Journal of Dentistry 89 (2019) 103174

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Fifteen-year outcome of posterior all-ceramic inlay-retained fixed dental prostheses

Merlind Becker*, M. Saad Chaar, Anne Garling, Matthias Kern

Department of Prosthodontics, Propaedeutics and Dental Materials, Christian-Albrechts University, Arnold-Heller Str. 16, 24105 Kiel, Germany

ARTICLE INFO

Keywords:
Clinical outcome
Fracture analysis
Inlay-retained fixed dental prostheses
All-ceramic
Lithium-disilicate ceramic

ABSTRACT

Objectives: To evaluate the long-term clinical outcome of inlay-retained fixed dental prostheses (IRFDPs) made from lithium-disilicate glass-ceramic.

Material and methods: Forty-five IRFDPs were placed in 42 patients (21 women, mean age 36.1 years and 21 men, mean age 42.0 years). The IRFDPs replaced 4 premolars and 19 first molars in the maxilla and 4 premolars and 18 first molars in the mandible. All teeth were prepared following a standardized protocol for ceramic inlay restorations. Five of the 45 FDPs were hybrid-retained restorations, i.e. one abutment tooth with an inlay retainer and one with a full crown retainer.

All restorations were fabricated from heat-pressed lithium-disilicate ceramic (IPS e.max Press, Ivoclar Vivadent AG). The minimal size of the proximal connector was 16 mm^2 (4 mm × 4 mm in height and width) with a minimum occlusal ceramic thickness of 1.5 mm. Hydrofluoric acid etching (5%) and silane application was used for conditioning the bonding surfaces. Standard adhesive luting techniques were performed using a dentin adhesive and a resin composite. Standardized follow-up reports were performed annually. The survival rates were performed using the Kaplan-Meier analysis.

Results: The mean observation period was 100 months (minimum 4, maximum 234 months). Thirty-three FDPs (73%) failed during the observation period and had to be replaced by other restorations. The Kaplan-Meier survival rate for IRFDPs was 57% after 5 years, 38% after 8 years and 22% after 15 years, while for hybrid-retained FDPs it was 100% after 5 years, 60% after 8 years and also 60% after 15 years.

Conclusion: With the design used in the current, study lithium-disilicate ceramic IRFDP had a high clinical failure rate and cannot be recommended for regular clinical use.

1. Introduction

Conventional crown-retained fixed dental prostheses and dental implants have been considered the standard treatment for single missing premolars and molars with a good clinical outcome [1,2]. Both treatment options, however, have clinical drawbacks. When teeth are prepared for crowns, approximately 63–73% of the coronal tooth structure is removed [3]. Therefore, a considerable risk to pulp vitality and irreversible pulp injury due to this invasive preparation is present [4–6].

Therefore, it seems desirable to adjust the design of abutment preparation to avoid the extensive loss of tooth structure for posterior fixed dental prostheses (FDPs) as an alternative to dental implants. A design with a box-shaped preparation to support the IRFDPs was used in this clinical trial. This design is relatively minimal invasive, especially for abutments with existing class I or class II defects/fillings. The first promising results with inlay-shaped retainers for metal-ceramic resin-bonded IRFDPs in the posterior region were shown through implementing bonding procedures [7]. However, the demand of metal-free materials has become more important for both, clinicians and patients. With the introduction of high-strength ceramic materials, all-ceramic systems may become a useful treatment option for premolar and molar replacement.

For a valid clinical application of all-ceramic materials for IRFDP, long-term data are necessary. The clinical outcome of all-ceramic IRFDPs has been investigated in different studies [8–15]. Laboratory investigations are also available [16–20]. However, available data shows that IRFDPs are inferior to conventional FDPs in term of their clinical outcome [21].

Despite promising in-vitro results, medium- to long-term clinical data of all-ceramic IRFDPs show a dramatically decreased survival rate over time [8,9,12,14,22]. Nevertheless, the clinical results with all-ceramic IRFDPs of more than 10 years are still missing. Therefore, the

* Corresponding author.
E-mail address: mbecker@proth.uni-kiel.de (M. Becker).

https://doi.org/10.1016/j.jdent.2019.07.012
Received 16 May 2019; Received in revised form 21 July 2019; Accepted 22 July 2019

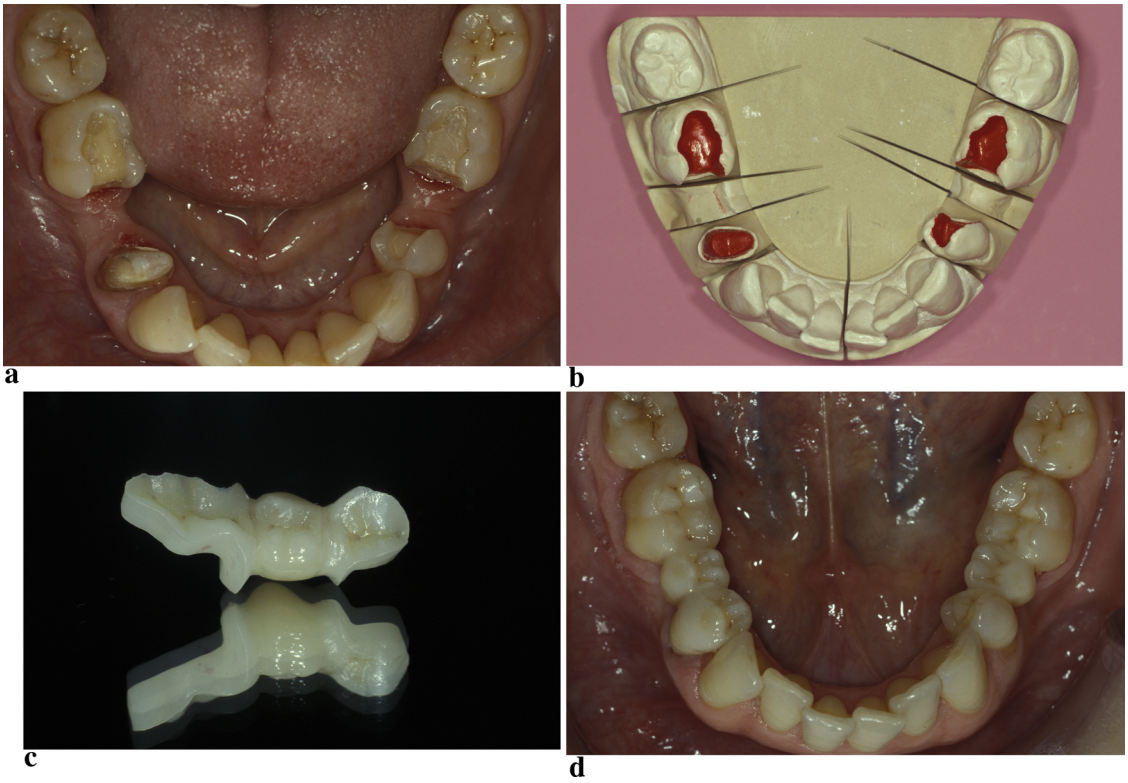

Fig. 1. Preparation design for tree-unit IRFDP in the right mandible and for hybrid-retained FDP in the left mandible and related cast. Three-unit IRFDP for the replacement of a second premolar in occlusal-lingual view. FDPs in situ immediately after luting (left to right/ top to bottom).

Table 1
Distribution by location of 40 inlay-retained and 5 hybrid-retained fixed dental prostheses (FDPs).

Location	Type of FDP Inlay-retained	Hybrid-retained
	Right maxilla	
Second premolar	3	–
First molar	5	1
	Left maxilla	
Second premolar	1	–
First molar	12	1
	Left mandible	
Second premolar	1	–
First molar	8	1
	Right mandible	
Second premolar	1	2
First molar	9	–

FDP = Fixed dental prosthesis.

Table 2
Outcome of FDPs (n = 45) after a mean observation time of 100 months.

Outcome	Type of FDP Inlay-retained	Hybrid-retained	Total
Successful	2	2	4
Surviving	2	1	3
Unknown	5	–	5
Dead	–	–	–
Repaired	–	–	–
Failed	31	2	33

FDP = Fixed dental prosthesis.

objective of the present study was to assess the long-term clinical outcome of heat-pressed lithium-disilicate glass-ceramic IRFDPs after a service period of at least 15-years.

2. Materials and methods

2.1. Study design

Patients referred to the Department of Prosthodontics, Propaedeutics and Dental Materials of the Christian-Albrechts University, Kiel, Germany with the need for a 3-unit FDP were selected for the study. All patients were in good health condition and were in need of one or two three-unit FDPs. Otherwise their dentitions were sufficiently restored.

Informed consent for the study was obtained from all subjects on a written form approved by the Ethical Committee of the Medical Faculty of the Christian-Albrechts University at Kiel. The edentulous space had to be equal or smaller than the width of a molar. The bone level of the vital abutment teeth had to correspond to at least two thirds of the root length with no signs of active bone resorption or periapical pathology. A maximum tooth mobility of grade 1 [23] was accepted.

Oral hygiene had to be good with relatively low caries activity. Patients with probing depths greater than 4 mm, vertical bone loss around abutment tooth, extreme bruxism (self-reported bruxism with wear facets in posterior teeth exposing the dentin), and limited vertical space for the required connector height of 4 mm or a conspicuous medical or psychological history were excluded from the study.

2.2. Clinicians

All clinical treatment of the patients included in this study was performed by fifteen clinicians. The mean vocational experience of the clinicians was 2.9 ± 1.0 years. The clinical treatment procedures were supervised and inspected by 2 dentists with a specialization in prosthodontics (approved by the German Society for Prosthodontics and Dental Materials [DGPro]). To ensure homogeneity in treatment procedures during the study, all clinicians were calibrated considering the following treatment procedures.

Table 3
Descriptive analysis of biological problems that occurred in 4 inlay-retained and 3 hybrid-retained FDPs.

Patient	Gender	Replaced tooth	Time to failure	Failure mode	Restoration type
1	F	36	150 mo	Caries at 37; still in situ at 202 mo	IR
2	M	36	93.5 mo	Caries at 37; still in situ at 220 mo	HY
3	F	35	17.2 mo	Endo of 34; still in situ at 235 mo	IR
		45	72.4 mo	Caries at 46; still in situ at 235 mo	HY

F = Female; M = Male.
IR = Inlay-retained FDP; H = Hybrid-retained FDP.
mo = months.
Tooth numbers shown are FDI.

Table 4
Descriptive analysis of failures that occurred in 40 inlay-retained and 5 hybrid-retained FDPs.

Failure mode		n
Fracture of one inlay retainer	(Fracture I)	16[a]
Fracture of both inlay retainers	(Fracture II)	4
Fracture of pontic area	(Fracture III)	2
Total Fracture		22
Debonding of one inlay retainer	(Debonding I)	4
Debonding of both inlay retainers	(Debonding II)	3
Total Debonding		7
Fracture and Debonding of both inlay retainers	(Combined)	4[b]
Total		33

[a] One out of 16 fixed dental prostheses (FDP) showing fracture I failure mode was a hybrid-retained FDP.
[b] One out of 4 fixed dental prostheses (FDP) showing combined failure mode was a hybrid-retained FDP.

2.3. Prosthodontic procedures

Inlay preparation procedures were performed in accordance with the general principles for ceramic inlay restorations. Abutment teeth were prepared with mesial-occlusal, distal-occlusal or mesial-occlusal-distal box-shaped inlay cavities using fine (30–40 µm grain) diamond instruments under avoidance of any sharp angles. The finishing line was a shoulder without bevels. In five cases, there was a need for complete crown preparation of one of the two abutment teeth. In these five cases, hybrid-retained restorations (one abutment tooth with an inlay retainer and one with a complete crown retainer) were fabricated (Fig. 1).

After abutment preparation, impressions were taken with a dual-mix technique using polyether material (Permadyne, 3M ESPE, Seefeld, Germany). The impressions were cast with type IV gypsum (GC-Fuji Rock EP, Tokyo, Japan) and a die spacer was applied to each master die (Vita In-Ceram Distanzlack, VITA, Bad Säckingen, Germany). All IRFDPs/-hybrid-retained FDPs were made from a heat-pressed lithium-disilicate glass-ceramic (IPS e.max Press, Ivoclar Vivadent AG, Schaan, Liechtenstein) according to the manufacturer's instructions.

For the fabrication of the IRFDPs/-hybrid-retained FDPs, the wax patterns were fabricated and invested with a special investment material (IPS-Press Vest Speed, Ivoclar Vivadent AG), then pressed in one piece and no additional veneering was conducted. After the pressing process, minor adjustments to fit the castings to their dies were performed under a light microscope (magnification x 20) if necessary. The use of additional veneering ceramic was only performed in cases where small corrections were necessary (i.e. pontic tissue contact area). The individualization of colour was achieved by using universal intensive stains (Universal Stains Kit, Ivoclar Vivadent AG).

The minimum occlusal ceramic thickness for inlays and crowns was 1.5 mm. For the proximal connector the minimum dimensions were 4 mm in height and 4 mm in width (16 mm^2).

The marginal fit of the abutments was checked intraorally with a silicone based indicator paste (Fit Checker, GC, Leuven, Belgium). If necessary, adjustments were performed. The marginal fit of the restorations was accepted, if the silicone indicator paste showed a thin and homogeneous layer. No temporary cementation of the IRFDPs/hybrid-retained FDPs was performed to avoid microcracks in the ceramic material.

All restorations were cemented adhesively. The surfaces of the inlay retainers were etched with 5% hydrofluoric acid (Ceramic etchant, Ivoclar Vivadent AG) for 20 s followed by silane coating for 60 s (Monobond S, Ivoclar Vivadent AG). Then the restorations were bonded to the abutment teeth with standard luting techniques using a dentin adhesive (Syntac Classic, Ivoclar Vivadent AG) and a dual polymerizing luting composite system (Variolink II, Ivoclar Vivadent AG). Rubber dam protection was used during adhesive cementation procedures. After cementation, a radiograph of the restoration and its abutment teeth was obtained.

2.4. Follow-up clinical examinations

One to three weeks after cementation patients were scheduled for a final evaluation. Follow-up examinations were performed after 6 months, 12 months and then annually.

Three patients who did not attend the follow-up examination were

Table 5
Descriptive analysis of failures that occurred in 40 inlay-retained and 5 hybrid-retained FDPs related to the failure site.

	Replaced teeth	Failure mode				Total
		Fracture	Debonding	Combination: Fracture and Debonding	No failure	
Maxilla	15	1	0	1	1	3
	16	2	1	0	3	6
	25	0	1	0	0	1
	26	6	2	3	2	13
Mandible	35	0	0	0	1	1
	36	6	0	0	3	9
	45	1	1	0	1	3
	46	6	2	0	1	9
Total		22	7	4	12	45

Tooth numbers shown are FDI.

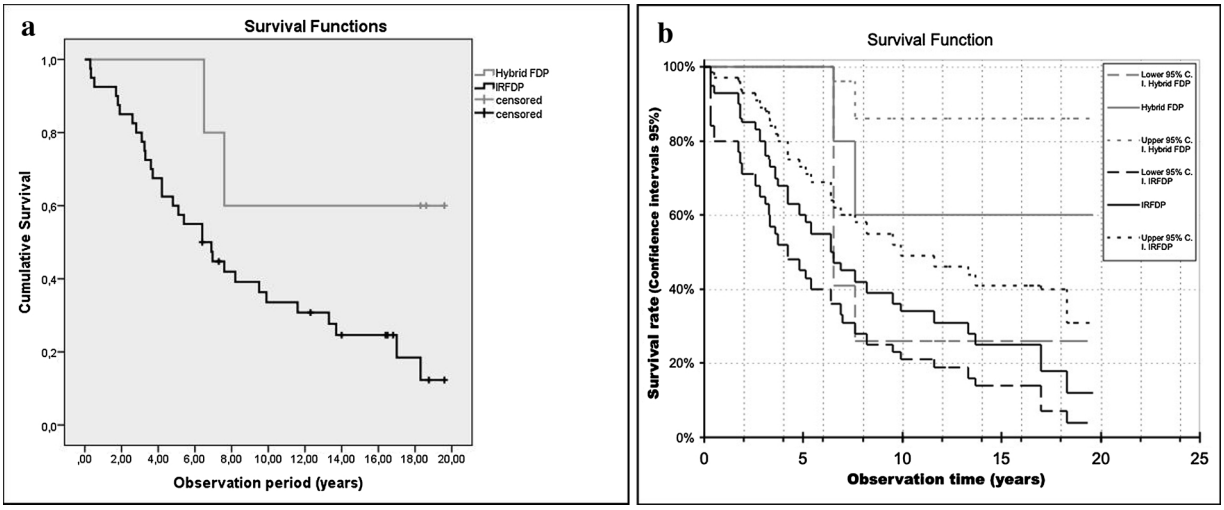

Fig. 2. (a) Kaplan-Meier curve demonstrating the cumulative survival with the censored restorations being marked for inlay-retained (black line) and hybrid (grey line) FDPs. (b) Kaplan-Meier curve demonstrating the survival rate with both lower and upper 95% confidence interval for inlay-retained (black lins) and hybrid (grey lines) FDPs.

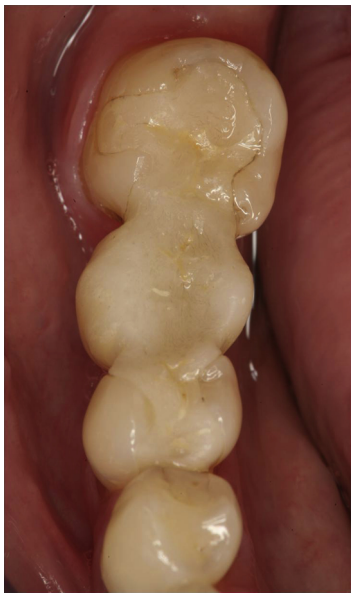

Fig. 3. Successful IRFDP after an observation time of 18 years.

contacted via telephone. They were asked 2 standardized questions: (1) "Is the restoration still in situ?" and (2) "Do you have any problems with your teeth in general and especially with the restoration?"

2.5. Statistical evaluation

Kaplan-Meier survival analysis [24] was used to demonstrate the cumulative survival rates. Survival was considered when the restorations were free of complications or still in function despite managed complications.

Survival time was described by the time period between the date of cementation and the date of the last follow-up examination. In case of failed FDPs, survival time was described by the time period between the date of cementation and the date of failure. For the dead and unknown categories survival time was described between the date of cementation and the latest date of known status.

3. Results

3.1. Patients

Forty-two patients were included in the study and gave their written consent (21 women with a mean age of 36.1 years, range 20–61 years; 21 men with a mean age of 42.0 years, range 24–67 years). Altogether, 40 IRFDPs and 5 hybrid-FDPs were inserted. The distribution of the replaced teeth is shown in Table 1.

3.2. Outcome of FDPs

Table 2 shows the distribution of all IRFDPs/-hybrid-FDPs to the different outcome categories. After a mean observation time of 100 months (minimum 4 months = first failure, maximum 234 months = last observation), only 7 out of 45 IRFDPs/ hybrid-FDPs were still in situ, whereas the status of five IRFDPs remained unknown after an observation period of 15 years (drop-out). Their last known status, after clinical investigations, was successful.

In four IRFDPs/-hybrid-FDPs incorporated in 3 patients, biological problems occurred (Table 3). In one case endodontic treatment of one abutment tooth was performed 17 months after cementation. Moreover, caries occurred in the same patient of one abutment tooth of another restoration 72 month after cementation. In two other cases, caries occurred at one abutment tooth after 93 and 150 months after cementation. After the needed restorative therapy of the caries, all of these restorations are still in function.

The descriptive analysis of the failures that occurred in 40 IRFDPs and 5 hybrid-retained FDPs are shown in Table 4. Thirty-three (73%) out of 45 FDPs were lost during the observation period. Twenty-two out of 45 FDPs were lost because of fractures (67%) and seven because of debonding of one or two of the inlay retainers (21%). In four cases (12%), the restorations were lost because of a combination of fracture and debonding of the inlay retainers. The two failures that occurred in the hybrid-retained FDP group were fractures of the inlay retainer (Table 4). The Gehan-Wilcoxon test showed no significant differences in the survival rate in relation to gender ($p = 0.88$), tooth position (maxilla/mandible, $p = 0.49$) or replaced tooth (molar/premolar, $p = 0.47$).

The descriptive analysis of failures occurred in 40 inlay-retained and 5 hybrid-retained FDPs related to the replaced tooth site is shown in Table 5. Thirteen out of 22 fractures occurred in the mandible while 4 out of 7 restorations were lost due to debonding in the maxilla. All

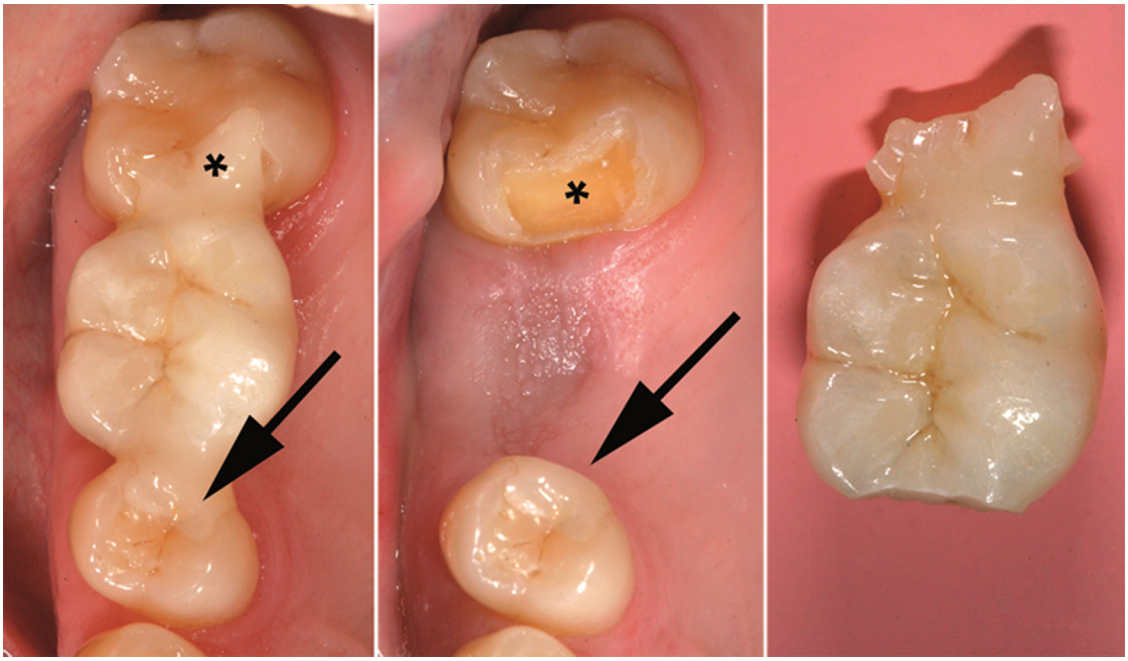

Fig. 4. Example of an IRFDP that failed due to debonding and fracture of the distal inlay retainer (asteroids). The fracture of the distal retainer occurred at the intersection between the occlusal part and the proximal box of the inlay. Bonding of the mesial retainer (arrow) was sufficient and the inlay was left in situ.

combined failures occurred in the maxilla.

The cumulative survival of the IRFDP/-hybrid-retained FDPs according to Kaplan-Meier is demonstrated in Fig. 2a, b. The five-year survival rate for IRFDPs was 57% and 100% for hybrid-retained FDPs. After 8 years, the calculated survival rate decreased dramatically to 38% for IRFDPs and 60%, respectively. The fifteen-year survival rate for IRFDPs was 22% and 60% for hybrid-retained FDPs (Fig. 2a, b).

4. Discussion

In this present prospective clinical study we investigated the 15-year-outcome of three-unit IRFDPs and hybrid-retained FDPs made of lithium-disilicate ceramic. Compared with the outcome of crown-retained FDPs made also of lithium-disilicate ceramic [25,26] IRFDPs presented a poor result (Fig. 3).

In the present study, debonding, fracture or a combination of fracture and debonding at the isthmus of one abutment, i.e. the connection between the occlusal part and the proximal box of the inlay (Fig. 4) caused the majority of failures of the IRFDPs.

Eccentrically stress attacking the adhesive interfaces during chewing [17] might have been responsible for the high fracture and debonding rate. Additionally, the used design of the IRFDPs, which is bonded to a big dentin area, is considerably less durable than bonding to enamel, with the design only mounted in small areas [27]. Most of the failures due to fracture or debonding were related to FDPs replacing first molars (Table 5).

In order to improve the results of the IRFDPs, various proposals for material and framework design have been published [12,20,28,29]. In laboratory studies zirconia-based IRFDPs showed significantly higher fracture strength than IRFDPs made from lithium disilicate ceramic [29–31]. On the contrary, clinical trials with zirconia frameworks for IRFDPs with a conventional inlay-retainer design similar to our study also showed high failure rates due to debonding, fractures and chipping after 12 months of observation [12]. In a clinical study with 30 IRFDPs over a ten-year observation period, the most often observed complications were chipping and debonding. In this study the cumulative 10-year survival and success were 12% and 0%, respectively [8]. In 2006 Wolfart and Kern described a framework design for zirconia IRFDPs with additional retainer wings and shallow inlays [28]. However, one laboratory study on IRFDPs zirconia showed promising results for replacing single premolars with the inlay design seems to have no significant influence on the fracture strength of these restorations [32].

The modified design of the framework (zirconia framework with additional wings) provides higher fracture strength than lithium-disilicate [33,34]. The maximized bonding area and minimized torsion forces on the inlay-retainers lead to no clinical failures within the first two years [33]. Chaar and Kern reported a 5-year cumulative survival of IRFDP with this modified design of 96% [35]. Currently, a systematic review reported that IRFDPs are a viable treatment option for replacing a posterior missing tooth. Appropriate case selection, abutment preparation, luting procedures and dental material may be decisive for clinical success [36].

5. Conclusions

The clinical outcome of experimental inlay-retained FDPs made from lithium-disilicate ceramic was not acceptable when compared to conventional crown-retained FDPs. Therefore, this clinical application cannot be recommended for general clinical use.

Acknowledgements

This study was supported by Ivoclar-Vivadent AG, Schaan, Liechtenstein. The authors want to thank the participating dentists and patients for their kind cooperation and the dental technicians B. Schlueter and R. Gerhardt for the laboratory work.

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