Clinical Behavior of Zirconia-Based Fixed Partial Dentures Made of DC-Zirkon: 3-Year Results

Joachim Tinschert, Prof Dr Med Dent[a]/Karen A. Schulze, Dr Med Dent[b]/Gerd Natt, MDT[c]/
Peter Latzke, DDS[d]/Nicole Heussen, Dr Rer Stat[e]/Hubertus Spiekermann, Prof Dr Med, Dr Med Dent[f]

Purpose: The aim of this prospective study was to evaluate the clinical performance of anterior and posterior fixed partial dentures (FPDs) with frameworks made using DC-Zirkon after a mean observation time of 3 years. ***Materials and Methods:*** Forty-six patients with 1 to 3 missing anterior or posterior teeth were included in this study. All abutment teeth were prepared for full crowns with a chamfer preparation of 0.6 to 0.8 mm. The zirconia frameworks were produced with the Precident DCS system and veneered with veneering porcelain (Vita D). A self-curing resin cement was used for the anterior FPDs and a conventional zinc oxide phosphate cement was used for the posterior FPDs. ***Results:*** Fifteen anterior FPDs and 50 posterior FPDs were recalled at least once a year after cementation. The mean observation period was 38 (± 18.0) months for the anterior FPDs and 37 (± 15.5) months for the posterior FPDs. Within the observation time, no remakes were necessary, but in 4 cases a small chipping of the veneering material occurred in the posterior region. Two FPDs were recemented after decementation, and 3 teeth needed endodontic treatment. No negative influences at the gingival margin were observed. ***Conclusions:*** Within the mean observation time of 3 years, zirconia-based FPDs demonstrated a sufficient success rate under clinical conditions. However, special attention should be paid to designing the zirconia framework to ensure a sufficient veneering layer thickness with a range between 1 to 2 mm. *Int J Prosthodont 2008;21:217–222.*

Clinical studies of all-ceramic fixed partial dentures (FPDs) have shown limited success using conventional glass-ceramic or feldspathic porcelain as a result of high failure rates.[1,2] The glass-infiltrated aluminum oxide ceramic In-Ceram Alumina (Vita Zahnfabrik) was one of the first ceramics recommended by the manufacturer for short-span anterior FPDs. Follow-up studies of In-Ceram Alumina FPDs have not always been in agreement. Some studies indicated higher fracture risks, while others showed a high success rate within the observation period.[3–7] In-Ceram FPDs have also been tested in the molar region, which is against the manufacturer's recommendations. In a large clinical study using 40 In-Ceram FPDs in the molar region, a fracture rate of 35% after 3 years was observed. This high failure rate did not suggest the use of all-ceramic FDPs in general dental practice.[6] In a recent study by Olsson et al,[8] success rates of 93% and 83% after 5 and 10 years, respectively, were reported. As a result of the increased fracture strength of the new zirconia-reinforced In-Ceram ceramic, FPDs made of this material may have even higher survival rates.[9]

As alternatives to In-Ceram ceramics, lithia disilicate–reinforced ceramics such as IPS Empress 2 (Ivoclar Vivadent) or Optec OPC 3G (Generic & Pentron) are available. The manufacturers recommend these ceramics for anterior and premolar regions only. Clinical studies with IPS Empress 2 FPDs have emphasized that only by following the manufacturers' instructions with regard to appropriate ceramic reinforcement can fractures of the framework and veneering material be

[a]*Associate Professor, Department of Prosthodontics, Aachen University, Germany.*
[b]*Associate Professor, Department of Restorative Dentistry, University of the Pacific Arthur A. Dugoni School of Dentistry, San Francisco, California.*
[c]*Köln, Germany.*
[d]*Assistant Professor, Department of Prosthodontics, Aachen University, Germany.*
[e]*Institute for Statistics in Medicine, Aachen University, Germany.*
[f]*Professor and Chair, Department of Prosthodontics, Aachen University, Germany.*

Correspondence to: *Prof Dr Joachim Tinschert, Department of Prosthodontics, RWTH Aachen University, Pauwelsstr 30, 52074 Aachen, Germany. Fax: 49 (0)241 80 82410. E-mail: jtinschert@online.de*

prevented.[10–12] FPDs made of Procera-AllCeram (Nobel Biocare) using a densely sintered aluminum oxide are another alternative to all-ceramic FPDs. However, because of a lack of controlled studies, the clinical behavior of this material is difficult to assess.[13]

Compared to previously used ceramics, it seems possible to improve the fracture strength of all-ceramic FPDs when using frameworks made of zirconia ceramics such as DC-Zirkon (DCS Dental). Like other zirconia ceramics used in dentistry, DC-Zirkon is characterized by exceptionally high strength properties, which are based on the "phase transformation effect," ie, the tension-induced tetragonal-to-monoclinical phase transformation of metastasizable zirconium oxide particles.[14] In contrast to conventional dental-ceramics, the polycrystalline material DC-Zirkon contains almost no glass. In addition, the densely sintered DC-Zirkon ceramic blanks are compressed in a hot isostatic pressing process to improve the ceramic's resistance to microcrack growth and thus its long-term behavior. Because of the strength properties of zirconia ceramics, the load-bearing capacity on 3- or multiunit FPDs investigated in several in vitro studies resulted in exceptionally high fracture values.[15,16] However, those restorations must be tested clinically before a general recommendation can be given to the practitioner. The aim of this study was to determine the clinical behavior and success rate of anterior and posterior FPDs made of DC-Zirkon in a prospective study.

Materials and Methods

Patient Selection

The present study was performed in agreement with the local research ethics committee. A total of 46 patients (27 women, 19 men) between 20 and 58 years of age received at least 1 FPD in the posterior or anterior region. Before treatment, all patients were informed about the aims of the study, clinical procedures, and material to be used, including the advantages and risks of all-ceramic restorations. Each patient who wanted to be provided with an all-ceramic restoration also agreed to follow-up appointments for evaluation purposes.

The following inclusion criteria were used for the selection of the participants: 1 to 3 anterior or posterior teeth missing, periodontally healthy abutment with no signs of bone resorption or periapical pathology, and balanced occlusal forces with no missing antagonistic teeth. The opposing occlusal surface of the antagonistic teeth consisted mainly of enamel (35%) and ceramic (27%), along with composite (14%), amalgam (14%), metal (9%), and other filling materials (1%). Additionally, in 1 case an anterior FPD replacing 5 teeth was also included in this study.

The exclusion criteria were as follows: unacceptable oral hygiene, teeth with wide pulp chambers, and deep bites. To minimize the risk of fracture or chipping of ceramic material or decementation of the restorations, patients with bruxism, highly parafunctional activities, and reduced crown length were also excluded.

Following the clinical and radiographic examinations, all patients underwent comprehensive dental care including a regular checkup after the incorporation of the finished restoration. The treatment was performed at the Department of Prosthodontics of Aachen University. Two experienced clinicians treated all patients, except for 6 FPDs that were made by students.

Clinical Approach

All abutment teeth were prepared with a 0.6 to 0.8 mm chamfer preparation. The occlusal reduction was between 1.5 to 2.0 mm to ensure sufficient room for the veneering porcelain surrounding the zirconia framework. A 12- to 15-degree angle of convergence was used for the preparation, and all sharp edges were rounded and smoothed.

Thirty-five percent of cases required no restoration other than the full-coverage restoration. For the majority of abutments (65%), core buildups were created using composite, phosphate cement, and glass-ionomer cement materials. Of 26 endodontically treated abutments, 13 teeth received a cast post and core, 7 received a prefabricated post and core made of titanium, 3 received a prefabricated post and core made of zirconia, and the remaining teeth were provided only with core buildups.

Laboratory Techniques

All FPD frameworks were fabricated in a dental lab by 2 dental technicians using the Precident DCS system (DCS Dental). The frameworks were assembled from hot isostatic pressed DC-Zirkon that was meta-reinforced in the tetragonal phase and contained 5% by weight yttrium oxide. The abutments had a uniform wall thickness of 0.6 mm. The goal was to construct a cross-section area at the connection location between the abutment and pontic of 16 mm^2 (4×4 mm). All FPD frameworks were veneered following the manufacturer's instructions using Vita D veneering ceramic (Vita Zahnfabrik). Prior to the veneering process, the cross-section areas of the connectors were determined.

FPD Placement

Prior to the final cementation, all FPDs were temporarily cemented for 1 to 2 weeks using Provicol (Voco). For the final cementation in the molar region, Harvard

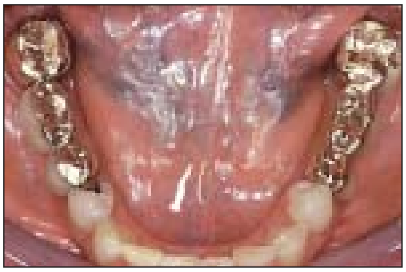

Fig 1a Preoperative occlusal view of 2 posterior FPDs veneered with composite in the mandible.

Fig 1b Try-in of a 3- and 4-unit framework made of DC-Zirkon replacing the mandibular first molars.

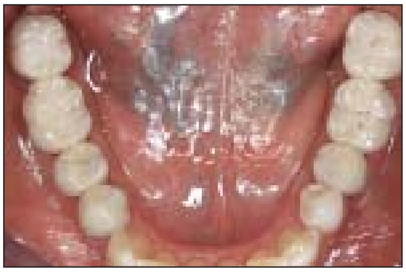

Fig 1c Veneered all-ceramic posterior FPDs after cementation with Harvard cement.

Cement (Harvard Dental) was used, while Panavia 21 (Kuraray) served as the bonding material for the anterior FPDs.

Follow-up Examinations

After final cementation, the patients were examined at least once a year to assess framework fractures, loss of veneering material, secondary caries, decementation, and vitality of the teeth. The periodontal situation was determined checking the Plaque Index (PI), Gingiva Index (GI), Papilla Bleeding Index (PBI), and the pocket depth of all abutment teeth and selected control teeth.[17,18] All control teeth had to be caries free, uncrowned, and contralateral or opposite from the abutment teeth. In addition, the esthetic appearance of the incorporated FPDs was evaluated by asking the patients whether they liked the esthetic outcome of their restorations using a scale system from 1 (very good) to 5 (not satisfied). A single clinician performed all of the patient evaluations.

Statistical Analysis

The longevity of the restorations was determined by the last follow-up appointment or at an earlier time in case of a failure. In the latter case, the longevity is the duration time starting at the day of cementation of the FPD to the day where failure was noted. A criterion for an absolute failure was fracture of the FPD framework, because a new restoration had to be made. All other events where the FPD could remain in the patient's mouth were considered as relative failures.

The longevity of the restorations was analyzed calculating the mean and standard deviation. All parameters concerning the periodontal situation were described with a score system of 0 to 3 (PI, GI) or 0 to 4 (PBI), and the frequency of each score was established. The pocket depth was measured in mm (1 to 4 mm). The Bowker-test analysis was applied to the data for comparisons of the results between restorations and between restorations and control teeth. The statistical analysis included only those restorations and control teeth that were checked at least once a year during a 3-year period.

All tests were performed at a 5% significance level. The univariant tests resulted in a P value. Because of the explorational character of the study, no adjustment of the significance level was included in the analysis. Hence, a P value of .05 was an indication for a statistically significant result. For statistical analysis, the SAS 8.2 program (SAS Institute) was used.

Results

A total of 46 patients received 65 FPDs (3 or more units). Fifteen FPDs (14 patients) were placed in anterior regions and 50 (34 patients) in posterior regions. One patient received 4 FPDs, 1 patient received 3 FPDs, 11 patients received 2 FPDs, and 21 patients received 1 FPD. The majority of restorations contained 3 or 4 units fitting on 2 abutments (Figs 1a to 1c). In addition, multiunit FPDs with more than 2 pontics and 2 FPDs with cantilevers at a size of 1 premolar were placed (Table 1). Regarding the framework design of the FPDs, a connector cross section of 16 mm^2 was desired for the connection location between the abutment and pontic. Because of the clinical conditions, only 57% of FPDs inserted in the posterior area and 39% of FPDs inserted in the anterior area reached this goal (Table 2).

During the observation period, 6 patients with 7 FPDs were lost to follow-up for different reasons: 5 patients moved away and 1 patient declined to participate further in the study. Therefore, a total of 58 FPDs could be recalled within the observation period. The mean observation time was 38 months ($\pm$ 18.0 months; maximum: 69 months) for anterior FPDs and 37 months ($\pm$ 15.5 months; maximum: 65 months) for posterior FPDs. During this time, no absolute failures (framework fracture) were observed (Table 3).

In 4 cases, veneering material fractured in the posterior region of FPDs, resulting in a relative failure rate of 6%. A renewal of the restoration was not necessary because the fracture areas could be polished without

Table 1 No. and Location of Abutment Crowns and Pontics of the Anterior and Posterior FPDs

	No. of pontics 1	2	3	5
Anterior FPDs				
3-unit ●❍●	10	–	–	–
4-unit ●❍●●	1	–	–	–
6-unit ●●❍❍●●	–	2	–	–
7-unit ●●❍❍❍●●	–	–	1	–
10-unit ●❍●❍❍❍❍●●●	–	–	–	1
Total	11	2	1	1
Posterior FPDs				
3-unit ●❍●	24	–	–	–
With cantilever ●●❍	1	–	–	–
4-unit ●❍●●	7	–	–	–
●❍❍●	–	6	–	–
With cantilever ●❍●❍	–	1	–	–
5-unit ●❍●❍●	–	2	–	–
●❍❍●●	–	6	–	–
●❍❍❍●	–	–	2	–
6-unit ●❍❍❍●●	–	–	1	–
Total	32	15	3	–

● = Abutment tooth; ❍ = pontic

Table 2 Average Height and Width of the Connector Areas Before Veneering of the Frameworks

	Connector height (mm)	Connector width (mm)
Anterior FPDs	5.0 ± 0.9	3.2 ± 0.6
Posterior FPDs	4.0 ± 0.5	4.1 ± 0.4

Table 3 No. of Relative Failures Within the Observation Period*

Relative failure	Anterior FPDs	Posterior FPDs	Time of failure
Fracture of veneering material	0	4	11, 12, 13, and 16 mo
Loss of vitality	0	3	15, 23, and 23 mo
Decementation	0	2	17 and 32 mo
Secondary caries	0	0	–

*No absolute failures were observed.

Table 4a Results (*P* values) of the Bowker Test Comparing the Values Between the 1-Year (R1) and 3-Year (R3) Examinations for Abutment Teeth (n = 46) and Control Teeth (n = 31)

	R1 vs R3
Abutment teeth	
Plaque Index	.7530
Gingiva Index	.0578
Papilla Bleeding Index	.7744
Vestibular pocket depth	.1116
Lingual pocket depth	.5062
Control teeth	
Plaque Index	.8335
Gingiva Index	.7744
Papilla Bleeding Index	.8013
Vestibular pocket depth	.6444
Lingual pocket depth	.9659

Table 4b Results (*P* values) of the Bowker Test Comparing the Values Between Abutment and Control Teeth at the 1-Year (R1) and 3-Year (R3) Examinations*

	R1 (n = 32)	R3 (n = 31)
Plaque Index	.1218	.1386
Gingiva Index	.4795	.6444
Papilla Bleeding Index	.4142	.8013
Vestibular pocket depth	.4795	.2615
Lingual pocket depth	.9002	.7974

*One of the 32 control teeth was covered by a crown restoration in the third year.

esthetically compromising the appearance of the FPDs. Fractures of veneering materials occurred only on abutments in the mandible. The connector area between abutment and pontic was always affected in those cases, resulting in partial exposure of the zirconia framework.

Three of 130 abutments (2%) required endodontic treatment. Two 3-unit FPDs in the molar region needed recementation because 1 abutment tooth of each FPD decemented. For removal of the second abutment, the CORONAflex system (KaVo) was used. The cause for this friction loss was assumed to be deficiency in cementation or resistance form. No caries was found at any follow-up appointments within the observation time.

Although 58 FPDs were recalled during the observation time, the statistical analysis of the periodontal parameters was carried out for only 19 FPDs, because these restorations were checked at exact 1-year intervals (± 2 weeks) during observation. A comparison of the periodontal parameters at the first and third year of observation showed no statistically significant differences (Bowker-Test) between the abutment and control teeth as well as within the groups of the abutment and control teeth (Tables 4a and 4b). The majority of all measured pocket depths were 1 to 2 mm; values were rarely above 2 mm. A tendency for higher pocket depths for abutment teeth compared to control teeth was found.

The analysis of the esthetic appearance showed that most of the patients gave scores of 1 (68%) or 2 (23%). None of the patients gave a score of 5, while scores 3 (6%) and 4 (3%) were given in few cases.

Discussion

The results of this study support the assumption that all-ceramic FPDs with a DC-Zirkon framework exhibit a sufficient success rate in both anterior and posterior regions of the mouth. No absolute failures (fracture of

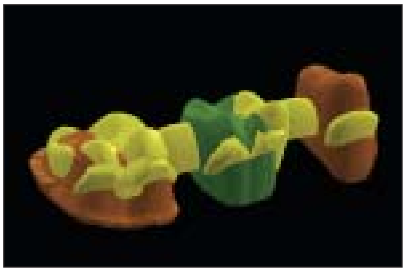

Fig 2a Framework of a mandibular FPD. On the buccal and lingual sides of the framework, additional parts of core material (yellow) were added to support the veneering porcelain.

Fig 2b Modified framework made of DC-Zirkon, with additional parts of core material on the buccal and lingual sides to support the veneering porcelain.

Fig 2c Modified framework made of DC-Zirkon, with additional parts of core material on the buccal side to support the veneering porcelain.

zirconia framework) were observed for any FPDs. The number of FPDs with more than 4 units as well as the number of cantilever FPDs was too small to establish a definitive conclusion.[19] Experimental fracture tests of more than 4-unit FPDs suggest that they will perform very well in clinical applications.[15] The promising clinical results for DC-Zirkon FPDs reported in this study are in agreement with other clinical studies with short-term observation times of 1 year[20,21] and medium-term observation times of up to 3 years.[22–24] All of those studies reported no fractures of zirconia frameworks.

In the present study, the suggested FPD design with a connector cross-section area of 16 mm^2 was hard to fulfill, as a high percentage of the frameworks could not reach this guideline. However, with regard to the material properties and preliminary clinical results, it seems possible to use small FPDs, ie, 3- and 4-unit FPDs, with a reduced connector design of 9 to 12 mm^2 according to the recommendations of recent studies.[23,25] Of course, this suggestion cannot be confirmed for multiunit FPDs because of the lack of clinical experience. Therefore, FPDs with 3 pontics and especially the 10-unit FPD of the present study must be considered as a very risky restoration even for an FPD made of metal-ceramic.

Although no absolute failures were found, the relative failures must be analyzed. The most common relative failures were fractures in the veneering materials in the posterior region. According to other studies,[22–24] veneer fractures occurred after 2 to 3 years in 3% to 15% of cases. Those results are comparable to commonly used porcelain-fused-to-metal restorations, which indicate a loss of veneering material of 5% to 8% after 5 years.[26] One possible explanation for the loss of veneering material may be the missing support of veneering layers because of the zirconia framework. A large amount of veneering material is especially inappropriate for small zirconia frameworks. For future designs, it is important to construct the zirconia frameworks more similarly to the tooth anatomy to enlarge the surface area. This better distributes the applied force and assures an even thickness of veneering material. The latter requirements can be achieved using special software of the DCS system that constructs an individual design for the framework (Figs 2a to 2c). Another reason for loss of veneering material could be that during sandblasting of the zirconia surface with aluminum oxide prior to the veneering process, an alteration occurs of the crystal structures of the zirconia surface. The same alteration can occur during application of the first opaque or bonding layer when the veneering process begins in the lab. This effect can cause a change of the temperature expansion coefficients.[27] Additionally, unfavorable shear forces between the zirconia framework and veneering material can influence the long-term connection of these materials. The fracture of veneering materials was only observed in the mandibular molar region. It is well known that the mandible has a higher flexibility compared to the maxilla. The veneering procedure should always be carried out according to the manufacturer's instructions with a veneering material that is adjusted to the temperature expansion coefficients of the zirconia framework.[28]

The chamfer preparation of 0.6 to 0.8 mm for the abutment teeth in this study has been a practically approved method. The present study showed no absolute failures, which indicates that the chamfer preparation is sufficient for zirconia-based restorations. Furthermore, the clinical results confirm that a wall thickness of 0.6 mm is sufficient for abutment crowns of FPDs, especially in posterior regions. There is almost no difference when preparing a crown for a metal-ceramic or zirconia-based FPD.

Regarding the cementation procedure, a conventional cementation technique with Harvard Cement was used for the final cementation of the posterior FPDs. Because of the high requirements for a sufficient adhesive cementation technique (including complete isolation of the operating field), a conventional cementation procedure was preferred in the posterior area, whereas anterior FPDs were bonded with Panavia 21. Except for the decementation of 2 abutment crowns, no disadvantage was observed for the conventionally cemented restorations. Also, temperature sensitivity after placement of the anterior or posterior FPDs was not reported. This may be the result of good isolation properties of ceramics in general.

No significant differences were found between abutment teeth and control teeth regarding periodontal health. This indicates no adverse reactions to all-ceramic crowns of the surrounding marginal periodontal tissue. In summary, regarding periodontal evaluation, this study is in agreement with other studies of Dicor and IPS Empress restorations, which reported no differences between crowns and control teeth.[29–31]

Finally, the overall positive evaluation from the patients with respect to the esthetic appearance of the FPDs is evidence of a high satisfaction with and acceptance of this type of restoration.

Conclusions

Considering the mean observation time of 3 years, all-ceramic FPDs seem to exhibit promising properties as restorations for posterior and anterior regions. No increased fracture probability compared to metal-ceramic FPDs was observed, and good soft tissue compatibility and patient satisfaction with esthetics were also evident. Compared to metal-ceramic FPDs, the DC-Zirkon FPDs do not require a special crown preparation or cementation technique, but further studies are necessary to obtain data for FPDs with more than 4 units and to determine the influence of the design of the zirconia frameworks.

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