the IC devices, the primary recommendation should be adapted to the patients' current situation. Complementary to this conventional instruction in dental practice, due to the increased use of digital media (e.g., smartphones) in all age groups, it is conceivable that these can be used to guide oral hygiene at home, as described by Günay et al. [7]. To be successful in the long term in the context of patient-centered dentistry, any recommendations on home oral hygiene should be properly communicated [15]. Patients should be treated with equal respect and should be "met on an equal footing" (e.g., according to the principle of Participatory Decision Making [17]). Instructions should not be given "top-down" [5]. In addition, according to the principle of evidence-based dentistry, the primary recommendation should be evaluated after implementation regarding clinical success and adjusted if necessary (evidence-based decision making). However, when considering the recommendations for the selection of specific IC devices based on current scientific studies, the available study results show some contradictions. For the prevention and treatment of gingivitis and periodontitis, respectively, size-adapted IDB, as opposed to dental floss, are recommended as first choice for IC[1]. When the point of contact between adjacent teeth is tight with open interdental spaces, as after attachment loss, flossing is not very effective in biofilm management due to the concave root surfaces below the cemento-enamel junction (CEJ) [3]. Due to a higher potential for trauma, e.g., as a result of a tight point of contact and thus increased force [2], flossing may even be contraindicated. However, the surveyed participants favored dental floss and IDB equally often over all other IC devices in their recommendations, regardless of their qualification and time of evaluation (Tab. 2). Evidence-based dental floss, as well as rubber interdental bristles, dental woodsticks or oral irrigators, are only recommended for interdental space morphology if it is not possible to clean with IDB[1]. Therefore, the present questionnaire study specifically asked DPs about the newer group of rubber interdental bristles, which, according to Abouassi et al. [1], have a higher patient acceptance and, according to the present results, are already recommended as an alternative by 25 % of the participants. On the other hand, van der Weijden et al. [16] found only very weak evidence of rubber interdental bristles for gingivitis and plaque reduction in their recent meta-analysis among gingivitis patients.

This is possibly due to the reduced cleaning effectiveness, which is inherent to the functional design of the IC device, in contrast to the IDB with metal core [6]. The use of nylon bristles of conventional IDB with the possibility of cleaning even concave interdental surfaces can be clearly mentioned as an advantage here. However, these bristles must be fixed with a metal core, which often leads to discomfort, trauma to the soft tissues or bending. This can only be prevented by intensive training of the DPs on the necessity and scope of structured instruction and motivation with adaptation of the correct IC device and its correct size to the individual patient's situations and preferences. Although approximately 44 % of all participants in the current study reported evidence-based findings as the basis for their recommendations to patients, more efforts need to be made to make the basis of decision-making less dependent on personal perception (approximately 75 % of all participants).

For example, flossing is difficult for many people, as it requires some fine motor skills in the fingers and also an understanding of how to use it and how it works [5]. Therefore, it is often not used correctly by patients [18], since in the layman's perception a single snap through the contact point is sufficient to remove food debris, but this does not succeed in removing biofilm. However, many of the surveyed participants seem to be aware of this misunderstanding, since although they themselves use dental floss as the IC device of first choice (approx. 70–80 % of all participants), they recommend IDB to their patients in 90–100 %. If flossing is still pre-

[1] S3-Leitlinie „Die Behandlung von Parodontitis Stadium I bis III, AWMF 083-043"; S3-Leitlinie „Häusliches mechanisches Biofilmmanagement in der Prävention und Therapie der Gingivitis", AWMF 083-022

Evaluation time point	2018 (1. EV)	2021 (2. EV)
Do you use interdental cleaning devices?		
Daily	55.1 % [49]	62.4 % [68]
Every second day	29.2 % [26]	31.2 % [34]
Once per week	12.4 % [11]	6.4 % [7]
Once per month	3.4 % [3]	0.0 % [0]
When do you use interdental cleaning devices?		
Predominantly in the morning	19.1 % [17]	21.1 % [23]
Predominantly at noon	3.4 % [3]	1.8 % [2]
Predominantly in the evening	85.4 % [76]	82.6 % [90]
Only in combination with a toothbrush	33.7 % [30]	34.9 % [38]
If you use an interdental cleaning product, which one do you use regularly?		
Dental floss	77.5 % [69]	83.5 % [91]
Interdental brushes	75.3 % [67]	77.1 % [84]
Wood sticks	0.0 % [0]	0.9 % [1]
Rubber interdental bristles (e.g. TePe EasyPicks, Gum Softpicks Advanced)	13.5 % [12]	15.6 % [17]
Oral irrigator	2.2 % [2]	0.9 % [1]
Do you use additional products?		
I use interdental cleaning devices together with toothpaste (you apply toothpaste to the interdental cleaning device).	15.7 % [14]	16.5 % [18]
I use interdental cleaning devices together with interdental gel (you apply interdental gel to the interdental cleaning device).	5.6 % [5]	6.4 % [7]
I use interdental cleaning devices without additional products.	76.4 % [68]	78.9 % [86]
Which interdental cleaning devices do you recommend to your patients?		
Dental floss	75.3 % [67]	78.0 % [85]
Interdental brushes	98.9 % [88]	95.4 % [104]
Wood sticks	0.0 % [0]	0.0 % [0]
Rubber interdental bristles (e.g. TePe EasyPicks, Gum Softpicks Advanced)	23.6 % [21]	26.6 % [29]
Oral irrigator	3.4 % [3]	5.5 % [6]
Do you recommend additional products? I recommend my patients to use interdental cleaning devices		
together with toothpaste.	25.8 % [23]	22.0 % [24]
together with interdental gel.	32.6 % [29]	20.2 % [22]
without additional products.	55.1 % [49]	75.2 % [82]
At what time/occasion do you recommend the use of interdental cleaning devices to your patients?		
Always in the morning	6.7 % [6]	18.3 % [20]
Always at noon	2.2 % [2]	2.8 % [3]
Always in the evening	84.3 % [75]	78.9 % [86]
Only in combination with a toothbrush	21.3 % [19]	21.1 % [23]

Table 2 Specific results per evaluation time point in 2018 versus 2021 (number [N]).
1. EV: first evaluation time point; 2. EV: second evaluation time point

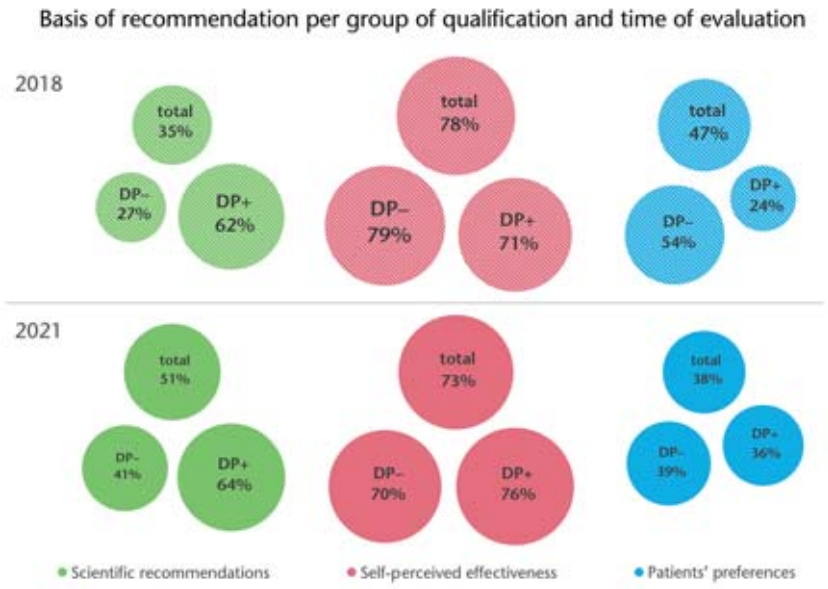

Fig. 2: C. Graetz

Figure 2 Basis of recommendation per group of qualification and time of evaluation. Percentage distribution of participants regarding their recommendation basis of scientific recommendations, self-perceived effectiveness of interdental cleaning devices, and patients' preferences, based on the Likert items. Divided according to the evaluation time points 2018 (hatched) and 2021 (filled) (DP+: dental professionals with certified education in dental hygiene; DP–: dental professionals without certified education in dental hygiene)

ferred, floss holders can be an alternative. By facilitating their use, they help patients get used to regular IC and possibly better understand the actual benefits of the IC at home [10].

On the other hand, the outcome of patient-side recommendations or personal use of mechanical IC devices together with toothpastes must be critically questioned. Overall, almost 16 % of all participants in the survey stated that they use IC devices with additionally applied toothpaste and approximately 24 % also recommended this to their patients. This is not in line with the guidelines, since the abrasive cleaning agents often contained in toothpastes must be assumed to cause greater destruction of the interdental tooth structure. This applies to areas below the CEJ, as the root cementum and dentin are less hard than the enamel above the CEJ. Therefore, if only areas above the CEJ are touched by mechanical IC devices, a low risk of tooth structure damage can be assumed. However, even here, due to the firmer structure of IDB with metal wire, the additional use of abrasive toothpastes may have an increased destructive effect. If a complementary chemo-preventive effect is desired, then non-abrasive interdental gels can be recommended, which simultaneously help to reduce frictional resistance [4]. This was recommended by about 33 % of the participants (Table 2). To avoid risks of trauma due to lack of knowledge of the abrasiveness of the complementary product, guideline-simplified recommendations were made to reject the use of toothpaste altogether for any mechanical IC.

However, the results on the use/recommendation behavior of the studied cohort also raise the question of how well understandable and applicable such evidence-based guideline recommendations are. About 9 % of all participants who additionally recommended toothpastes with IC devices stated that they followed scientific recommendations. There is certainly a need for further improvement in the establishment and transfer of evidence-based knowledge into dental practice. It can also be noted that a higher professional qualification, which includes appropriate content of individual guidance on the instruction, motivation and techniques of IC, does not seem to change the personal IC of the DHs and DPAs surveyed and is comparable to the IC of DPs without appropriate further training. This can be interpreted to mean that if the practice team is appropriately instructed and motivated in home oral hygiene, even DVs without certified continuing education and training can provide individualized fitting of IC devices and patient instruction as part of the delegation, provided the staff is aware of and familiar with the guidelines.

For this, it proves useful to conduct regular training on oral hygiene instruction within the practice team. From 2018 to 2021, the proportion of participants without certified further education and training who made recommendations on IC based on scientific evidence increased by about one third (from 27 % to 41 %). This potential should be considered when it comes to transferring scientific knowledge into practice in a comprehensible way. It can also certainly help to ease the current high demand for trained dental assistants (e.g., in the context of the new German periodontal treatment directive from 2021). Instead of relying on non-specialist staff who do not know the patient-specific situation (e.g., in pharmacies), the authors suppose that it is a better alternative to have dental assistants recommending IC devices.

Limitations of the study

One of the limitations of this 2-part online survey study was that it was not a longitudinal study in which the same participants were interviewed at both time points. Thus, for the present study, it is not possible to determine whether study participants who were surveyed in 2018 also participated in 2021. On the other hand, by means of the data management (IP addresses supported) of the survey software used, repeat participation of individuals at the evaluation times in 2018 and 2021 could be excluded. Another point that limits the possibility of generalizing the study results is the limited number of participants, which results from the selective choice from the 3 dental training institutes. This could also explain why more DP+ participated in 2021 than

in 2018. On the other hand, the cooperation with the dental training institutes made it possible to respond to any queries on site. Future studies with larger cohorts should be able to overcome these limitations with findings from online education during the Corona pandemic.

Conclusion

The own application behavior of the surveyed dental assistants seems to be the main basis for the given IC recommendations, despite continuing education with evidence-based knowledge transfer. The influence on the recommendation behavior of the instructing professionals by recommendations of guidelines even 3 years after their publication is not visible. Since, on the one hand, both patient-specific factors and scientific findings were only given secondary consideration by all participants, irrespective of further training in the field of prophylaxis, efforts must be made to improve the knowledge of all dental professionals (externally). On the other hand, after appropriate guidance and training (internal), dental professionals can also take over the instruction and motivation of IC as part of the delegation.

Conflict of interest

Prof. Dörfer conducts third-party funded oral hygiene studies with various auxiliaries. He is a member of the international scientific advisory board of P&G and gives educational lectures funded by P&G.

The other authors declare that there is no conflict of interest.

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Photo: C. Graetz

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Posthumous fame despite early death: DGZMK President and Tübingen Professor Eugen Fröhlich

Introduction: To this day, the name Eugen Fröhlich stands for successful work in science and professional politics. But what was his influence on the development of dentistry and what was his relationship to National Socialism? These are precisely the questions that this article explores.

Material and methods: The study is based, among others, on primary documents of the State Archives Baden-Württemberg as well as the University Archives and the University Library of Tübingen. In addition, sources from the Federal Archives in Berlin were evaluated. Furthermore, a comprehensive analysis of publications by and about Fröhlich was carried out.

Results: Fröhlich left clear traces on the institutional, professional-political and scientific level: In Tübingen he had a decisive influence on the new clinic building completed in 1968 and the reorganisation of the clinic structures, and in Ulm, he initiated the establishment of today's University Dental Clinic. He was active in professional politics as chairman of the ARPA (Working Group on Periodontology), the "Zahnärztliche Dozentenvereinigung" (Association of Lecturers in Dentistry) and the "Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde" (German Society for Dental and Oral Medicine, DGZMK), and he made scientific contributions to oral surgery, prosthodontics and periodontology. In the Third Reich Fröhlich was a member of the NSDAP (National Socialist German Workers' Party) and the SA (Storm Department), among others.

Discussion and conclusion: Fröhlich is to be regarded as an important promoter of the institutional development of university dentistry: He initiated the new clinic building in Tübingen and prompted the establishment of several independent chairs in dentistry, thus becoming a model for other locations. Through his visible work in ARPA, he also brought the subject of periodontology into focus, and with the introduction of the term "dysgnathia" he set himself a professional monument. Fröhlich's political role in the Third Reich was that of a follower. After 1945, however, he tried to construct a distance to National Socialism by means of half-truths and whitewashing.

Keywords: ARPA; DGZMK; dysgnathia; National Socialism; Tübingen

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Introduction

Despite his early death half a century ago (1971), the university lecturer and professional politician Eugen Fröhlich was able to develop an astonishing posthumous fame that continues to this day: in Tübingen, he is considered the decisive promoter of today's University Clinic for Dental, Oral and Maxillofacial Medicine, the "Deutsche Gesellschaft für Parodontologie" (German Society for Periodontology) established the "Eugen Fröhlich Prize" in his honour in 1971, and with the term "dysgnathia" he coined a technical term in 1954 that has endured to this day. Against this background, it seems worthwhile to subject Fröhlich's life and professional œuvre to a detailed analysis and to shed light on his multi-layered influence on university dentistry – on the scientific, professional-political and institutional-structural levels. A further focus is on his hitherto unexplored relationship to National Socialism in the Third Reich.

Material and methods

The study is based on files from the State Archives of Baden-Württemberg, the University Archives and the University Library of Tübingen and the card index of the Reich Medical Association (RÄK). In addition, documents from the Federal Archives in Berlin were evaluated. Scientific papers published by Fröhlich served as additional sources.

Furthermore, a comprehensive evaluation of the existing secondary literature available was carried out – especially on Fröhlich as a person, on the history of the Tübingen Dental Clinic and on the development of the DGZMK in the "Fröhlich era". Laudations and obituaries on Fröhlich, but also individual journal articles and lexical contributions were included.

Results and discussion

1. Eugen Fröhlich: concise biographical data and stations in life

Eugen Fröhlich (Fig. 1, [7]) was born on March 8, 1910 in Ulm [29, 43, 45, 50–52, 54–56, 60, 61], where his parents owned a house each in Frauenstraße and Grünhofgasse [45]. In his youth, he intensively pursued folding-boat and canoeing sports and even wrote his first publication on this subject in 1930 [10].

After graduating from high school, Fröhlich began studying dentistry at the University of Munich (1929). The most important academic teachers in Munich at that time were the professors Peter-Paul Kranz (1884–1955) and Karl Falck (1884–1957) [49] as well as the young scientists Erwin Reichenbach (1897–1973) [35] and Maria Schug-Kösters (1900–1975) [37], who completed their habilitation there in 1930 and 1931 respectively. Fröhlich spent the entire period of study in Munich – which was not the rule at the time –, passed the dental examination in 1933 and subsequently obtained his licence to practise dentistry. In August 1933, he undertook an extensive folding-boat tour on the rivers Rhine, Rhone, Reuss, Aare and Schaue (Skawa) [45]. In the same year, he obtained his doctorate in Munich under Erwin Reichenbach with the thesis "Beiträge zur Kautschukvulkanisation" (Contributions to Rubber Vulcanisation) [11] and took up a position as a volunteer assistant. In 1934, he became a scheduled assistant in the "Kieferklinik" (Oral Surgery Department) at the – non-university – Rudolf Virchow Hospital (RVK) in Berlin with Martin Waßmund (1892–1956) [23, 42].

Waßmund was one of the best known and most renowned maxillofacial surgeons at that time. His "Kieferklinik" was the first in Berlin and the second on German soil after the "Westdeutsche Kieferklinik" (West German Jaw Clinic) in Düsseldorf. In 1936 Fröhlich arrived at the RVK as a "Fachzahnarzt für Kieferchirurgie" (specialist dentist for jaw surgery). The said specialist title had only been established in April 1935 and required several years of specific surgical activity as a dentist; it was renamed "Fachzahnarzt für Kieferkrankheiten" (Specialist dentist for jaw diseases) in 1944 [57]. It was no longer awarded in the Federal Republic.

From August to October 1937, Fröhlich completed basic military training. As Fröhlich aspired to a university career, he moved to the University of Tübingen in November 1937. There he took up a position as senior dentist in the surgical and restorative department of the dental institute with Ferdinand Wasmuth (1883–1940) [48]. In 1938, he then began studying medicine in Tübingen – parallel to his dental work. This was due to the fact that until well into the second half of the century, medical schools predominantly considered dual-trained candidates for professorships in dentistry – even when they were not specifically looking to fill chairs in oral and maxillofacial surgery.

Image database, year of origin 1965, photographer: Charlotte Gröger, courtesy of Tübingen University Library

Figure 1 Eugen Fröhlich [60]

Fröhlich was able to complete his second degree in 1942/43 – in the middle of the war – with the medical examination and licence to practise medicine. At this time, he was already deputy head of the department for maxillofacial and reconstructive surgery at the reserve hospital in Tübingen – a position he held until 1945. As early as 1940, due to Wasmuth's unexpected death, he took on further teaching responsibilities, namely in the fields of dental surgery and restorative dentistry. Despite this workload, he was able to complete his second doctorate (Dr. med.) in 1943 – also at the University of Tübingen. He wrote his dissertation on "Erfahrungen über den plastischen Verschluss von erworbenen Oberkiefer-Gaumendefekten, unter besonderer Berücksichtigung der Palati-

Term of office	Name	NSDAP Membership	Life data
1906–1926	Otto Walkhoff	+	1860–1934
1926–1928	Wilhelm Herrenknecht	+	1865–1941
1928–45, 1949–54	Hermann Euler	+	1878–1961
1954–1957	Hermann Wolf	+	1889–1978
1957–1965	Ewald Harndt	+	1901–1996
1965–1969	Gerhard Steinhardt	+	1904–1995
1969–1971	**Eugen Fröhlich**	**+**	**1910–1971**
1972–1977	Rudolf Naujoks	–	1919–2004
1977–1981	Werner Ketterl	+	1925–2010

Table 1 The presidents of the CVDZ (from 1933: DGZMK) who experienced the Third Reich as adults and their party-political orientation

nallappenplastik" (Experiences on the plastic closure of acquired maxillary palatal defects, with special reference to palatal flap surgery) [12].

After the end of the war, Fröhlich continued to work as senior physician and head of the surgical and tooth-preserving department of the Dental Clinic in Tübingen. In 1946, he also became provisional head of the Clinic. This was due to the dismissal of his superior Walter Adrion (1891–1960), who had been appointed to Tübingen in 1942 as Wasmuth's successor [4, 46, 48]. Fröhlich acted as commissary until Hans-Hermann Rebel (1889–1967) [48] was appointed as the new director of the institute in 1947.

After Rebel took office, Fröhlich was listed as head of the Department of Restorative Dentistry. In 1948, he achieved his habilitation in dentistry with Rebel. This was followed by the appointment as "Privatdozent" (private lecturer). In 1951, after the aforementioned specialist dentist (1936), Fröhlich also attained the "Facharzt für Zahn-, Mund- und Kieferkrankheiten" (medical specialist for dental, oral and jaw diseases), which was reserved for those who were both doctors and dentists. He thus fulfilled the increased requirements that were meanwhile placed on maxillofacial surgeons in the Federal Republic. In 1954, Fröhlich was appointed associate professor and in 1958 he completed the final step of his university career in Tübingen with his appointment as full professor of dental, oral and maxillofacial medicine and director of the Dental Institute [48]. Fröhlich remained in this position until autumn 1971.

In September 1971, during the 6th Lake Constance Conference in Lindau, he collapsed due to a "cerebral stroke" [61] "in the middle of a discussion he was leading" [56]. He was taken to Tübingen University Hospital, where he died about three weeks later, on October 2, 1971, "despite intensive medical efforts" [54]. Fröhlich was buried in the Bergfriedhof (mountain cemetery) in Tübingen [52, 61].

2. Fröhlich's scientific and professional significance

Eugen Fröhlich was without a doubt one of the most successful and influential dental university teachers of his time. Accordingly, there was no lack of attempts to call him away from Tübingen: for example, in 1958 he received a call to the vacant chair in Würzburg (as successor to Hermann Wolf [1889–1978] [39]), whereupon those responsible in Tübingen also offered him a full professorship, so that he ultimately decided to remain in Tübingen. In 1965, he was offered another full professorship and directorship in Münster as well as a professorship at the University of Bonn, both of which he declined.

These successes, however, strengthened his position in Tübingen. There he was able to push through an impressive new clinic building in the 1960s. He exerted influence on the construction and set himself a monument with the building "already in his lifetime" [61]. He also subjected the internal structures of "his" clinic to far-reaching changes: While he was originally the only full professor at the Tübingen Dental Clinic, at his instigation three departments of the clinic were now expanded into further, each independent directorates and full professorships. In 1968, Fröhlich published a journal article introducing the innovative building complex and the concept underlying its construction. As could be read there, the complex included scientific laboratories, library rooms, a lecture hall and demonstration rooms. He emphasised the national importance and pioneering character of the building: "New jobs have been created in Tübingen with the new clinic, which will help to alleviate the impending shortage of dentists. Once the new clinic is fully staffed, twice as many students can be taught […]. Two chairs have already been filled, and the appointment process is underway for a third. The Tübingen Clinic is the first in Germany to be built according to the recommendations of the 'Wissenschaftsrat' (Science Council) on the principle of dividing the discipline into four parts" [26]. He also founded the "Eugen Fröhlich Fund" in 1968/69 to provide financial support for the Tübingen Dental Clinic [59].

It is noticeable that Fröhlich was omnipresent in German university dentistry in the 1960s, despite his intensive activity in Tübingen [61]: from 1960 to 1970 he served as president of the German ARPA (since 1971: Deutsche Gesellschaft für Parodontologie [German Society for

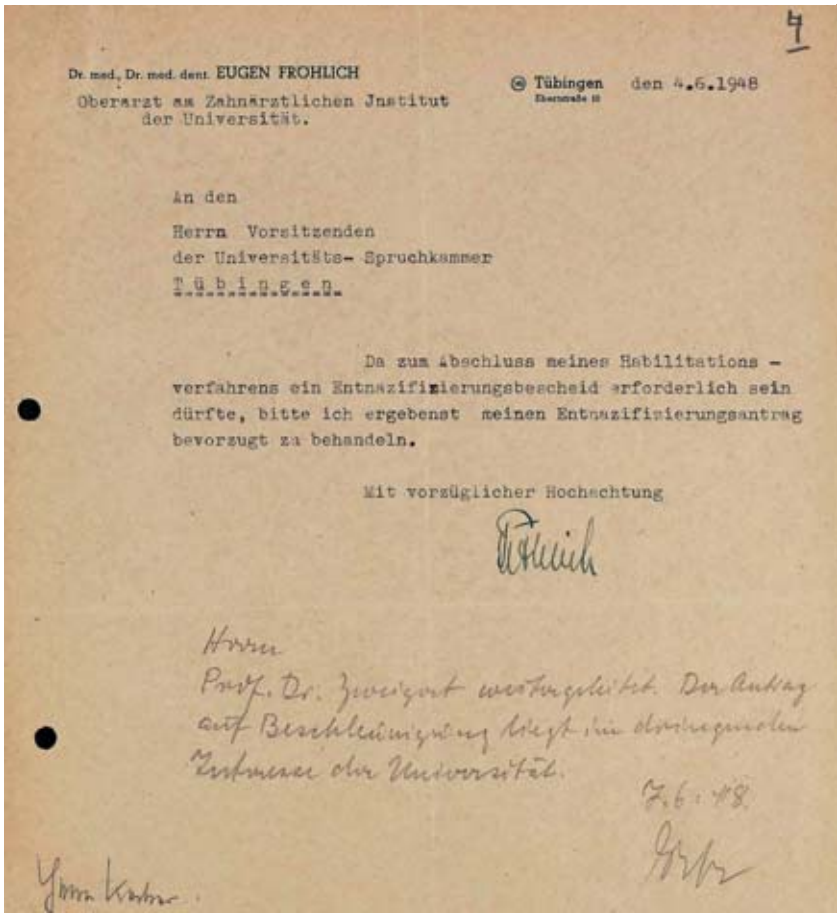
Periodontology, DGP], today DG PARO) [3], and from 1961 to 1965 he was also chairman of the dental lecturers' association. In 1969, Fröhlich won the election of the DGZMK president against Carl-Heinz Fischer (1909–1997) [43, 44], a full professor from Düsseldorf, in a competitive vote [9]. Fischer was also considered a professional "heavyweight": at that time, he was Dean of the Düsseldorf Medical Faculty and also on the verge of becoming Rector (University President), which he took up the following year. Fischer was visibly affected by this defeat and reported in his memoirs that he had only lost to Fröhlich "by two votes". Fischer also referred to Fröhlich in many other places in his memoirs, implicitly underlining Fröhlich's contemporary significance [8, 9].

It is certain that Fröhlich was a strong advocate for the further development of university dentistry and for the recognition of dentistry as an academic discipline. He was excellently networked – within and outside dentistry. For example, he was an academic teacher and confidant of Herbert Veigel (*1922), who served as president of the "Bund Deutscher Zahnärzte" (Association of German Dentists, BDZ) (today: German Dental Association, BZÄK) from 1969 and in this function was an important partner for the DGZMK and university dentistry. In addition, Fröhlich was a member of the board of the Baden-Württemberg Dental Association from 1960 to 1964 [47]. He also had a say in Baden-Württemberg's university policy. In 1970, for example, he succeeded in initiating a planning committee "for the establishment of a center for dental, oral and maxillofacial medicine in Ulm", which he himself chaired [54] – although he died shortly after this committee was established. Besides, in 1970, at the dental conference in Bad Nauheim, he proposed the establishment of independent chairs of periodontology at all university dental clinics in Germany. All German university professors of dentistry, oral medicine and maxillofacial surgery present in Bad Nauheim agreed to the proposal [28]. However, only a few such chairs were to be established in the following years. In addition, Fröhlich wrote a far-sighted "Exposé on the future direction of the DGZMK" in 1971 [29, 43]. He did this in his capacity as President of the DGZMK together with his then fellow board member Erich Körber (1925–2020) – the first holder of the Chair of Prosthodontics in Tübingen, which was established at Fröhlich's instigation. In the exposé, both called for closer cooperation between the DGZMK and the aforementioned BDZ. BDZ and DGZMK – the most important professional and scientific organization of the dental profession – should no longer compete but join forces for the benefit of German dentistry and thus create added value: "The opportunities that present themselves must be viewed without bias. On both sides […] mistrust, prejudices must be reduced and more understanding awakened" [29, 43]. The BDZ president Veigel wrote an obituary for the suddenly deceased Fröhlich only a few months later, in which he emphasized and paid tribute to Fröhlich's importance as a provider of impulses for professional policy: "During the two years of my term of office, Eugen Fröhlich was significantly involved in all essential consultations on the future of the profession, especially with regard to new study and examination regulations. His advisory activities in the Science Council and in the European Commission for the harmonization of dental education and establishment within the EEC have also had an extremely beneficial effect" [61]. And Fröhlich's student Willi Schulte (1929–2008), in another obituary, expressed the view that Fröhlich had always devoted all his energy to the further development of dentistry and that his life had been "without any exaggeration a sacrifice for these tasks"; moreover, "there was little time left for other things" [56].

Fröhlich was also active and respected as a scientist. In 1954, for example, he introduced the technical term "dysgnathia", which is still in use today, into the specialist vocabulary [50, 58]. In fact, Fröhlich's first mainstay was maxillofacial surgery: like Karl Schuchardt (1901–1985) [31] and Alfred Rehrmann (1910–1979) [1], he saw himself primarily as a student of the maxillofacial surgeon Martin Waßmund, to whom he also "owed the most, in his own opinion" [61]. Accordingly, Fröhlich made several contributions to maxillofacial surgery, especially until the middle of the century, and went public with corresponding publications [13, 14, 18]. Fröhlich considered Waßmund "one of the most successful oral surgeons of his time" and noted in an obituary of his mentor: "From an insignificant, small dental outpatient clinic of the Rudolf Virchow Hospital in Berlin, Waßmund developed and continuously expanded a 'clinic for oral and maxillofacial surgery of international reputation'." [23].

Fröhlich's work on (surgical) prosthodontics was in turn influenced by his first doctoral supervisor, the prosthodontist and wartime surgeon Erwin Reichenbach [35], who had recommended him to Tübingen in 1937 and later advanced to vice president of the National Academy of Sciences Leopoldina in Halle. Both became friends and Reichenbach paved the way for Fröhlich's admission to this academy [9]. Contributions to prosthodontics and the interactions of dental restorations can be found in Fröhlich's work at all times [17, 19, 20], but he gained the greatest attention as an author at the end of his life with the textbook "Die Planung der prothetischen Versorgung des Lückengebisses" (The Planning of Prosthetic Restoration of the Gap Denture), which he published together with Erich Körber in 1970 and which was reprinted several times even after Fröhlich's death [27].

Another focus of his publications was dental radiology; there he devoted himself primarily to intraoral radiographs and their diagnostic significance [16, 21, 22]. Finally, Fröhlich's contributions to periodontology received special attention. Although he was a generalist rather than a specialized periodontist, he published regularly in this field [15, 22, 24, 25]. Through this – and even more through his enormous presence as ARPA president for many years –



Dr. med., Dr. med. dent. EUGEN FROHLICH
Oberarzt am Zahnärztlichen Institut
der Universität.

Tübingen den 4.6.1948

An den
Herrn Vorsitzenden
der Universitäts- Spruchkammer
T ü b i n g e n

Da zum Abschluss meines Habilitations - verfahrens ein Entnazifizierungsbescheid erforderlich sein dürfte, bitte ich ergebenst meinen Entnazifizierungsantrag bevorzugt zu behandeln.

Mit vorzüglicher Hochachtung

Figure 2 Fröhlich's application for preferential denazification (1948) [45].

he brought periodontology as a discipline into the professional eye.

Fröhlich published about 150 technical papers until 1971. Besides, he could look back on several offices, honors and awards at the end of his life: In addition to the aforementioned functions as chairman of the German ARPA, the dental lecturers' association and the DGZMK, as well as his activities for the Science Council and the European Commission, he was co-editor of the journal "Deutsche Zahn-, Mund- und Kieferheilkunde" (German Dental, Oral and Maxillofacial Medicine) from 1962 to 1971. In 1962 he received the "Alfred Rowlett Award" of the "Fédération Dentaire Internationale" (FDI) and in the same year the "ARPA Suisse" appointed him a corresponding member. In 1963/64 he was Dean of the Medical Faculty in Tübingen. In 1965 he was conference president of the DGZMK, and one year later he was appointed honorary member of the "ARPA Internationale". In 1967 he was admitted to the Leopoldina, and in the same year he received the annual best prize of the DGZMK. Finally, the "crowning glory of his international activities" was the scientific chairmanship of the international FDI meeting in Munich in 1971 [61].

3. Between fiction and truth: Fröhlich's relationship to National Socialism

Fröhlich joined both the NSDAP and the SA during the Third Reich. He became a member of the SA in 1938 and of the NSDAP in 1939 (Party No. 7,302,237). Fröhlich was 28 and 29 years old at this time. During the same period, he joined two other Nazi organisations: the "NS-Volkswohlfahrt" (Nazi People's Welfare) (on May 11, 1938) and the "NS-Ärztebund" (Nazi Doctors' Association) (on March 8, 1940) [6, 45, 53, 62].

There is no doubt that Fröhlich was classified as politically loyal – not least because of his memberships in these organisations. For example, there is a statement by Karl Pieper (1886–1951), the feared leader of the Reich's dental lecturers, who, as an ardent National Socialist, watched over the political attitude of the (prospective) university teachers of dentistry [33]. In 1943, Pieper judged Fröhlich, who was only 33 years old at the time and had not yet habilitated, as "still too young" for an appointment. However, he did not express any doubts about Fröhlich's political stance, although such comments were the core element of many of Pieper's statements and thus caused some careers to stumble [5, 33].

The sources consulted also reveal that Fröhlich staged himself after 1945 as a person who had been highly critical of National Socialism. He presented this self-image in two different contexts: in the "Spruchkammerverfahren" (denazification proceedings) against his former superior Walter Adrion as well as in his own denazification trial.

As far as the proceedings against Adrion were concerned, Fröhlich appeared as a prosecution witness together with his colleague from Tübingen, Rainer Strack (1912–1969). Strack had been head of the department of prosthetics and orthodontics in Tübingen from 1943 and was thus a colleague of equal rank to Fröhlich, who, as mentioned, was head of the surgical and restorative department. Both stated that their superior Adrion was "consciously National Socialist" and "also gave particular emphasis to this attitude" [46]. In fact, Adrion had joined the NSDAP and the SA, among others, in 1933, and after his appointment to Tübingen he became "chairman" of the Nazi lecturers' association at the dental institute there [4].

But in the end, the statements of Fröhlich and Strack remained without consequences for Adrion: In a revision procedure initiated by the latter (1949), the testimonies of the two department heads were given less weight and their former superior Adrion was finally classified as a mere follower. The final reasoning stated: "If the senior dentists Dr. Strack and Dr. Fröhlich concluded from the strict discipline and order in the

clinic that the person concerned was susceptible to National Socialist ideas, this conclusion […] is not compelling […]. Although the person concerned was certainly a follower of the Nazi world view until the end of the war, he did not make outwardly activist use of this attitude" [46].

More decisive than the question of the effects of the statements on Adrion is the fact that Fröhlich morally elevated himself above Adrion with his actions and incriminated him. After all, Fröhlich was not only a party member himself, but had also belonged to several other Nazi organisations. Fröhlich was obviously pursuing the goal of putting himself in political opposition to Adrion and thus demonstrating a personal distance to National Socialism. The same statement by Strack is to be classified differently: There were no indications of party membership in his case, nor were there any other signs of a political burden. Strack was thus one of the dentists who worked successfully at the university in the Third Reich even without political affiliation [41].

In view of his appearance in the trial against Adrion, it is not surprising that Fröhlich took a similar position in his own denazification trial, which he was forced to go through as a former party member: he stated that he had an inner distance from National Socialism. According to this, he had applied for admission to the SA on May 1, 1938 solely "at the urging of the lecturer leader". He was then "transferred from my SA formation to the party on December 1, 1939 without any action on my part […], so I could not prevent my entry into the party" [45]. This "automatic" party admission claimed by Fröhlich was also stated by some former party members in the post-war period, but it does not correspond to the usual practice of joining the NSDAP. Party admission was tied to the explicit application of the aspirant. The admission procedure followed precise rules, which were strictly observed. For example, it was indispensable to sign the admission form in person and hand it in at the responsible NSDAP local group. There were no "automatic" or even unnoticed admissions. The leader of the local group also had to document his consent on the application form and send it to the party headquarters in Munich. Admission to the NSDAP was only official when one received the membership card from the Reichsleitung (the highest party-political office in the NSDAP).

In addition, Fröhlich cited strong religious ties – specifically: his closeness to the "Bekennende Kirche" (Confessing Church) – and saw this as evidence of his claimed distance from Nazi ideology [45]. He also emphasised that his remaining at the university would not have been possible without the aforementioned memberships. But his statements are already refuted by a look at the curriculum vitae of his senior colleague Rainer Strack, who was almost the same age: although he kept his distance from the Party until 1945, he had received the Miller Prize in 1938 – the highest science prize of the DGZMK, which had been politically centralised in 1933 – and in 1943 he had achieved the appointment as a civil servant senior dentist and head of the Department of Prosthetics and Orthodontics in Tübingen [41].

Despite his exculpation strategy, Fröhlich did not succeed in denazification quickly. When the procedure had still not been completed in the early summer of 1948, he sent a letter of request, dated June 4, 1948, to the Spruchkammer chairman (cf. Fig. 2; [45]): "Since a denazification decision is likely to be necessary for the conclusion of my habilitation procedure, I sincerely request that my denazification application be given preferential treatment" [45]. In September 1948, he was denazified as a "follower" (Group IV) [45] – and the path to his habilitation and thus to an impressive post-war career was clear.

Conclusions

Due to his diverse functions and professional initiatives, Fröhlich had a strong influence on the structural development of the discipline of dentistry. He emerged above all as the promoter of the institutional four-way division of university dentistry: the new clinic building in Tübingen and the establishment of four independent chairs there – including the first full professorship for orthodontics in Germany, held by Dorothea Dausch-Neumann (1921–2013) [38] – became a model for other clinic locations. Through his visible work in the ARPA, he brought periodontology into focus, and with the introduction of the term "dysgnathia" he stayed in the memory of the professional world.

Fröhlich's tragedy – and also the tragedy of organised university dentistry and the still unconsolidated discipline of periodontology – was that he died at the height of his influence and initiatives and thus could not complete his work. Above all, the modernisation of the DGZMK that he envisaged was therefore reserved for his successor Rudolf Naujoks (1919–2004) [40]. However, after Fröhlich's death, two developments occurred which, from today's perspective, can be seen as a legacy and at the same time kept Fröhlich's memory alive:

In 1971, the German ARPA posthumously established the "Eugen Fröhlich Prize" and in 1982, after many years of preparation and various retarding moments, the Ulm Dental Clinic (today: Centre for Dental, Oral and Maxillofacial Medicine) was founded, as initiated by Fröhlich. Fröhlich did not live to see the opening of the clinic in his native city, but one of his academic students – Reinhold Mayer (1929–2020) [34] – became the founding professor and medical director of the Clinic for Dental Preservation and Periodontology there.

While Fröhlich stood out among his colleagues from a professional point of view, he behaved in a politically conformist manner during the Third Reich. In the years up to 1945, he served the Nazi state as a party member and by joining several parties. Accordingly, he can be classified as a political follower, as were almost 10% of all Germans and around 45% of physicians [30, 32, 36]. There are no indications that he critically reflected on his behaviour after 1945. Rather, he tried to maintain a personal distance from National Socialism by making an incriminating state-

ment against his superior Walter Adrion and by half-truths and embellishments in his own denazification proceedings.

By decision of 18 September 2020, the "Eugen Fröhlich Prize" was renamed the "DG PARO Science Prize".

Conflicts of interest

The author declares that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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Moderniser without a Nazi past: life and work of DGZMK president Rudolf Naujoks (1919–2004)

Introduction: For many dentists, the name Rudolf Naujoks stands for top-class basic research and professional-political commitment. The present article takes this positive but general image as an opportunity to highlight Naujoks' concrete influence on the development of dentistry; a further focus is on his relationship to National Socialism.

Material and methods: The methodological basis of the study are files from the Hamburg State Archive. In addition, research was conducted at the Berlin Federal Archives. The scientific publications of Naujoks and the secondary literature available on his person were evaluated as further sources.

Results: Naujoks was one of the most sustainable modernizers of German dentistry in the second half of the century. During his term of office as president of the German Society for Dental and Oral Medicine (DGZMK), the "Akademie Praxis und Wissenschaft" (Academy Practice and Science, APW, 1974) and various working groups were established, which significantly promoted the further development of the DGZMK and beyond. His scientific achievements included innovative research on caries prophylaxis and fluoridation. There were no indications of a political connection to National Socialism.

Discussion and conclusion: Compared to his predecessors, Naujoks had specific characteristics and approaches: These relate to his educational path, his understanding of dentistry, his research approach, his publication practice, his vision with regard to the DGZMK and his political orientation. These characteristics show that Naujoks initiated a far-reaching paradigm shift both within the DGZMK and within university dentistry.

Keywords: APW; cariology; DGZMK; fluoridation; National Socialism

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Introduction

Although Rudolf Naujoks already became emeritus in 1987 and passed away in 2004, he still has the reputation of a distinguished and basic research-oriented scientist known beyond the borders of Germany. He acted as chairman of several national and international organisations – including the dental lecturers' association (1967–1969) and the DGZMK (1972–1977). It was in these offices that he provided essential scientific and professional impulses.

This article examines Naujoks' life and his contributions to the development of German dentistry and the DGZMK. The focus is on the questions of Naujoks' self-image as a university teacher, on possible unique features of his actions and on his concrete significance for the further development of university dentistry. Further attention is paid to Naujoks' relationship to National Socialism during the Third Reich.

Material and methods

The source material for the study consists of files from the Hamburg State Archives. Research was also conducted in the Federal Archives in Berlin. The academic papers published by Naujoks served as further sources. In addition, a comprehensive evaluation of the secondary literature available to date on his person and on the history of the Würzburg Dental Clinic was carried out. In particular, laudations, obituaries and lexical contributions, but also individual journal articles were consulted.

Results and discussion

1. From Koenigsberg to Würzburg: The stations of Rudolf Naujoks' life

Rudolf Karl Naujoks was born on July 24, 1919 in Koenigsberg (today: Kaliningrad) in East Prussia [5, 7, 26–28, 33, 34, 47, 49, 52, 53]; see Fig. 1 [2]). His parents were Karl Naujoks, a city employee at the Koenigsberg horticultural office, and Berta Naujoks, née Klotzki.

Rudolf Naujoks attended the "Burgschule" (castle school) – a secondary school in Koenigsberg. There he obtained his general qualification for university entrance on March 2, 1938. He initially completed work and military service and was deployed in the field after the outbreak of the Second World War, where he took part in battles in the West, East and South (Italy). In the winter semester of 1941/42 he enrolled to study dentistry at the University of Koenigsberg, but soon had to suspend his studies due to the war.

Before the end of the war, he married Christa Heinrich in 1944. The couple had two children together. They first settled in Bargteheide (Holstein), just 30 km north of Hamburg. It was not until the winter semester of 1945/46 that Naujoks was able to resume his studies in dentistry – now at the University of Hamburg. In 1948 he passed the dental examination and obtained his licence to practise dentistry. He then became an assistant at the Dental Clinic of the University of Hamburg to the maxillofacial surgeon Karl Schuchardt (1901–1985) [11]. The dissertation was supervised by Schuchardt and was entitled "Ueber Zaehne und Tonsillen bei der fokalen Infektion" (On teeth and tonsils in focal infections) [35].

In 1949, Naujoks became a member of a working group on "Caries and Sugar Degradation in the Saliva of the Mouth" (translation by DG), which also included the nutritional researcher and cariologist Fritz Bramstedt (1911–1976). In July 1955, Naujoks then obtained his habilitation in dentistry under Schuchardt in Hamburg with the study "Histotopochemische Untersuchungen am Zahnorgan" (Histotopochemical Investigations on the Dental Organ) [36]. This was followed by his appointment as a private lecturer. In 1958, Naujoks was appointed senior physician and, moreover, head of the "Abteilung für zusammenfassende Behandlung von Zahn-, Mund- und Kieferkrankheiten" (Department for the Comprehensive Treatment of Dental, Oral and Maxillofacial Diseases) at the Hamburg University Dental Clinic. The next step in his career was his appointment as associate professor in 1961.

Courtesy of Deutscher Ärzteverlag

Figure 1 Naujoks, Rudolf [2]

From March to May 1962, Naujoks worked as a visiting professor at the Harvard School of Dental Medicine in Boston. The following year he was appointed to the chair of dentistry at the University of Würzburg [26, 27, 33, 34]. The background to the announcement was the sudden cardiac death of Hans Schlampp (1900–1962) in July 1962, which made it necessary to fill the Würzburg chair. With that professorship, Naujoks also took over the direction of the Würzburg University Clinic and Polyclinic for Dental, Oral and Maxillofacial Diseases. He also acted as head of the conservative, prosthetic and orthodontic departments. Only maxillofacial surgery was in the hands of a second full professor: also in 1963, the respective position was filled by the maxillofacial surgeon Friedrich Schröder (1912–1996).

Naujoks saw his main professional focus in dental conservation and therefore initiated the spin-off of dental prosthodontics in 1972 – with the appointment of his former student Wilhelm Kühl (*1929) – and the spin-off of orthodontics in 1974 – with the appointment of Emil Witt (*1934) from Freiburg [27, 41].

Until his retirement in 1987, Naujoks served as clinic director and head of the Department for Restorative Dentistry in Würzburg [26, 27, 33, 34]. But even after his retirement he remained professionally active. For example, he coordinated a study

Term of office	Name	NSDAP Membership	Life data
1906–1926	Otto Walkhoff	+	1860–1934
1926–1928	Wilhelm Herrenknecht	+	1865–1941
1928–45, 1949–54	Hermann Euler	+	1878–1961
1954–1957	Hermann Wolf	+	1889–1978
1957–1965	Ewald Harndt	+	1901–1996
1965–1969	Gerhard Steinhardt	+	1904–1995
1969–1971	Eugen Fröhlich	+	1910–1971
1972–1977	**Rudolf Naujoks**	–	**1919–2004**
1977–1981	Werner Ketterl	+	1925–2010

Table 1 The presidents of the CVDZ (from 1933: DGZMK) who experienced the Third Reich as adults and their party-political orientation

on the oral health status and oral health behaviour in Germany until 1991 [40].

Rudolf Naujoks died on March 27, 2004 in Würzburg. His second wife – Jutta Naujoks, née Patz, born in 1928 – survived him by nine years. She was also a dentist and, after her habilitation (1974), worked from 1978 to 1987 as associate professor and senior physician for dental preservation at Naujoks' chair [27].

2. Naujoks' scientific and professional significance and his political classification

In the second half of the century, Rudolf Naujoks was one of the most influential and visible German-speaking university teachers of dentistry and held a large number of representative offices, which can only be mentioned here in extracts [5, 7, 26–28, 33, 34, 47, 49, 52]. For example, he served as Dean (1965/1966) of the Würzburg Medical Faculty, as President of the "Continental European Division" of the "International Association for Dental Research" (CED-IADR, 1965), as President of the "European Organisation for Caries Research" (ORCA, 1967/1968, [3]) and as Chairman of the German "Zahnärztliche Dozentenvereinigung" (Dental Lecturers Association) (1967–1969). He was also the initiator of the permanent "Konferenz der Lehrer für Zahnerhaltung und Parodontologie" (Conference of Teachers of Dental Preservation and Periodontology).

Of all the offices held, Naujoks' work as president of the DGZMK (1972–1977) deserves special attention [7, 23] (cf. Tab. 1). He not only "administered" the office during this time, but also endeavoured to reorient the professional society in terms of content. To this end, in 1974 he issued a four-page "programmatic statement" in the "Deutsche Zahnärztliche Zeitschrift" (DZZ) entitled "Die Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde. Gestern – Heute – Morgen" (The German Society for Dental, Oral and Maxillofacial Medicine. Yesterday – Today – Tomorrow) [37] (cf. Fig. 2). In this article, Naujoks first reflected on the past and present of the professional society and then commented on its future orientation. In his opinion, the future DGZMK had tasks to fulfil "on three levels": (1) dealing with clinical-scientific issues "which are of current importance for the practice of dentistry and which, for example, require a professional, expert-scientific basis in negotiations with the statutory health insurance funds", (2) the "promotion of developing new special sciences" by establishing corresponding working groups and (3) "post-academic education". With regard to the latter task, "systematically structured series of courses […] usually on weekends […] should convey the new findings of the last five to seven years in the fields of knowledge relevant to modern dental practice" [37]. During his time as a member of the board of the DGZMK (1967–1969) and especially in his position as president (1972–1977), Naujoks initiated the foundation of several working groups and associations. These included the "Working Group for Basic Research" (1967), the "Working Group for Paediatric Dentistry and Prophylaxis" (1973) and the "Working Group for Work Science and Dentistry" (1973). The same applies to the working groups "Epidemiology and Public Health" (1976) and "Forensic Odonto-Stomatology" (1976) [23]. However, as DGZMK president, Naujoks had the reputation of taking up the cause of founding such organisations even when the actual initiative came from other people. Römer noted, for example, that Naujoks had rejected a written application to establish a "Society for Paediatric Dentistry within the DGZMK", citing formal reasons. According to Römer, "with this tactic, which is popular in dental professional meetings – rejecting a motion and replacing it with his own 'more far-reaching', but in principle comparable motion – Naujoks opened up the possibility of taking the initiative […]" [50]. Nevertheless, it remains to be noted that Naujoks clearly promoted the establishment of these AKs and AGs. The founding of the "Akademie Praxis und Wissenschaft" (APW) also took place during Naujoks' term of office (1974). It was constituted as a subsidiary of the DGZMK with the goal formulated by Naujoks of making structured further education accessible to the dental profession. The APW subsequently developed into a particularly great and lasting success. Today, it is impossible to imagine structured con-

tinuing education in dentistry without it.

Naujoks' visionary activities as DGZMK president were recognised as such at an early stage. For example, the dental professional politician and chronicler Karlheinz Kimmel (1925–2013) stated in 1977 in an almost prophetic manner: "Under the presidency of the nationally and internationally equally well-known and recognised Würzburg university teacher, Rudolf Naujoks, with his unmistakable (East) Prussian nature, the 'German' [DGZMK] has developed into a great scientific institution of our discipline […]" [55]. The foundation of the APW and the various working groups under the umbrella of the DGZMK were groundbreaking; this can be considered certain today, viewed from the distance of half a century. The aforementioned organisations gave the professional society a modern, future-oriented character.

Naujoks' role as a researcher was just as important as his role as a professional politician. With his fundamental papers on caries prophylaxis and fluoridation, on the biochemistry, aetiology, diagnostics and therapy of caries, on the histochemistry of the dental organ as well as through biochemical saliva and plaque examinations, he attracted great scientific attention [1, 4, 29–32, 38–40, 42–44]. In some cases, these were joint studies with the already mentioned Fritz Bramstedt and with Adolf Kröncke (1922–2009), but he also regularly collaborated with foreign authors. Kröncke, like Bramstedt, was one of Naujoks' Hamburg companions and later also became a full professor at a Franconian university (Erlangen, 1964).

Naujoks also succeeded in acquiring high-ranking research funds. For example, he played a leading role in establishing the "DFG Special Research Area" (Sonderforschungsbereich der Deutschen Forschungsgemeinschaft) named "Biology of the Oral Cavity" (1971), which was based at the University of Würzburg – a rare success in contemporary university dentistry, and one that was accordingly much acclaimed. In the 1960s and 70s, Naujoks also conducted research on caries epidemiology and oral health with various industrial cooperation partners [45–46]. Even in retirement he remained active as a researcher. He appeared in public with a total of over 150 publications.

Naujoks, who took over the direction of the Würzburg Dental Clinic in 1964 and in the first years also headed the three departments of restorative dentistry, prosthodontics and orthodontics, assigned himself professionally to dental conservation (and periodontology). He saw no point in retaining responsibility for all the above-mentioned areas in his hands; instead, he endeavoured to relinquish parts of his management functions and thus also his sphere of influence. Accordingly, he undertook a "systematic further subdivision of dentistry and oral medicine" by establishing independent chairs [41]. First, he initiated the establishment of a "Chair for Experimental Dentistry" in Würzburg in 1964/65 – unique in Germany at the time. In addition, he played a decisive role in filling the aforementioned professorship with his Hamburg companion Fritz Bramstedt, who was eight years his senior. This was followed in 1972 by the spin-off of dental prosthodontics and in 1974 by the independence of orthodontics [41]. Naujoks was one of the first full professors to relinquish personal influence and decision-making power in order to promote specialisation – similar to Eugen Fröhlich (1910–1971) from Tübingen, his immediate predecessor in the office of DGZMK president, who died prematurely [20].

While Naujoks did not consider the clinic his personal "power base", he fought vehemently for a systematic expansion of the dental clinic as such. In the end, he was able to obtain construction funds amounting to 85 million DM for reconstruction and expansion measures. However, he did not live to see the final result of the hurdle-laden and protracted renovation measures and extensions of the dental clinic during his term of office as clinic director, because the latter ultimately lasted beyond the turn of the millennium [56].

Naujoks was held in high esteem among the specialists in university dentistry. Peter Riethe (1921–2020) even described him as a "'special type' of homo sapiens" who had developed to "ideal perfection and completeness"; he attributed to Naujoks in particular the qualities of "powers of observation, memory, intelligence and imagination" [49].

Naujoks was very well connected, to which his many offices at home and abroad contributed significantly. In addition to the aforementioned Bramstedt and Kröncke, his longstanding research partners and companions in the German-speaking world included Günther Ahrens (1926–1999) and Hans Mühlemann (1917–1997), whom he succeeded as president of the CED-IADR (Continental European Division of the International Association for Dental Research) in 1965. Naujoks' best-known academic students – apart from the two above-mentioned collaborators Jutta Naujoks, née Patz, and Wilhelm Kühl – were Wolfgang Büttner (1926–1981, 1967 move from Gießen to Würzburg and habilitation recognition), Hans-Dietrich Mierau (1930–2019), Wolfgang Wiedemann (*1944) and Johannes Einwag (*1954) [22].

Naujoks' professional reputation and extensive networking were reflected in numerous honours and awards in the second half of his professional life: in 1973, for example, he received the pin of honour of the "Deutsche Zahnärzteschaft" (German Dental Association). In 1975 he was made a Fellow of the "American College of Dentists", in 1976 he received honorary membership of the "Österreichische Gesellschaft für Zahn-, Mund- und Kieferheilkunde" (Austrian Society for Dental, Oral and Maxillofacial Medicine), and in 1977 he was elected a member of the National Academy Leopoldina. In 1978 he was awarded the Honorary Pin of the DGZMK, in 1979 he received the "Award of Merit" of the Fédération Dentaire Internationale (FDI) and the bronze medal of the "Ordre National des Chirurgiens Dentistes" (National Order of Dental Surgeons) in France. In 1983, he was awarded the Golden Badge of Honour of the German Dental Association and in 1984, honorary membership of the German Society for Dental Conser-

vation (DGZ). In 1986, he became an honorary member of the DGZMK.

Unlike his predecessors in office, Naujoks started his post-war career without a political mortgage. The research on a possible political involvement in National Socialism ended with a clear result: there were no indications of membership in the NSDAP or of National Socialist statements or activities [25].

Conclusions

Prima vista, Naujoks seems to share basic characteristics with many of his predecessors in office: He was a respected representative of his field and achieved high visibility in his office as president.

And yet, a closer look reveals a whole series of unique personal features. They not only identify Naujoks as a special type of university lecturer, but also prove that he stands for a paradigm shift within the DGZMK as well as within university dentistry. Indicators for this assumption are (1) Naujoks' educational path, (2) his understanding of dentistry as a subject, (3) his research approach, (4) his publication practice, (5) his vision with regard to the DGZMK and (6) his political orientation.

The first indicator of a paradigm shift is provided by Naujoks' educational background: he was the first DGZMK president since Otto Walkhoff, appointed in 1906 [9, 15, 16], who was not at the same time a doctor, but only licensed as a dentist. All other predecessors – Wilhelm Herrenknecht (1926–1928) [17], Hermann Euler (1928–1945, 1949–1954) [10, 14, 24], Hermann Wolf (1954–1957) [18], Ewald Harndt (1957–1965) [13] and Gerhard Steinhardt [19] (1965–1969), but also his immediate successor Werner Ketterl (1925–2010) [21] – were doubly trained and licensed. Naujoks thus stands prototypically for a new era and a new generation of university teachers of dentistry – university teachers who were able to qualify academically at the medical faculties as pure dentists and, moreover, specialised in a sub-area within dentistry. In fact, until well into the second half of the century, the medical faculties that were decisive for appointments in dentistry and were run by physicians preferred double-appointed candidates – even when it was not a question of chairs with a focus on maxillofacial surgery. This was obviously also due to the fact that dentistry did not have the Abitur (A level) as a study requirement before 1909 and the right to award doctorates in the subject before 1919 [6, 12, 23, 51]. It eventually took even longer to be perceived and accepted by the majority of faculty members as an academic subject of equal standing. Thus, additional medical training was long considered an almost indispensable qualification for professors of dentistry, for whom more and more university posts had been created since the 1920s. The life and career path of Naujoks indicates a change in this respect that began in the 1960s, also reached the level of DGZMK presidents in the 1970s and has increasingly intensified until today.

A second peculiarity is evident in Naujoks' understanding of the subject: he was no longer a representative of holistic dentistry and ac-

Zur 100. Jahrestagung

Dtsch. zahnärztl. Z. 29, 361–364 (1974)

Die Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde — Gestern — Heute — Morgen

Von R. Naujoks, Würzburg*
Präsident der DGZMK

Nur wenige wissenschaftliche Gesellschaften der Heilkunde können heute für sich in Anspruch nehmen, auf eine 115jährige Geschichte zurückzublicken wie die Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde und nur wenige haben bereits 100 Jahrestagungen durchgeführt. Wenn die Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde heuer das Jubiläum ihrer 100. Jahrestagung feiert, so kann zurückschauend festgestellt werden, daß ihre Geschichte eigentlich die Entwicklung der Zahn-, Mund- und Kieferheilkunde in Deutschland, ja zum Teil auch auf internationaler Ebene widerspiegelt.

Aus einer beträchtlichen Anzahl von Parallelgründungen hat sich die DGZMK – damals noch Zentralverein Deutscher Zahnärzte – als einzige behaupten können. Seit Jahrzehnten ist sie jetzt die anerkannte Repräsentantin der Deutschen Zahn-, Mund- und Kieferheilkunde, wobei hiermit sowohl der praktisch-klinische als auch der wissenschaftlich-experimentelle Aspekt des Gesamtfachgebietes gemeint ist. Von ihrer Satzung her ist sie verpflichtet, sich um beide Aspekte der Zahn-, Mund- und Kieferheilkunde zu bemühen. Dieser Verpflichtung ist sie stets gerecht geworden. Die ihr gestellten Aufgaben waren im Wandel der Geschichte jedoch beträchtlichen Schwankungen unterworfen.

Die deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde – gestern

Es kann hier nicht der Ort sein, die Geschichte der Deutschen Gesellschaft für Zahn-, Mund- und Kieferheilkunde aufzuzeichnen. Dieses ist an anderer Stelle [1] in bemerkenswert gelungener Weise erfolgt. Hier sei lediglich auf zwei große Zeitabschnitte mit ihren für die Entwicklung unserer DGZMK besonders bedeutenden Einflüssen hingewiesen. Dabei betrifft die erste Spanne den Zeitraum bis etwa zum 2. Weltkrieg.

Die ersten Jahrzehnte in der Geschichte der DGZMK waren geprägt durch jene Bemühungen, die in der damaligen Zeit in fast allen wissenschaftlichen Disziplinen zu beobachten waren, nämlich durch das Suchen nach Wegen zum Austausch von Erfahrung und Wissen. Es war endgültig jener Zeitabschnitt beendet, in dem erlerntes und erarbeitetes, durch Erfahrung oder Intuition gewonnenes Wissen ängstlich gehütet wurde. Die Kommunikation auf wissenschaftlicher Ebene wurde auf eine immer breitere Basis gestellt.

Damals verstand sich die Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde vor allem als „wandernde Schule der zahnärztlichen Praxis". Während der 50. Jahrestagung im Jahre 1911 in Dresden – von heute aus gesehen also nach der halben Distanz – wurde der Beschluß gefaßt, für praktizierende Zahnärzte Demonstrationen und Fortbildungskurse über aktuelle Fragen aus der Praxis durchzuführen. Teilnahmeberechtigt sollten nur Mitglieder der Gesellschaft sein. Die Einrichtung wurde zu einer Dauerinstitution. Hierauf wird noch zurückzukommen sein. – Die Förderung der wissenschaftlichen Zahn-, Mund- und Kieferheilkunde wurde daneben aber nicht vergessen.

Zu den Aufgaben der Deutschen Gesellschaft für Zahn-, Mund- und Kieferheilkunde gehörte in jener Zeit aber noch ein weiterer Aspekt. Sie hatte in nicht unbeträchtlichem Ausmaß auch die standespolitischen Interessen der Deutschen Zahnärzteschaft wahrzunehmen. Es ist sicher-

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Figure 2 Rudolf Naujoks' policy paper on the development of the DGZMK [37]

cordingly did not claim to lead all sub-areas of dentistry in his role as clinic director. Rather, he saw himself as a specialist within dentistry and accordingly promoted its differentiation into individual sub-areas with independent chairs ("departmental structure"). It is evident that Naujoks' "modern" position on this issue carried weight among university dental teachers, for after all, Naujoks was also chairman of the dental lecturers' association, as well as initiator of the permanent "Conference of Teachers of Dental Maintenance and Periodontology" and, indeed, for many years president of the DGZMK – by far the most important German professional society. Naujoks thus acted as a role model on this issue (together with Eugen Fröhlich, who died at an early age). He was, so to speak, the antithesis of older colleagues who saw themselves as doctors and generalists in the field of dentistry and often combined this holistic self-image with the claim to retain decision-making power over all the departments of "their" clinic. A prototypical representative of this traditional view was Herman Euler (1878–1961) as clinic director in Breslau [10, 14, 24]. However, this attitude was most pointedly stressed by the double-appointed full professor Matthäus Reinmöller (1886–1977), who headed the Rostock University Dental Clinic until 1955. He emphasised, for example, that every future university lecturer in dentistry had to be a doctor at the same time and that dental clinics needed a hierarchical structure with a superior head. Reinmöller also established four specialist departments in Rostock in the post-war period but ensured that these were led by senior doctors who were "subordinate" to him. For him, it was constitutive that "all departments were looked after by a single directorate" and not that "each department represented, or wanted to represent, its own clinic" [55]. Naujoks thus represented the modern counter-model to this increasingly anachronistic understanding of university dentistry.

A third indicator of change is provided by Naujoks' research approach: he gave significantly more weight to basic research than his (mostly clinically oriented) predecessors in the presidency. Although Naujoks also worked on individual clinical-practical issues, he clearly drew his professional reputation from his fundamental histological and biochemical studies, which also made him compatible with modern transdisciplinary bioscientific research at an early stage.

This corresponded with a fourth characteristic of Naujoks: his publication practice. Naujoks published far more than earlier presidents of the DGZMK or other former professors of dentistry together with other authors. Until then single authorships had predominated. In addition, his publications were more internationally oriented than those of previous presidents – both in terms of the publication organs chosen and the co-authors involved. Moreover, Naujoks clearly preferred the journal article as a form of publication over book contributions or the traditional monograph. While many former presidents of the DGZMK, such as Willougby D. Miller (1853–1907) [8], Walkhoff (1860–1934) [9, 15, 16], Euler (1878–1961) [10, 14, 24], Harndt (1901–1996) [13] and most recently Fröhlich (1910–1971) [48], remained in the collective memory of several generations of students precisely because of their successful textbooks, Naujoks broke with the tradition of classic book authors.

Naujoks was also out of the ordinary with his vision for the DGZMK: Like no other president before him, he pushed the promotion of the "special sciences" and the further "differentiation" of the DGZMK – by founding working groups and associations and by establishing the subsidiary organisation APW. Even though Naujoks had important comrades-in-arms in these initiatives, he was ultimately the "enabler" and essential motor of this reorientation – thus helping the DGZMK to gain more attractiveness and a new self-image.

Finally, the research on Naujoks' political orientation in the Third Reich also led to a personal peculiarity: Naujoks was the only one among a total of nine presidents in the period under consideration from 1906 to 1981 who did not join the NSDAP in the Third Reich and who maintained party-political neutrality in the years until 1945. This fact can only be explained to a limited extent by his late year of birth (1919); after all, even among the dental university professors born after 1919 there are still NSDAP members, such as his successor Ketterl. Naujoks' behaviour is more likely to have been rooted in a personality trait: namely, not following contemporary trends or orienting himself towards the established, but first and foremost pursuing his own convictions and intuitions.

Conflicts of interest

The author declares that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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Professionally impressive, politically surprising: life and work of DGZMK President Werner Ketterl

Introduction: Werner Ketterl is one of the most successful university teachers of the recent past. Since the 1960s, he has had a lasting influence on the development of university dentistry as a scientist and professional politician. In addition, he was one of the few protagonists of the discipline who dealt with National Socialism in autobiographical memoirs. Against this background, this article focusses on the life and work of the Mainz professor in the Third Reich and the Federal Republic of Germany.

Material and methods: The central basis of the study are, among others, primary sources from the Federal Archives Berlin and the State Archives Munich as well as Ketterl's autobiography from 2000. In addition, a comprehensive analysis of professional publications by and about Ketterl was carried out.

Results: Werner Ketterl was probably the most influential specialist representative in the field of Restaurative Dentistry, especially in the 1970s and 1980s – alongside Adolf Kröncke and Rudolf Naujoks. However, he was more clinically oriented in research than the aforementioned colleagues and he also developed a stronger focus on periodontology. In the Third Reich he showed himself to be loyal to the regime. He applied for membership in the NSDAP (National Socialist German Workers' Party) in the month of his 18th birthday and was accepted three months later.

Discussion and conclusion: Ketterl understood dentistry as a unity of science and professional policy. With this symbiotic approach, he shaped the development and the public perception of dentistry like hardly any other university lecturer of his time – both at the University of Mainz and on a national scale. However, his commitment to the NSDAP is beyond the expected – especially in view of the fact that he concealed his party membership in his memoirs and, moreover, frankly discredited the supporters of National Socialism.

Keywords: tooth preservation; periodontology; Mainz; NSDAP; National Socialism

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Introduction

Anyone who deals with German university dentistry from the 1960s to the 1980s will come across the name Werner Ketterl: The latter shaped the scientific development of restorative dentistry and periodontology, steered the fortunes of the "Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde" (German Society for Dental and Oral Medicine, DGZMK) as president and exerted influence on structures in the university and professional-political field. He is also one of the few representatives of the profession to have written an autobiography. In these memoirs, Ketterl not only deals with his professional stations and activities, but also with the political and social conditions of his time – and especially with the Third Reich and National Socialism.

Against this background, it seems worthwhile to elaborate on Ketterl's multi-layered life and work as documented in archival sources and to compare the historical facts with the statements in the aforementioned autobiography.

Material and methods

The central basis of the study are primary sources from the Federal Archives in Berlin and Ketterl's "Spruchkammer files" (denazification files) kept in the Munich State Archives. These are compared with the "Lebenserinnerungen eines Hochschullehrers" (Memoirs of a University Teacher) written by Ketterl and published as book at the turn of the millennium.

In addition, a comprehensive analysis of Ketterl's specialist publications and secondary literature on his person, his academic environment and his specialist contributions was carried out. Moreover, laudations, necrologies and lexical contributions on Ketterl were evaluated.

Results and discussion

1. Werner Ketterl – a biographical outline

Werner Ketterl (Fig. 1 [67]) was born in Munich on January 14, 1925. His father was the Munich "Dentist" Alois Lorenz Ketterl (*1898). At that time, there were two professions licensed to treat teeth in Germany: the academic "Zahnärzte" and the artisan-trained "Dentisten". All that is known of his mother is that she bore the birth name Halder before marriage. Alois Ketterl had a practice in Munich since the 1920s. In 1953, in the course of the abolition of the professional group of "Dentisten", he was admitted to the newly established "unified profession" and was henceforth allowed to call himself a "Zahnarzt" [1, 9, 18, 78].

Werner Ketterl's life stages are well documented on the basis of autobiographical information and other primary and secondary sources [5, 11, 30, 54, 60, 62–67, 71, 72]: He grew up in the Schwanthaler Höhe near Munich's Theresienwiese. After attending primary school, he transferred to the Wittelsbacher Gymnasium in the Munich district of Maxvorstadt in the mid-1930s. The humanistic grammar school, which still exists today, had been founded in 1907. Since Ketterl was called up for military service, he finished school early in 1943 with the "Notabitur". The latter was a facilitated university entrance qualification in which the written maturity examinations were omitted; instead, the last class tests in the main subjects were assessed [60].

Ketterl stated that as a child he wanted to become a locomotive driver, as a teenager a teacher and then as a young adult a geographer and geopolitician [60]. This changed again during wartime, which he experienced from 1943 onwards as a gunner in the artillery, as a lieutenant in the reserves (with training in Landsberg am Lech, Lenggries, Traunstein, and Dresden) and as an officer in Italy and on the Eastern Front. At the end of the war, he spent several weeks in American captivity in Nauen and Salzgitter. He escaped from there and returned to Munich. At that time, according to his own account, he still had a "bullet in his chest, which could later be removed without complications" [60].

In the meantime, he had decided to study dentistry and gave pragmatic considerations for this: "With the end of the thousand-year Reich, my former career aspirations also perished. Reason prevailed" [60]. After

University Archives Mainz, courtesy of the photographer Reiner Wierick [67]

Figure 1 Werner Ketterl

successfully completing a "remedial course", he was able to enrol in dentistry at the University of Munich in autumn 1945. His academic teachers in this subject were Maria Schug-Kösters (1900–1975) [24] and – from 1947 – Peter-Paul Kranz (1884–1957) [31]. Kranz – like his fellow professors Karl Pieper (1886–1951) [20] and Karl Falck (1884–1955) [77] – had been discharged by the military authorities in 1945 for political reasons, but was able to return to the Munich Dental Clinic as director after completing his denazification process in the fall of 1947. Until then, Schug-Kösters – the first female dentist in Germany with a habilitation (1931) and the only professor at the clinic without NSDAP membership – had held the directorship on a provisional basis; she fell back to the position of head of the "Department of Restorative Dentistry" when Kranz returned.

In February 1949, Werner Ketterl passed the dental examination after seven semesters of standard study time. He was able to complete his doctorate (Dr. med. dent.) three weeks before the exam: he had already looked for a doctoral topic after the "Physikum" (intermediate examination) and had found it in physiology. Here, during the clinical semesters, he had written a dissertation on the nucleic bases "Thymin und Uracil" (Thymine and Uracil), which was already completed half a year before the state

Term of office	Name	NSDAP Membership	Life data
1906–1926	Otto Walkhoff	+	1860–1934
1926–1928	Wilhelm Herrenknecht	+	1865–1941
1928–45, 1949–54	Hermann Euler	+	1878–1961
1954–1957	Hermann Wolf	+	1889–1978
1957–1965	Ewald Harndt	+	1901–1996
1965–1969	Gerhard Steinhardt	+	1904–1995
1969–1971	Eugen Fröhlich	+	1910–1971
1972–1977	Rudolf Naujoks	–	1919–2004
1977–1981	**Werner Ketterl**	+	**1925–2010**

Table 1 The presidents of the CVDZ (from 1933: DGZMK) who experienced the Third Reich as adults and their party-political orientation

examination [36, 60]. As early as March 1949, he took up a position as assistant dentist in the Department of Restorative Dentistry at Schug-Kösters, where he ultimately remained for ten years as a lecture assistant.

In 1953, Ketterl married Susanne Vogel. The couple became parents of two children [78]. In the same year, Ketterl enrolled for a second degree in medicine – also in Munich. This resulted from the fact that in Bavaria the habilitation in dentistry required an additional degree in medicine – and it was precisely this habilitation that he was striving for. He explained: "Since I wanted to become a university teacher, I had to study medicine, which I never regretted" [60].

In February 1956 he passed the medical examination and in July 1957 he obtained his doctorate in medicine (Dr. med.). His second dissertation was a work on medical history and dealt with the "History of Paranasal Sinus Surgery" [38].

In 1954, the maxillofacial surgeon Josef Heiß (1908–1973) [73] had succeeded the emeritus clinic director Kranz in Munich and was thus the formally responsible specialist supervisor for the habilitation Ketterl was seeking. In terms of content, however, Ketterl's topic was in restorative dentistry and thus fell under the responsibility of Schug-Kösters, in whose department he continued to work. In order to understand the explosive nature of this personnel constellation, one must know that Schug-Kösters was continuously defamed by Heiß in Munich. Heiß's "public insults" and "false statements" [3] against Schug-Kösters were aimed at discrediting her on a professional and personal level. These accusations soon became known outside Munich [13] and Ketterl was also drawn into the disputes. He wrote in his memoirs: "The director of the clinic called me in to tell me that he was dismissing me and that he had already discussed this with his lawyer […]. When I reported this to Schug-Kösters, she laughed and said he should dare. The dismissal was reversed. Those were really exciting moments […]" [60].

Despite the circumstances, Ketterl was finally able to habilitate with Josef Heiß in Munich in April 1960 – at the age of 35 – and was then out of the firing line. Schug-Kösters, on the other hand, remained the focus of Heiß's attention and tried to defend herself in 1964 by filing a criminal complaint with the Munich public prosecutor's office because she saw "the protection of the teaching activities of a university lecturer violated by public insults" [3].

Ketterl's habilitation thesis was entitled "Studie über das Dentin der permanenten Zähne des Menschen" (Study of the Dentin of Permanent Human Teeth) and was one of his rather few histological works; it was also published as a journal article in 1961 [40]. After his appointment as Privatdozent (privat lecturer, 1960), he was responsible for the phantom course in dental conservation with the corresponding three-hour lecture as well as the course "Pathohistology of Teeth" [60].

Ketterl remained in Munich for a total of 16 years – the first years as an assistant and then as senior assistant [60]. In 1963, a career change was on the cards for the first time: In that year, he was offered a professorship in Graz. But after negotiations with the clinic director Richard Trauner (1900–1980) [35] he turned it down – among other things because of suboptimal financial conditions [60]. In 1964, he received another call from Heidelberg – without having to "audition", as he wrote himself [60]. There, the second chair next to Reinhold Ritter (1903–1987) [21, 29] was to be filled.

Almost at the same time, he was invited to Mainz for a trial lecture, which was also followed by a call. The Mainz University Dental Clinic was only founded after the war with the appointment of Martin Herrmann (1895–1976) [33] in April 1948. In contrast, the dental clinic in Heidelberg had already existed since 1895 and could refer to a number of prominent university teachers, including Gottlieb Port (1867–1918), Georg Blessing (1882–1941) [24], Hermann Euler (1878–1961) [17, 22, 28] and the aforementioned Ritter [21, 29]. In the end, Ketterl rejected the call to Heidelberg "with a bad conscience" because of the framework and working conditions there. He noted: "If a patient or assistant had to go to the toilet in Heidelberg, the way led through the treatment room of the head of department […] A new building was out of the question in Heidelberg at that time" [60].

Although the existing conditions in Mainz were also very difficult, the construction of a new clinic had already begun. So Ketterl accepted the position: "In the end, the decisive factor was the shell of a new clinic, which was already nearing completion, and the conception of this institution" [60]. According to Beck, Ketterl's academic teacher and mentor Maria Schug-Kösters had played a decisive role in the appointment to Mainz: "Schug-Kösters endeavoured to propose him in Mainz, which was crowned with success" [3].

In Mainz, Ketterl was temporarily classified as "functional clinic director", but soon advanced to associate professor and then in 1966 to full professor and director of the Clinic for Dental Conservation. Ketterl remained in Mainz throughout his professional life, worked for many years as managing director of the clinic and became emeritus professor there in 1993 – after reaching the age of 68 and a total of 29 years on site. His students honoured him with a torchlight procession on the occasion of his retirement [60].

Werner Ketterl remained a resident of Mainz and died there on December 23, 2010 shortly before reaching the age of 86 [30, 67, 76].

2. Ketterl's scientific and professional-political significance

Since the beginning of the 1960s at the latest, Ketterl was regarded as one of the hopefuls in German university dentistry – especially in the field of restorative dentistry. As mentioned, he received three professorship appointments in 1963 and 1964, choosing the chair in Mainz. There Ketterl succeeded Josef Kluczka (1897–1966) [14], a Silesian dentist and periodontist.

Kluczka was a general dentist: Martin Herrmann, the founder of the Mainz clinic, had got to know and appreciate him during the Second World War as a member of staff in a military hospital for patients with facial and jaw injuries. In the course of establishing the dental clinic in Mainz (1948), Herrmann offered a position to Kluczka, who had been expelled from Silesia after 1945. Despite his lack of previous university experience, he made Kluczka head of the new department of restorative dentistry, which had yet to be founded. Kluczka was able to habilitate at the advanced age of 52 and start a late scientific career. He made a name for himself as a periodontist and periodontology assessor and with the establishment of an "aseptic root treatment room". This idea was much discussed among his contemporaries, but was ultimately unsuccessful [32, 60].

Ketterl spoke very highly of his predecessor ("[…] a renowned representative of our discipline known throughout Germany" [60]). In any case, it is noticeable that Ketterl sketches the persons mentioned by name in his memoirs largely positively. This clearly distinguishes him from his (similarly influential) colleague Carl-Heinz Fischer (1909–1997), who made so many critical comments about colleagues in his memoirs that a court prohibited their distribution [13, 28]. In contrast, Ketterl paid tribute to many of his companions – such as his two predecessors in the office of DGZMK president, Eugen Fröhlich (1910–1979) [25, 60] and Rudolf Naujoks (1919–2004) [26, 60], his deputy on the DGZMK board Karl Palmen (1916–2013) [10, 60] or the aforementioned Martin Herrmann (1895–1976) from Mainz [33, 60].

Ketterl was particularly appreciative of his Munich mentor Maria Schug-Kösters. He honoured the latter with a laudation [41] on the occasion of her 60th birthday and with an obituary [52] after her death. He pointed out that she was "usually years ahead of her time": "In 1950 she taught the 'Efficiency principle' – today it is impossible to imagine our work without the resulting ergonomic ideas in the dental field. The introduction of aseptic restraints in endodontics, direct and indirect capping, vital amputation and vital extirpation were taught by her to the students 10 years before the introduction of the new Bema [fee schedule] and practised in the course. As early as 1955, under her leadership, the special training of students in periodontology began […] a level that has not yet been reached today at all German universities in our field" [52]. He only briefly sketched the former head of the Munich clinic, Josef Heiß, who had already died in 1973, as a disputatious superior who had focused primarily on "maintaining power" [60].

Ketterl's move to Mainz marked the beginning of his rapid rise as a scientist and expert politician. Both careers – that of the researcher and that of the professional politician – require closer examination:

As far as research achievements are concerned, a look at Ketterl's scientific œuvre provides concrete insights: According to this, he was unquestionably one of the authors with the most contributions. He published well over 300 papers, the majority of which they were not oriented to basic research but concerned clinical issues. This is what distinguished him from the two other prominent "dental researchers" of his time, Rudolf Naujoks [26] and Adolf Kröncke (1922–2009) [69], who were primarily basic researchers and also had a stronger transdisciplinary orientation. Ketterl's research and writings focused on the fields of tooth preservation – especially endodontics – and periodontology. He dealt especially with the pulp and pulpitis therapy [2, 37, 68] and with root canal treatment [42, 45, 47, 49, 57, 61]. From the mid-1960s onwards, Ketterl's focus shifted more towards periodontology [8, 12, 44, 46, 48, 53, 55, 56, 58]. Further work concerned tooth sealing [7, 70], the field of filling materials and filling therapy [38, 39, 50, 51, 74] as well as the specific treatment of the child and elderly patient [43, 45, 49, 59]. In addition, Ketterl served as editor of the "Deutscher Zahnärzte-Kalender" (German Dentists' Calendar) from 1977 to 1995 and as one of four editors of the highly successful specialist book series "Praxis der Zahnheilkunde" (Dentistry Practice). In that series, a double-digit number of volumes appeared in a total of three editions in the last third of the century; it was not until the fourth edition – at the turn of the millennium – that a new editorial team was appointed [60].

But Werner Ketterl also had a clear influence on the university lo-

cation of Mainz and its surroundings. This can be seen firstly when looking at dentistry in Mainz: he succeeded in developing the dental clinic in Mainz into a university centre in the 1970s and 1980s. He established by-laws for the department of dental medicine, which stipulated that the managing clinic director was "elected for 2–3 years" and rotated [60]. In addition, he was able to considerably expand the staff of dental conservation and periodontology during his term of office – from one senior dentist and 5 assistants at the time he took up his post to 5 senior dentists and 12 assistants at the time of his retirement [60]. In addition, he succeeded in bringing an endowed professorship for experimental dentistry with further personnel and material resources to Mainz via the Blendax company [60].

Ketterl's influence in Mainz was by no means limited to dentistry. This can be seen from the fact that he took over the office of dean several times. Having already served as Vice Dean in 1970, he acted as Dean of the Faculty of Medicine for the first time in 1971/72. After a restructuring and the establishment of an independent "Fachbereich Zahnmedizin" (Faculty area of Dentistry), he also presided over this as Dean in 1974 (until 1977). In 1982, he was appointed dean for the third time in Mainz, now representing the "Fachbereich Medizin" (Faculty area of Medicine); this time he held this office until 1984 [60]. In addition, from 1972 to 1996 he was a member of the Mainz "Institut für medizinische und pharmazeutische Prüfungsfragen" (Institute for Medical and Pharmaceutical Examination Questions, IMPP), which was influential in medical training [60]. In 1978/79 he was also chairman of the "Concilium Medicinale", founded in Mainz in 1973. He held prominent positions outside the university as well: he acted as university advisor to the "Landeszahnärztekammer Rheinland-Pfalz" (Rhineland-Palatinate Dental Association) and was thus an advisory participant in all board meetings and also a member of the Assembly of Representatives there [60]. In addition, he was for a time chairman of

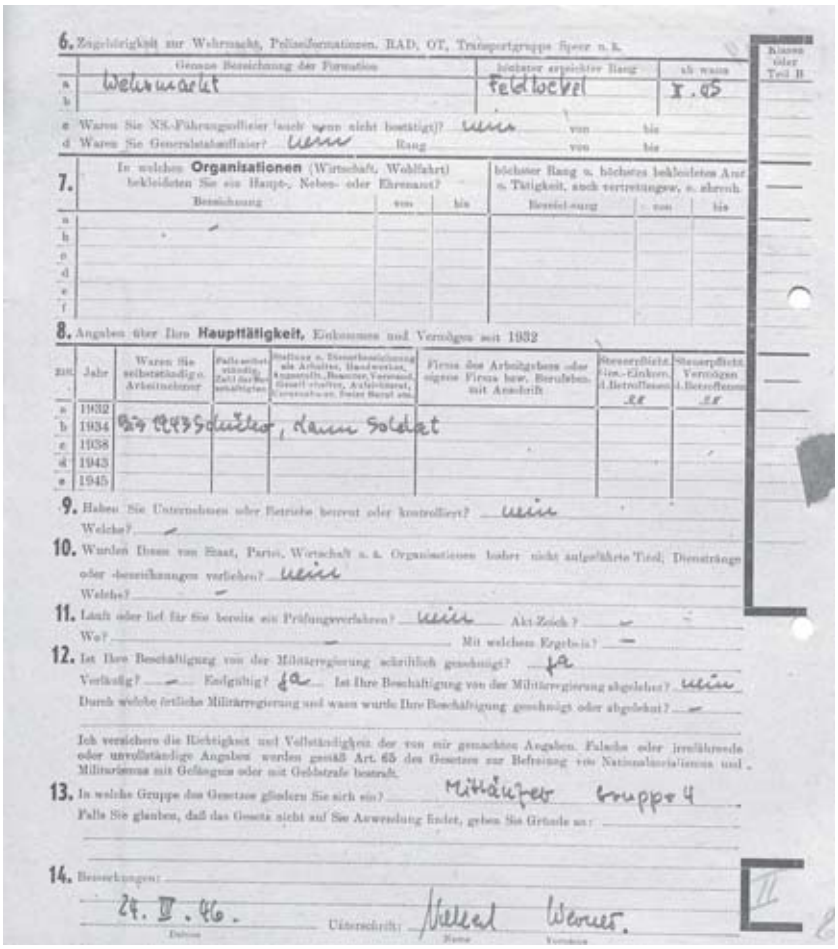
6. Zugehörigkeit zur Wehrmacht, Polizeiformationen, BAD, OT, Transportgruppe Speer u.ä.
Genaue Bezeichnung der Formation | höchster erreichter Rang | ab wann
a Wehrmacht | Feldwebel | 1.05
b
c Waren Sie NS-Führungsoffizier (auch wenn nicht hauptamtlich)? nein von bis
d Waren Sie Generalstabsoffizier? nein Rang von bis
7. In welchen Organisationen (Wirtschaft, Wohlfahrt) bekleideten Sie ein Haupt-, Neben- oder Ehrenamt?
Bezeichnung | von | bis | höchster Rang u. höchstes bekleidetes Amt o. Tätigkeit, auch vertretungsw., o. ehrenh. Bezeichnung | von | bis
a
b
c
d
e
f
8. Angaben über Ihre Haupttätigkeit, Einkommen und Vermögen seit 1932
Jahr | Waren Sie selbstständig o. Arbeitnehmer | Falls selbst. tätig, Zahl der Beschäftigten | Stellung a. Berufsbezeichnung als Arbeiter, Handwerker, Angestellt., Beamter, Vertreter, Gesellschafter, Aufsichtsrat, Generaldirektor, Freier Beruf usw. | Firma des Arbeitgebers oder eigene Firma bzw. Berufsbezeichnung mit Anschrift | Steuerpflicht. Einkommen i. Betroffenen | Steuerpflicht. Vermögen i. Betroffenen
a 1932
b 1934 Bis Kriegsende, dann Soldat
c 1938
d 1943
e 1945
9. Haben Sie Unternehmen oder Betriebe beherrscht oder kontrolliert? nein
Welche? –
10. Wurden Ihnen von Staat, Partei, Wirtschaft u. a. Organisationen bisher nicht aufgeführte Titel, Dienstränge oder -bezeichnungen verliehen? nein
Welche? –
11. Läuft oder lief für Sie bereits ein Prüfungsverfahren? nein Akt-Zeich.? –
Wo? – Mit welchem Ergebnis? –
12. Ist Ihre Beschäftigung von der Militärregierung schriftlich genehmigt? ja
Vorläufig? – Endgültig? ja Ist Ihre Beschäftigung von der Militärregierung abgelehnt? nein
Durch welche örtliche Militärregierung und wann wurde Ihre Beschäftigung genehmigt oder abgelehnt? –
Ich versichere die Richtigkeit und Vollständigkeit der von mir gemachten Angaben. Falsche oder irreführende oder unvollständige Angaben werden gemäß Art. 65 des Gesetzes zur Befreiung von Nationalsozialismus und Militarismus mit Gefängnis oder mit Geldstrafe bestraft.
13. In welche Gruppe des Gesetzes gliedern Sie sich ein? Mitläufer Gruppe 4
Falls Sie glauben, daß das Gesetz nicht auf Sie Anwendung findet, geben Sie Gründe an: –
14. Bemerkungen: –
24. II. 46. Unterschrift: Ketterl Werner.
Datum Name Vornamen

Figure 2 Extract from Ketterl's Spruchkammer files (State Archives Munich, 1946–1948, [75]).

the administrative board of the "Zentralinstitut für Zahnärztliche Ergonomie" (Central Institute for Dental Ergonomics) of the Rhineland-Palatinate Dental Association, which was established in 1971. Finally, he was a member of the identification commission of the "Bundeskriminalamt" (Federal Criminal Police Office) in the neighbouring city of Wiesbaden for several years [60].

Ketterl's status also grew visibly on a national scale: in 1967, for example, he succeeded the late Josef Kluczka on the board of the "Arbeitsgemeinschaft für Paradontoseforschung" (Working Group for Parodontosis Research, ARPA – since 1971: Deutsche Gesellschaft für Parodontologie, DGP; today: DG PARO) [5]. Over the years, he became a sought-after lecturer and surgeon in this field. For example, he offered live courses in periodontal surgery at the "Karlsruher Fortbildungsinstitut" (Karlsruhe Advanced Training Institute) from the early 1970s. In 1974 he was elected president of the DGP, a post he held until 1978 [5, 30, 60]. A year earlier – in 1977 – Ketterl had also succeeded Rudolf Naujoks as president of the DGZMK, the largest national professional society [15, 27]. At that time, he had already been a member of the society's executive board for 4 years and thus accompanied the foundation of the "Akademie Praxis und Wissenschaft" (Academy Practice and Science, APW) (1974) which was initiated under the aegis of Naujoks. The same applied for numerous working groups and study groups under the umbrella of the professional society. Ketterl also launched the long-established "Stellungnahmen der DGZMK" (DGZMK's statements) on current issues in dentistry during his term of office [60]. However, he left a much smaller mark on the structure of the society

than his predecessors Fröhlich and Naujoks. Thanks to Fröhlich and Naujoks, the DGZMK was considered largely consolidated and well equipped for future tasks when Ketterl took office. Ketterl retained the office of DGZMK president until 1981 [15, 27].

Ketterl also attained an important position in the "Bundesverband der Deutschen Zahnärzte" (German Dental Association, BDZ; today: BZÄK): He succeeded Carl-Heinz Fischer as BDZ continuing education officer [13, 60]. In this capacity he organised, among other things, for more than 10 years the popular "Fortbildungswoche in Meran" (Advanced Training Week in Merano) – an international conference at which he was able to gather up to 100 university lecturers in Merano which enabled him to expand his professional network [60].

In addition, he gained influence within the "Kassenzahnärztliche Bundesvereinigung" (National Association of Statutory Health Insurance Dentists, KZBV): there he was responsible for the appointment and professional supervision of periodontology assessors and reviewers [60].

Against the background of these diverse researches, offices and functions, it seems no exaggeration to attribute to Ketterl a leading and formative role in contemporary dentistry. He owed this status not only to his professional and professional-political qualities, but also to his appearance: He had a great presence, to which above all his strong and sonorous voice contributed ("This voice of his will still be remembered by many, a Bavarian bass who could often enough do without microphones" [30]). In addition, he was considered strong in opinion and decision-making. Against this background, his academic student Detlef Heidemann called him a "man who could get to the heart of a matter, who could also force decisions, always well prepared" [30].

Ketterl's standing in science and professional politics is also reflected in the honours he has received, especially since the 1980s: in 1980 he was awarded the Gold Badge of Honour of the German Dental Association and in 1982 the Badge of Honour of the DGZMK. In 1987 he received the Otto Loos Medal of the "Zahnärztlicher Verein zu Frankfurt am Main" (Frankfurt Dental Association). In 1990, the DGP appointed him an honorary member, in 1993 the DGZMK and in 1996 the "Deutsche Gesellschaft für Zahnerhaltung" (German Society for Tooth Preservation, DGZ) awarded him the same distinction. In 1992, he was awarded the "Bundesverdienstkreuz I. Klasse" (Federal Cross of Merit I. Class) being followed by an honorary membership of the Humboldt University of Berlin (1993). International awards included honorary membership in the "Società Italiana di Odontostomatologia" (1976), membership in the "Pierre Fauchard Academy" awarded in 1977, honorary membership in the "Österreichische Gesellschaft für Zahn-, Mund- und Kieferheilkunde" (Austrian Society for Dental and Oral Medicine, ÖGZMK) (1982), the medal of the "Tokyo Dental College" (1983) and the Fellowship of the "Academy of Dentistry International" (1985) [60].

Last but not least, Ketterl was exceptionally successful as a teacher and mentor: his academic students included the later full professors Friedrich Lampert (*1945), Detlef Heidemann (*1948), Claus-Walter Löst (*1948) and Werner Geurtsen (*1952). Ansgar Fesseler (*1933), Leo Kremers (1938–2018), the periodontist Lavinia Flores de Jacobi (*1944), the implantologist Karl-Ludwig Ackermann (1952–2020) and the endodontist Michael A. Baumann (*1962) were also among his assistants [60].

3. Werner Ketterl and his relationship to National Socialism

Ketterl had already joined the "Deutsches Jungvolk" (German Young People, DJ) at the age of 12, in March 1937 – an organisation within the Hitler Youth (HJ) that served the purpose of introducing young people to National Socialist ideology. Ketterl advanced there to the rank of "Fähnleinführer", which belonged to the "higher" ranks, recognised by the fact that they wore the rank insignia on their epaulettes. When Ketterl joined, involvement in the DJ was still optional; however, since young people's interest in this organisation had noticeably waned since the mid-1930s, compulsory membership in the DJ was established on March 25, 1939 [75].

More revealing than the involvement in the HJ is the fact that Ketterl applied for membership in the NSDAP in the month of his 18th birthday. He was admitted barely 3 months later (application January 22, 1943; admission April 20, 1943; party no. 9,531,925) [6]. Party admission was bound to the explicit application of the person concerned – even if after 1945 some former members made the protective claim in the denazification proceedings that they had been "automatically" transferred to the party [4], e.g. Eugen Fröhlich [25]. De facto, admission to the party without any action on one's part was ruled out in order to ensure that only ideologically convinced persons were admitted. This corresponds with the fact that the party repeatedly imposed admission bans to keep political opportunists out of the NSDAP – for example from May 1933 to May 1937 [4].

Due to his NSDAP membership, Ketterl had to undergo denazification proceedings after the end of the Third Reich. In these proceedings, it was common practice for those affected to present character references – soon popularly called "Persilscheine" (after the detergent "Persil") – in order to clear themselves of the accusation of a political burden [16]. In Ketterl's case, the references were intended to refute the accusation that he had been a full-time HJ leader and to document that his involvement in a Nazi youth organisation was mainly sporting and not politically motivated. He also tried to emphasise that the party membership was "purely nominal". Accordingly, the certificates stated that Ketterl's involvement "could by no means be counted as full-time HJ leadership activity" and that he had primarily sought physical challenges in the activities [75]. However, one of the written attestations also revealed that Ketterl had made a habit of appearing in Jungvolk uniform: "De-

spite wearing the Jungvolk uniform, he was never a Hail[sic] Hitler greeter or shouter". However, it was not claimed that Ketterl had become a party member involuntarily or "automatically"; this assertion would have been particularly implausible with an entry age of 18 [75].

Ketterl also had to assess himself in the proceedings: In his questionnaire on April 24, 1946, he remarkably did not classify himself as unencumbered, but as a political "follower" [Fig. 4, 75]. However, he ultimately fell under the "Youth Amnesty" enacted by the Bavarian special minister Anton Pfeiffer (CSU, 1888–1957) in the summer of 1946: it decreed a blanket exemption from punishment for those "who were born after January 1, 1919" and had not committed Nazi crimes [34]. The denazification procedures became more and more of a farce: In the American occupation zone in particular, a number of exemptions from punishment were decided upon, as the denazification procedures took far longer than originally thought: therefore, the next step was a "Christmas amnesty" at the end of 1946, which spared people with physical disabilities and financially weak persons further proceedings. Then, in mid-1947, amnesties were also issued for assumed "followers" with low incomes and, in the spring of 1948, an amnesty for (late) returnees from the war. Despite the "Youth Amnesty", the proceedings against Ketterl were not officially concluded until January 27, 1948 [75].

When assessing NSDAP membership, it is necessary to evaluate the – individually different – backgrounds [16, 18, 23]. In the case of Ketterl, 2 aspects are important: firstly, he was very young when he applied for membership. In this respect, it is reasonable to assume in his favour that he may not yet have been able to fully grasp the implications of such a party-political commitment. Secondly, the respective life situation must be taken into account: While many university professors after 1945 claimed that they had only joined the party in order to preserve their own chances of habilitation or appointment or to avoid falling behind their politically loyal competitors [19, 79], this argument did not apply to Ketterl, who was only born in 1925: as a high school graduate, he was by no means in a phase of life in which party membership would have been relevant to his career strategy. In other words, in his case there were no external constraints for joining the party.

One should not overestimate the early party-political commitment to National Socialism of the high school graduate Ketterl. However, the way in which the now 75-year-old university lecturer dealt with this biographical fact in his memoirs in 2000 is surprising:

Ketterl gave National Socialism and the Third Reich a lot of space in his autobiography – without needing to – but left his own party-political past completely unmentioned. Instead, with great pathos and moralising words, he placed himself above the many supporters of Nazi ideology: "Not even the 'Reichskristallnacht', which was experienced quite consciously, showed the people at home, but also abroad, whose brainchild the new government was, and no one can claim that they knew nothing about it. […] The National Socialist press spoke openly of the extermination of the Jews. Concentration camps came into being […]" [60].

He also expressed incomprehension that the German population showed no real counter-reaction to the announcement of total war: "That almost has something to do with hypnosis. And that too at a time when actually every thinking person knew that the war was lost" [60]. He described himself in the memoirs – in deliberate contrast to the National Socialists he sketched – as a convinced "pacifist": "War, that means for me the legalisation of the killing of other people […] So I am a pacifist. War [–] is a crime" [60].

Said statements – the indignation over the "Reich Pogrom Night" (commonly: "Reichskristallnacht" or "Night of broken glass"), the self-description as a pacifist and opponent of war, and the sharp condemnation of the increasingly escalating war rhetoric of the Nazi press – must also be surprising because Ketterl joined the party just in the spring of 1943: i.e. at a time when the consequences of the Reich Pogrom Night and the subsequent persecution of Jews had long been visible, the war had already cost millions of lives and, moreover, had been declared a "war of extermination" or "total war" by the Nazis.

It remains unclear why Ketterl, as a former NSDAP member, decided to make a moral assessment of the Third Reich in his memoirs at all. Hermann Euler (1878–1961), for example, had largely left the subject out of his autobiography [28]. Another possibility would have been to speak in the first person ("We, the people in the Reich") instead of the third person ("the people in the Reich") in order to assert less distance from the population. In any case, it can be ruled out that Ketterl had no memory of his own political past: After all, he was involved with National Socialism in one way or another for more than 10 years of his life – beginning with his entry into the DJ or HJ (1937–1942), through the years of party membership (1943–1945) to the conclusion of his trial before the Spruchkammer (1948). Another argument against memory gaps is that Ketterl describes his life in great detail in the memoirs and often gives impressively precise chronological details. Against this background, it can be assumed that Ketterl consciously used the autobiography to construct a different self-image for the Nazi period.

Conclusions

The available sources provide evidence in various respects of Werner Ketterl's special position in contemporary German dentistry. It should also be emphasised that Ketterl presents his own scientific and professional-political achievements in his autobiography in a factually correct manner. In this respect, the picture that the primary and secondary sources paint of the university lecturer and professional politician Werner Ketterl is congruent with the self-image in his memoirs.

It should also be noted that Ketterl understood dentistry as a unity of science and professional politics. With this symbiotic approach, he sought and found far-reaching opportunities for shaping and influencing – both in scientific professional

organisations and in professional-political committees and functions. Thus, he not only had an impact within the scientific community, but also shaped the public perception of dentistry like hardly any other university teacher of his time.

The situation is different with Ketterl's role in the Third Reich: there, Ketterl's autobiographical statements and the documented facts cannot be reconciled: In his memoirs, Ketterl not only conceals his own membership in the Nazi party, but also elevates himself morally above the supporters of National Socialism and the (in his eyes largely ignorant) German population with his statements. His autobiography thus offers an impressive example of how the construction of the autobiographical self and historical reality can diverge, especially when describing delicate life situations. This also shows the limited epistemic significance of autobiographical texts [28].

Against this background, the message Ketterl addressed to the readers of his autobiography takes on a second meaning. He stated: "Perhaps one can learn something for one's own life from my life, from my mistakes and successes, from my experience. That is the only justification for publishing memoirs […]" [60].

Conflicts of interest

The author declares that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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