Zirconia Posterior Fixed Partial Dentures: A Prospective Clinical 3-year Follow-up

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Purpose: The aim of this prospective clinical trial was to evaluate the reliability of three- and four-unit posterior fixed partial dentures (FPDs) with zirconia frameworks after 3 years of clinical function. ***Materials and Methods:*** Thirty patients, each needing a posterior FPD to restore one or two missing teeth, were included in the study. Preparation guidelines were: occlusal reduction of 1.5 to 2 mm, axial reduction of 1.5 mm, and circumferential chamfer preparation placed 0.5 mm subgingivally. Frameworks were fabricated using a computer-aided design/computer-assisted manufacture technique. All FPDs were cemented with glass-ionomer cement. At baseline and 12, 24, and 36 months after cementation, survival and success of the zirconia framework and the ceramic veneer were evaluated. To analyze the effect of placement of an all-ceramic restoration on the gingival tissue, Gingival Index, Plaque Index, sulcus bleeding index, and pocket depth at abutment (test) and contralateral analogous teeth (control) were assessed. Data were analyzed by descriptive statistics, the Wilcoxon test, and the McNemar test. ***Results:*** Of the 30 initial subjects, 27 patients with 27 zirconia FPDs were examined after a mean testing period of 34.2 months. All FPDs were still in use and unfractured, resulting in a 100% survival rate for the frameworks. One FPD exhibited a major chip after 36 months. The cumulative success rate was 96.3%. No significant differences between the periodontal parameters of the test and control teeth were observed. The Plaque Index revealed significantly higher scores for mesial and distal control teeth at baseline and after 12 and 24 months for distal control teeth. ***Conclusion:*** Posterior zirconia-based three- and four-unit FPDs present a reliable treatment modality after medium-term clinical use. *Int J Prosthodont 2009;22:597–603.*

In recent years, clinicians and their patients have shown interest in tooth-colored and metal-free fixed partial dentures (FPDs) for restoring teeth and replacing older FPDs. The rising demand for all-ceramic restorations may be attributed to their high biocompatibility and enhanced esthetics.[1] Nevertheless, stability and longevity are necessary for clinical success. Frameworks fabricated from presintered oxide ceramics were introduced to dentistry with the evolution of computer-aided design/computer-assisted manufacture (CAD/CAM) milling technology. Such industrially manufactured ceramic frameworks provide alternatives to metal-based restorations. They are strong, structurally reliable, and provide an acceptable fit in clinical practice.[2–5]

Conventional metal frameworks veneered with tooth-colored ceramics are regarded as the gold standard for posterior FPDs because of their low failure rate (8% to 10% after 10 years).[6,7] All-ceramic FPDs are complicated by fractures of the ceramic framework and notable chipping of the ceramic veneer.[8,9] Lithium disilicate glass-ceramics and aluminum-oxide ceramics are the preferred materials for FPDs and single crowns in the anterior region due to their excellent esthetic properties.[10,11] However, for replacing teeth in the

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stress-bearing posterior regions, zirconium dioxide–based ceramics are chosen for their favorable mechanical properties.[12,13]

The one major drawback of the zirconia framework is the increased porcelain chipping rate.[9,14–16] Fracture of a high-strength ceramic framework is rare.[9] After 2 years of service, minor chipping fractures were reported by Vult von Steyern in 15% of patients.[16] These defects were never noticed by the patients. Raigrodski et al[14] reported minor chipping of the veneering material after 3 years in 25% of three-unit posterior FPDs, primarily on the second molar retainer. They reported no delamination of the porcelain veneer and no fractures through the framework.[14] After the same examination period, Sailer et al[15] reported a clinical trial in which chipping of the ceramic veneer occurred in 13% of restorations and the framework had a 100% success rate. In the same study group after 5 years, the chipping rate increased to 15.2%, and one five-unit framework broke following external trauma.[9] In a meta-analysis of all-ceramic compared to metal-ceramic FPDs after 5 years, Sailer et al[17] calculated a fracture rate of 6.5% for the all-ceramic framework, a fracture rate of 13.6 % for the all-ceramic veneering material, a fracture rate of 1.6% for the metal-ceramic framework, and a fracture rate of 2.9% for the metal-ceramic veneering material. Currently, a few studies are available that assess the clinical long-term behavior of all-ceramic short-span FPDs. However, for long-span high-strength zirconia frameworks, which have only recently become available, clinical data are rare.[9,17–19]

The aim of this study was to investigate the outcome of all-ceramic FDPs with zirconia frameworks made using the Lava system (3M ESPE) after an observation period of 3 years.

Materials and Methods

This prospective clinical investigation was conducted at the Dental Clinic 2–Prosthodontics, University Clinic Erlangen, Erlangen, Germany. The study was approved by the ethical committee of the University Erlangen. Subjects were randomly selected from the patient clientele who needed to replace missing teeth in the posterior region with conventional FPDs and did not consider implant therapy as an alternative. After clinical and radiographic examination, 30 patients (13 women, 17 men) between the ages of 27 and 75 years met the following inclusion criteria:

- A three- to four-unit posterior FPD.
- One or two missing teeth from the second premolar to the second molar replaced, with a total gap width not smaller than 12 mm and not greater than 19 mm.
- Only FPDs with end abutments.
- Abutment teeth were vital or endodontically treated with a sealed root filling to the apical region, and had to be without apical periodontitis for the past 6 months.
- Free of periodontal disease (probing depth ≤ 4 mm and no bleeding on probing, no sign of active bone resorption, no furcation involvement of grade 2 or 3, and no mobility).
- Over the age of 18 with no severe medical or psychologic diseases.
- Adequate occlusogingival height for an appropriate connector area of at least 9 mm^2.
- Moderate or good oral hygiene (< 25% marginal plaque, sulcus bleeding index < 70%) and no active caries lesions.

Patients suffering from a general health impairment that prohibited restorative treatment, severe occlusal wear, parafunctional activities, or those lacking oral hygiene were excluded. Participating patients signed an informed consent and acceded to recall appointments and data collection for at least 6 years.

Treatment was performed by two experienced clinicians. Oral hygiene instructions were given and cleaning was done before the reconstructive therapy. The color of the adjacent teeth was determined by the technician and the operator using the Vita classical color tray (Vita Zahnfabrik). Core buildups (Clearfil Core, Kuraray) or post-and-core placement (Cerapost, Brasseler) was performed using the adhesive technique (Panavia 21, Kuraray; ED Primer, Kuraray) and rubber dam. The preparation guidelines were: 1.0-mm light chamfer preparation with a rounded inner angle, a preparation line following the scalloped free gingival margin on sound tooth structure, an axial reduction of 1.5 mm with a taper ≥ 4 degrees, and an occlusal reduction of 1.5 to 2.0 mm. Provisional restorations were fabricated directly in the mouth with Protemp Garant (3M ESPE) and cemented using eugenol-free temporary cement (Freegenol, GC America).

After insertion of the retraction thread in the gingival sulcus (Ultrapak, Ultradent), an impression was made using polyvinyl siloxane (Silaplast/Silasoft, Detax). Master cast fabrication was performed with a dental stone (Fujirock, GC America).

The scanning process included the abutment teeth, the gingival part of the gap, and the interocclusal index. A software tool enabled the technician to create an individually shaped framework to grant a uniform thickness to the ceramic veneer. A convex-to-ovate pontic design was the aim. Frameworks were milled from presintered yttria-stabilized zirconium oxide blanks with a grain size of 0.5 µm. Before sintering, the frameworks were stained in a dye lot according to the selected primary color. After sintering, the frameworks

were evaluated intraorally for accuracy of fit. The margins were inspected using a dental probe. Only slight visual discrepancies of the margins were allowed, according to the California Dental Association (CDA) quality evaluation criteria.[20] A silicone disclosing agent (Silasoft) was used to control the internal framework fit. Adjustment was necessary on three frameworks. One framework did not fit and consequently, a new impression was made. Veneering was accomplished according to the manufacturer's recommendations by an experienced dental technician (Lava Ceram). The patient's existing occlusion pattern was transferred. Before glaze firing, the fit of the surface of the pontic and proximal contact points and the occlusion were adjusted intraorally if necessary.

All restorations were cemented with glass-ionomer cement (Ketac-Cem, 3M ESPE). Hygiene instructions were given at the time of insertion and a hygiene maintenance program was initiated. Occlusal contact points were examined in maximum intercuspation and lateral excursion. Enamel (42%) was the main opposing surface of the antagonistic teeth, followed by metal (23%), composite (14%), amalgam (12%), ceramic (8%), and one glass-ionomer cement filling (1%).

Two dentists who were not involved in the restorative treatment examined the patients at baseline (2 weeks after cementation) and at the 12-month, 24-month, and 36-month follow-ups for material and biologic failures. Each evaluator rated the restorations independently. In cases of disagreement, the worst rating was used. The technical parameters of surface, color, anatomical form, and marginal integrity were rated according to the CDA quality evaluation criteria. The distances between the gingival tissue and the restoration margins were recorded. Pulp vitality was tested at abutment and control teeth using carbon dioxide. To evaluate the effect of all-ceramic restoration placement on gingival tissue, Gingival Index, Plaque Index, sulcus bleeding index, and pocket depth at abutment (test) and contralateral analogous teeth (control) were assessed. Silicone impressions were taken for further examination. Photographs from the occlusal and lateral views were taken, with marked occlusal contact points. Patients filled out a questionnaire and rated their personal satisfaction with the restoration in a three-stage evaluation (very satisfied, dissatisfied with esthetics or function, dissatisfied).

Data analysis consisted of descriptive statistics and statistical tests at a 5% significance level. All *P* values were two-tailed. *P* values ≤ .05 were considered to be descriptive differences. The Wilcoxon test was used to compare and evaluate differences in subsequent measurements for the technical parameters. The McNemar test was used to evaluate trends in binary periodontal data based on the binomial distribution. Success rates were determined by the CDA criteria. Every three- or four-unit FDP was considered to be one statistical unit. The overall classification of each restoration as a success or failure was based on the worst single evaluation. The evaluation criteria and abbreviations Romeo and Sierra (R, S) were defined as successes; Tango and Victor (T, V) were defined as failures. Patients lost to follow-up were excluded.

Based on previous findings for zirconia restorations, the working hypothesis was that no framework fracture would be observed after medium-term service. Higher fracture rates of the ceramic veneer compared to metal-ceramic restorations are suggested by excellent properties of the gingival tissue.

Table 1 FPD Position in the Mouth, Number of Units, and Service Time at the Last Follow-up

	Location*			Service time	
FPD no.	Ma	Ca	Da	(mo)	Event
1	45	46	47	36	Loss of vitality
2	45	46	47	36	–
3	23	24, 25	26	36	–
4	35	36	37	36	–
5	15	16	17	36	Minor chipping
6	45	46	47	24	–
7	15	16	17	36	Minor chipping
8	25	26, 27	28	36	–
9	45	46	47	36	–
10	44	45, 46	47	36	–
11	14	15, 16	17	36	–
12	44	45, 46	47	36	–
13	45	46	47	36	–
14	34	35, 36	37	36	–
15	23	24, 25	26	36	–
16	35	36	37	36	–
17	25	26	27	36	–
18	25	26	27	36	–
19	15	16	17	36	–
20	45	46	47	36	–
21	25	26	27	36	–
22	35	36	37	36	–
23	25	26	27	24	–
24	35	36	37	36	–
25	35	36, 37	38	24	–
26	45	46	47	24	–
27	25	26	27	36	Major chipping

Ma = mesial abutment tooth; Ca = connecting abutment; Da = distal abutment tooth.
*FDI tooth-numbering system.

Results

From the initial 30 subjects, 27 patients (18 men, 9 women) with 27 FPDs were examined after a mean testing period of 34.2 months. The mean age of the patients was 52.2 years. Twenty-three patients were followed for 36 months and 4 for 24 months. Three of the original 30 treated persons were not available for recall visits. Eight four-unit FPDs and 19 three-unit FPDs

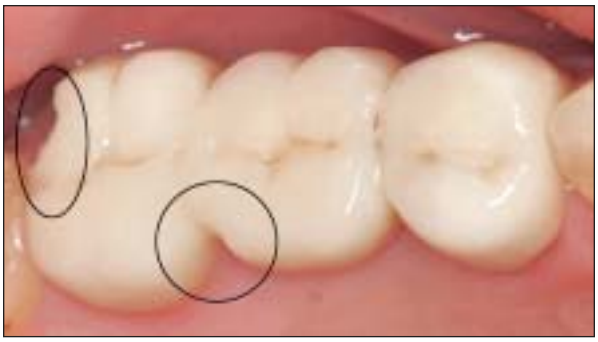

Fig 1 Major chipping of the ceramic veneer due to bruxism habit.

Table 2 Surface at Baseline and 12, 24, and 36 Months According to California Dental Association Criteria

Surface	Baseline (%)	12 mo (%)	24 mo (%)	36 mo (%)
Adequate				
Excellent (R)	19 (63)	12 (41)	13 (48)	14 (61)
Acceptable (S)	11 (37)	17 (59)	14 (52)	8 (35)
Insufficient				
Reparable (T)	0 (0)	0 (0)	0 (0)	1 (4)
Irreparable (V)	0 (0)	0 (0)	0 (0)	0 (0)
Total	30 (100)	29 (100)	27 (100)	23 (100)
P (comparison to baseline)		.098	.278	.361

Table 3 Color, Anatomical Form, and Margin Integrity at Baseline and 12, 24, and 36 Months According to Modified California Dental Association Criteria

	Color					Anatomy/function					Margin integrity				
	R (%)	S (%)	T (%)	V (%)	*P**	R (%)	S (%)	T (%)	V (%)	*P**	R (%)	S (%)	T (%)	V (%)	*P**
Baseline	77	23	0	0	–	97	3	0	0	–	100	0	0	0	–
12 mo	66	34	0	0	.234	100	0	0	0	–	100	0	0	0	–
24 mo	89	11	0	0	.349	100	0	0	0	–	93	7	0	0	1.000
36 mo	91	9	0	0	.191	100	0	0	0	–	91	9	0	0	1.000

*Comparison to baseline.

were inserted, with mean gap widths of 16.9 mm and 12.3 mm, respectively (Table 1). Twelve nonvital abutment teeth were endodontically treated, with 11 cores stabilized by posts. Forty-two abutment teeth were vital.

None of the FPDs had to be replaced due to framework fracture or unrestorable delamination of the ceramic veneer. Therefore, the survival rate was 100% after 34.2 months. In one case, major chipping of the ceramic veneer was recorded after 36 months, rated T according to the CDA criteria (Fig 1). A high success rate of the core and ceramic veneer under clinical function was observed (success rate: 96% after 34.2 months), with almost stable optimum rates and no significant differences compared to baseline (Table 2). A minor cohesive chip was located at one anterior and one posterior abutment. The major chips were located at the intermediate and the posterior abutment of the same FDP.

After 36 months, the marginal integrity at the abutment teeth was still ranked R in 91% of the restorations. In each of two FPDs, a discoloration on the margin was detected without evidence of caries or need for treatment. Most cases showed marginal integrity and there was no change over time (Table 3). No significant differences from baseline were detectable in the coloring of the restorations, and no impaired function was recorded after 36 months (Table 3). One abutment tooth became nonvital after 36 months because of irreversible pulpitis. It was treated endodontically through the retainer and the access cavity was restored with direct composite resin. The restoration was not disconnected and not rated V or T. There were no significant changes in gingival margin of the abutment teeth to the location of the restoration margin from baseline ($.173 \leq P \leq .951$). After 36 months, 57% of the restoration margins were isogingival, 22% were subgingival, and 21% were supragingival.

Probing depths were in the range of 2.5 to 4.0 mm. Significant differences between test and control teeth were not noted, nor did the depths tend to increase in deviation from baseline over time ($.073 \leq P \leq .866$).

With respect to sulcus bleeding index and Gingival Index, again, there were no significant differences between test and reference teeth ($.345 \leq P \leq .000$). There was no significant change over time ($.065 \leq P \leq .000$).

The Plaque Index, however, showed significant differences in the abutment teeth compared to references at baseline examination (Table 4). Plaque scores were frequently in the optimum region at P1 and P2, while reference scores (R1 and R2) were much less often optimal. The distal control tooth showed significantly more plaque after 12 and 24 months. Significant changes in comparison to baseline were rare, and were only found for reference value R1 after 12 months ($P = .035$). All patients were satisfied with their restorations and reported that they would reelect to undergo the same prosthetic approach again.

Table 4 Plaque Index (PI) at Baseline and 12, 24, and 36 Months

	Baseline				12 mo				24 mo				36 mo			
PI	P1	R1	P2	R2	P1	R1	P2	R2	P1	R1	P2	R2	P1	R1	P2	R2
0	24	12	24	11	26	21	24	18	20	16	20	11	16	13	15	13
1	6	13	6	13	3	5	5	4	5	8	5	13	6	8	7	6
2	0	5	0	6	0	3	0	7	2	3	2	3	1	2	1	4
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	30	30	30	30	29	29	29	29	27	27	27	27	23	23	23	23
P (P vs R)	< .001		< .001		.086		.027		.133		.013		.212		.330	

0 = no visible plaque; 1 = thin plaque film detectable by dental probe; 2 = continuous plaque at gingival margin; 3 = large quantity of plaque at gingival margin and interdental.

Discussion

After a mean testing period of 34.2 months, the survival rate of posterior three- and four-unit FPDs was 100%. No restorations had to be replaced due to framework fractures, as asserted in the working hypothesis. These results accord with other authors, and emphasize the success of zirconia core material for all-ceramic reconstructions replacing molars and premolars.[9,14,16,19,21]

After 36 months in this study, a major chip of the ceramic veneer took place in one restoration (rated T). With the patient's consent, the chipped area was polished and the restoration remained in situ for further examination. Minor cohesive fractures occurred in two restorations. Delamination of the veneering porcelain with exposure of the framework material was not detected. The success rate, according to the CDA criteria, was 96%. Consequently, the overall chipping rate was 11%, far beyond the evaluated veneer fracture rate of 2.9% after 5 years for metal-ceramic restorations.[17] Vult von Steyern et al[16] reported comparable results after a service time of 2 years, with 15% minor chipping fractures. Sailer et al[15] noted a 13% chipping rate after the same observation period. All restorations affected by chipping exhibited a cohesive ceramic failure at the second molar retainer, in accord with the findings of Raigrodski et al.[14]

No significant differences between test and control teeth were found in the periodontal parameters, probing depth, Gingival Index, and sulcus bleeding index. Previously published studies on FPDs with zirconia frameworks arrived at the same conclusion.[9,16,22] Higher plaque indices for the control teeth compared to the abutment teeth are notable. The difference at the distal abutment was significant at baseline examination and at the 12- and 24-month recalls. A lower plaque adhesion to the glass-ceramic Dicor compared to natural dentition was also obvious in previous findings.[23] For that reason, the bilayer of highly biocompatible zirconia as the framework material and glass-ceramic as the veneering material could be a good combination for biologic integration.

Chipping of the ceramic veneer is the most frequent occurrence that reduces the success rate of zirconia FPDs. The clinical reason for the major chipping may be that the affected patient exhibits abrasions, indicating a habit of bruxism. Therefore, as anticipated in the exclusion criteria, the use of all-ceramic restorations in patients with parafunctional habits is questionable. Furthermore, in 27.5% of the ceramic units, a slightly rough, rather than smooth, surface was detected by the examiners after 36 months. Molin and Karlsson[19] reported similar observation of a slightly rough or pitted surface in approximately 30% of zirconia-based three-unit FPDs after 5 years. A scanning electron microscopic inspection of a restoration acrylic resin replica with a slight roughness performed by the examiners shows a surface that is pitted by abrasion (Figs 2a and 2b). The pitting could lead to the initiation of microcracks and, under further wear, to pronounced chipping.

Some guidelines for laboratory and clinical procedures may extend the lifetimes of porcelain veneers, given the multifactorial causes for delamination. In the fabrication of conventional metal-ceramic FPDs, the application of a uniform thickness of porcelain veneer to anatomically formed frameworks is critical for success.[24] Not all CAD/CAM systems on the market enable the technician to adapt the framework design for proper support of the ceramic veneer, despite the evident benefit of such support.[21,25] On the other hand, the mechanical properties of the ceramic veneers should be strengthened, since the failures reported in the current literature are mainly cohesive failures of the ceramic veneers.[9,14,15,22] Clinically, the practitioner should aim to achieve a perfectly polished surface after occlusal adjustments.[26,27]

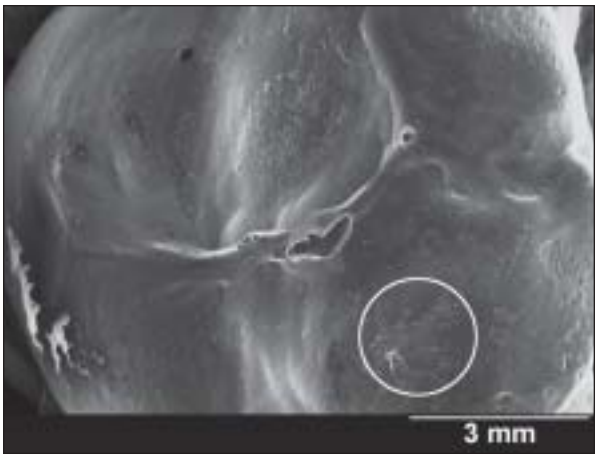

Fig 2a Scanning electron microscopic view of a slightly rough surface after clinical wear for 36 months.

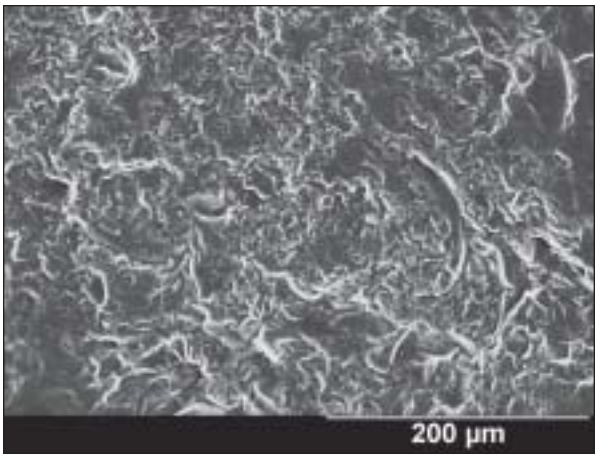

Fig 2b Further magnification shows a surface pitted by abrasion.

In the present study, the margin integrity of 91% of the restorations after 36 months was perfect and no FPD had to be replaced due to secondary caries. A similar result was reported by Raigrodski and Chiche[28] with almost all restorations rated Alpha, for excellent marginal integrity.[28] These clinical results validate the findings of in vitro studies, which reveal similar or even better marginal and internal fit of three-unit CAD/CAM-fabricated FPDs compared to either conventional metal or slip-cast infiltration ceramic frameworks.[2,5] Nevertheless, significant differences between various CAM and CAD/CAM systems are notable. Bindl and Mörmann[5] found higher interface and internal widths on chamfer shoulders and, significantly, on butt shoulders for the Cercon (Ceramco) CAM system compared to the Cerec (Sirona) and DCS CAD/CAM systems. Consistent with this in vitro finding, Sailer et al[9] noted secondary caries in more than 20% of cases, concluding that marginal gaps resulted when a prototype direct ceramic machining technique was used. In vitro findings suggest that Lava FPDs met the clinical requirements of marginal accuracy with a median marginal gap of 65 µm, observing the standard of 100 µm as the limit of clinical acceptability.[2] The absence of significant differences between restored and control teeth regarding the sulcus bleeding index and Gingival Index may be a further indication of the good marginal fits of the zirconia frameworks.

All restorations were inserted with glass-ionomer cement and were retained, despite in vitro findings that support stronger retention for acrylic resin luting agents and acrylic resin–modified glass-ionomer cement.[29] No failures of cementation were observed in the present study. However, Tinschert et al[21] observed two cases of retention loss in zirconia-based FDPs in the posterior regions when inserted with Harvard Cement. Vult von Steyern reported no loss of retention for zirconia FPDs after a service time of 24 months, or for In-Ceram (Vita) FPDs after 5 years, using conventional immediate cementation with zinc-phosphate cement.[16,30] By contrast, retention loss was reported by Sailer et al[9] after 33 months for one zirconia framework adhesively cemented with composite resin.

Particularly in the posterior regions, with a subgingival preparation design, adhesive cementation under dry conditions can be a challenge. Zirconium oxide–based materials allow the use of traditional cementation procedures because of their high fracture resistance.[4] Therefore, if fit and retention between abutment teeth and the framework is sufficient, conventional glass-ionomer cementation in posterior regions is recommended.[31]

In the present study, patient demand for esthetics and stability were fulfilled. They were satisfied with the restorations after 36 months. For over 90% of the FPDs, examiners found the color satisfactory after 36 months.

The results are limited by the relatively small sample size. A control group with metal-ceramic FPDs is missing from the analysis. Nevertheless, the small number of subjects who dropped out because of biologic complications encourages further examination to gain more relevant data. Additional in vitro and long-term clinical studies are necessary to revisit the durability of currently available ceramic veneers for zirconia frameworks, and to obtain clinical data on the most frequent technical complication, chipping.

Conclusions

Within the limitations of this medium-term test period, the following conclusions may be drawn:

- Zirconia frameworks for three- and four-unit posterior FPDs are sufficient for mechanical requirements in the stress-bearing posterior region.
- Cohesive fracture of the ceramic veneer is the only noted mechanical failure.
- Marginal adaptation of Lava CAD/CAM frameworks meets clinical requirements.
- The gingival tissue shows excellent response to the veneered zirconia restorations.

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