A Four-Year Prospective Clinical Evaluation of Zirconia and Metal-Ceramic Posterior Fixed Dental Prostheses

Jesus Pelaez, DDS, Dr Odont[a]/Pablo G. Cogolludo, DDS[b]/Benjamin Serrano, MD, DDS, Dr Odont[c]/
José F.L. Lozano, MD, Dr Med, DDS[d]/María J. Suárez, MD, Dr Med, DDS, Dr Odont[e]

Purpose: The aim of this study was to compare the survival rates and biologic and technical complications of three-unit metal-ceramic posterior fixed dental prostheses (FDPs) with those obtained with zirconia frameworks. ***Materials and Methods:*** Thirty-seven patients in need of 40 three-unit posterior FDPs were included in this study. The FDPs were randomly assigned to 20 zirconia and 20 metal-ceramic restorations. Abutment preparation guidelines consisted of a 1-mm-wide circumferential chamfer, axial reduction of 1 mm, and occlusal reduction of 1.5 to 2 mm. At baseline and 1, 2, 3, and 4 years after cementation, success of both types of restorations was evaluated. The restorations were assessed using the California Dental Association's assessment system. Periodontal parameters were assessed by determining the Plaque Index (PI), Gingival Index (GI), Marginal Index (MI), and pocket depth of the abutment and control teeth. Statistical analysis was performed by applying Wilcoxon rank sum and Wilcoxon signed-rank tests. ***Results:*** Patients were examined after a mean observation period of 50 ± 2.4 months. The survival rates for metal-ceramic and zirconia restorations were 100% and 95%, respectively. One biologic complication in a zirconia FDP was observed at the 3-year follow-up. No fractures of the zirconia or metal frameworks were observed. Restorations from both groups were assessed as satisfactory. Minor chipping of the veneering ceramic was observed in 2 zirconia FDPs after 4 years. No significant differences were observed between abutment and contralateral teeth for either type of restoration or within the groups with regard to PI, GI, and pocket depth. ***Conclusion:*** Zirconia-based FDPs demonstrated a similar survival rate to metal-ceramic FDPs after medium-term clinical use. *Int J Prosthodont 2012;25:451–458.*

Prosthetic technologies are increasingly adapting themselves to the demands of modern dentistry, as can be seen from the pronounced current trend for high-quality bioesthetic restorations. The demand for metal-free restorations is growing continually, resulting in a need for new and more up-to-date manufacturing systems.

The number of ceramic-based, metal-free restorative materials available is increasing, partly as a result of growing patient demands for highly esthetic restorations and partly because of the uncertain biocompatibility or negative visual or physical characteristics of alternative restorative materials. The ceramic-based systems developed over the past few years are particularly suitable for imitating the translucency of natural teeth and therefore present esthetic advantages with respect to conventional metal-ceramic restorations. Furthermore, these systems present good biocompatibility, very good margin adjustment, and acceptable mechanical properties—the most important criteria to be taken into account in the field of dental restorations.[1–3]

The main drawback of ceramic restorations is their lower fracture resistance with respect to metal-ceramic restorations, especially for fixed dental prostheses (FDPs) in the posterior region,[4] with the connector area often proving to be the weakest zone. Various studies have shown metal-ceramic restorations to have 5-, 10-, and 20-year survival rates of approximately 95% to 98%, 90%, and 41% to 73%, respectively.[5–7] In contrast, studies on ceramic FDPs have shown rather lower survival rates,[4] thus suggesting that their metal-ceramic counterparts currently remain the most widely used.

[a]Associate Professor, Department of Buccofacial Prostheses, Faculty of Odontology, University Complutense, Madrid, Spain.
[b]Researcher, Department of Buccofacial Prostheses, Faculty of Odontology, University Complutense, Madrid, Spain.
[c]Professor, Department of Buccofacial Prostheses, Faculty of Odontology, University Complutense, Madrid, Spain.
[d]Chairman, Department of Buccofacial Prostheses, Faculty of Odontology, University Complutense, Madrid, Spain.
[e]Professor and Vicerrector, Department of Buccofacial Prostheses, Faculty of Odontology, University Complutense, Madrid, Spain.

Correspondence to: *Dr María J. Suárez, Department of Buccofacial Prostheses, University Complutense, Pza Ramon y Cajal s/n, 28040 Madrid, Spain. Fax: +34 913941910. Email: mjsuarez@odon.ucm.es*

Table 1 Location of Pontics and Abutments for Zirconia and Metal-Ceramic FDPs

	Zirconia		Metal-ceramic	
	Abutment	Pontic	Abutment	Pontic
Maxilla				
Canine	2	0	0	0
Premolar	11	7	6	4
Molar	9	4	6	2
Mandible				
Canine	0	0	0	0
Premolar	9	2	14	2
Molar	9	7	14	12

Zirconia is currently the strongest and most stable ceramic material on the market. This material has excellent mechanical properties (flexural strength > 900 MPa), so it can be used to produce FDPs for posterior regions using computer-aided design/computer-assisted manufacture (CAD/CAM) techniques.[8,9]

When esthetics is a priority, ceramic prostheses are undoubtedly the current restoration of choice, and new zirconia ceramics provide the possibility of producing FDPs in posterior teeth with no restrictions concerning the tooth to be restored. The results of in vitro and clinical studies[8–15] suggest that this material is a promising alternative for the production of FDPs in posterior regions. Likewise, the low fracture rate (0% to 2.2%) found in these studies supports this conclusion.[10–12] However, it should be noted that zirconia restorations are not free from complications, with chipping of the veneering ceramic being one of the main problems encountered.[10–14,16,17]

In light of the fact that the results of medium-term clinical trials suggest that zirconia restorations may replace their metal-ceramic counterparts in the near future, clinical studies are needed to support this change in material choice by comparing both types of restorations in various indications and with different zirconia systems. Until recently, only one such study had been published,[13] but the zirconia frameworks were manually fabricated out of modeling wax previous to digitization since most of the zirconia systems digitized the prepared abutments directly.

The aim of this study was to compare the survival rates and possible biologic and technical complications arising from the use of three-unit metal-ceramic posterior FDPs with those obtained when using the zirconia-based Lava system (3M ESPE). The null hypothesis was that no differences would be found between the parameters studied for each type of restoration.

Materials and Methods

A total of 37 patients (22 women and 15 men) between the ages of 23 and 65 years in whom the placement of a three-unit FDP in the posterior region of the maxilla or mandible was indicated were included in this study. Prior to treatment, all patients were informed of the aims of the study, clinical procedure, materials used, risks and benefits of ceramic restorations, and alternatives to the proposed treatment. The inclusion criteria consisted of a posterior tooth (molar or premolar) needing replacement, vital abutments or abutments with sufficient endodontic treatment, abutments not crowned previously, periodontally healthy abutments with no signs of bone resorption or periapical disease, stable occlusion, and the presence of a natural dentition in the opposing arch. Those patients who required an FDP of more than three units or who presented poor oral hygiene, high caries activity, active periodontal disease, or bruxism were excluded. All patients provided written informed consent for inclusion in this study, which was approved by the Clinical Trials Committee at the Universidad Complutense de Madrid, Spain.

Forty posterior FDPs were produced and assigned randomly to either zirconia or metal-ceramic restorations by means of a randomization list. A total of 20 FDPs were placed using the Lava system (n = 17 patients) and 20 were metal-ceramic FDPs (n = 20 patients) (Table 1).

Clinical Procedures

Two clinicians with experience in placing fixed prostheses and use of zirconia restorations treated all patients, who received oral hygiene instructions and underwent professional tooth cleaning prior to commencing treatment. Abutment preparation was performed in a standardized manner: a 1-mm-wide circumferential chamfer, axial reduction of 1 mm, and occlusal reduction of 1.5 to 2 mm. The taper between the axial walls was approximately 10 to 12 degrees.

After preparation, full-arch impressions were taken using addition silicone (Express Penta Putty and Express Penta Ultra-Light Body, 3M ESPE) and the double-impression technique while using a Pentamix dispenser (3M ESPE) to ensure the homogeneity of the mixture. Provisional restorations (Protemp Garant, 3M ESPE) were then made and cemented using a temporary eugenol-free zinc oxide cement (Integrity TempGrip, Dentsply De Trey). Once the impression was cast using type IV dental die stone (GC Fujirock EP, GC), the casts were assembled in a semi-adjustable articulator and the appropriate color was

Fig 1 Posterior FDP made using the Lava system.

Fig 2 Clinical view of a mandibular posterior Lava FDP spanning from the second premolar to second molar after 4 years of service.

selected using the VITA Classic shade guide (VITA Zahnfabrik). The ceramic FDPs were cemented using a resin-based cement (Rely X Unicem, 3M ESPE), and the metal-ceramic FDPs were cemented using a glass-ionomer cement (Ketac Cem, 3M ESPE). Occlusion was adjusted and the surfaces were polished after cementation.

Laboratory Techniques

The ceramic restorations were prepared using a Lava CAD/CAM system equipped with a Lava scanner (3M ESPE) to digitize the abutments and the edentulous space. The morphology of the framework was designed using the software provided with the Lava CAD system (3M ESPE). The framework was milled from a presintered block of zirconia with a magnification of 20% to compensate for subsequent shrinkage upon sintering in the Lava Therm furnace (3M ESPE) at 1,500°C. The framework was tested postsintering to check its fit. Three frameworks were found not to fit well; a new impression was taken in all cases. The framework was manufactured with an anatomical shape and a minimum retainer thickness of 0.5 mm. The veneering ceramic was placed using Lava Ceram (3M ESPE) (Fig 1). All restorations were prepared by an experienced technician.

The metal-ceramic restorations were prepared from chromium-cobalt alloy (Heraenium Pw, Heraeus Kulzer) using the conventional casting technique. The framework was modeled in wax and subsequently introduced into the investment cylinder, with Bellavest T (Bego) as the investment material. The cylinder was then preheated in an oven to 920°C. Casting was performed using a CL-IG vacuum/pressure casting machine (Heraeus Kulzer) with induction heating. The framework was then tested to check its fit. The veneering ceramic was placed covering all surfaces using VITA VM 13 (VITA Zahnfabrik). All restorations were prepared by the same technician.

Clinical Follow-up Protocol

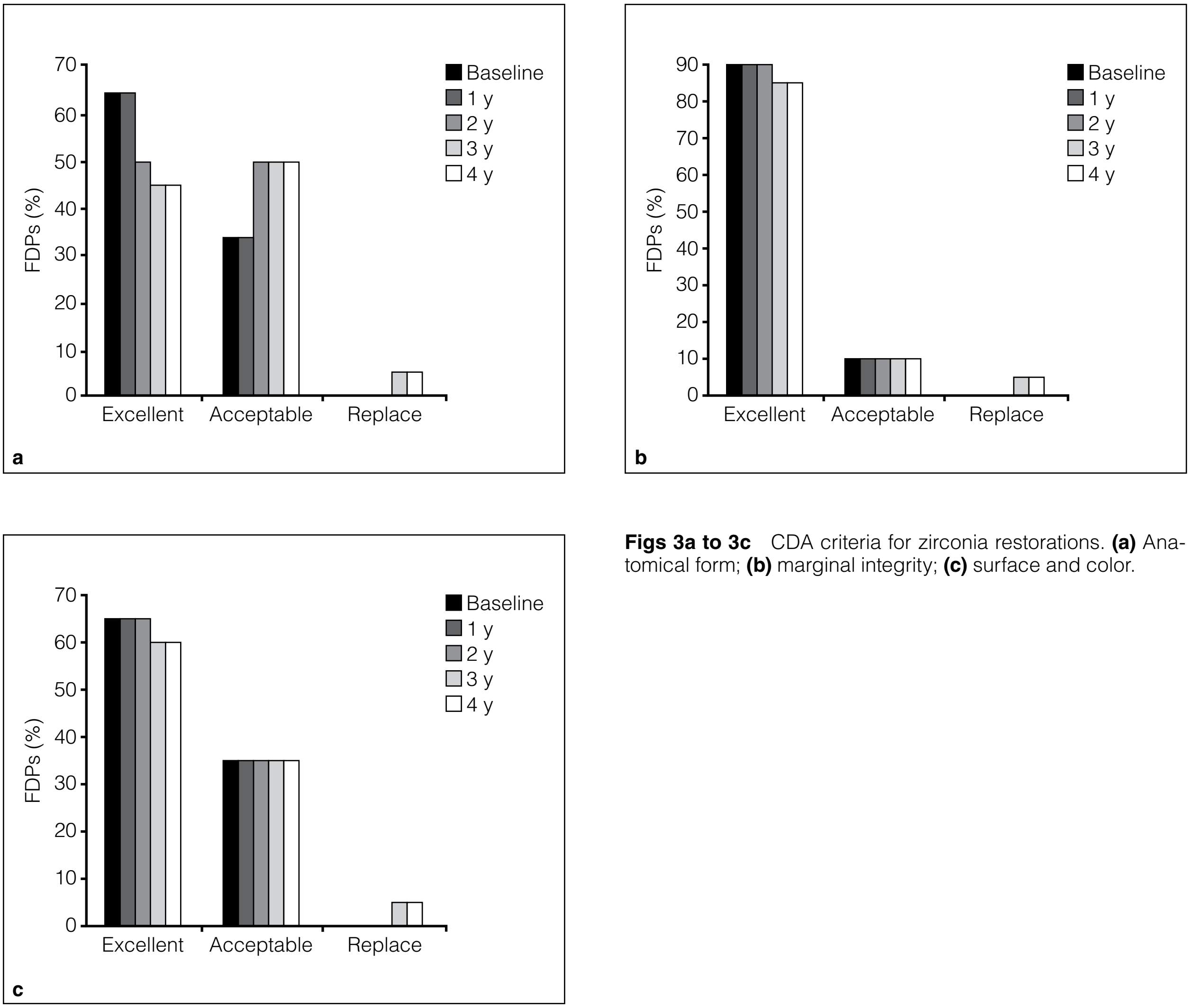
All 40 FDPs were examined at 1 week (baseline) and 1, 2, 3, and 4 years by two researchers who were not involved in the restorative treatment (Fig 2). Each assessor evaluated the restorations independently, and the worst assessment was used in the event of discrepancies.

Restorations were assessed using the California Dental Association's (CDA) assessment system,[18] which takes into account the surface and color, anatomical form, and marginal integrity. Thus, each CDA criterion was judged on a scale of 1 to 4, where 4 is excellent, 3 is good, 2 is acceptable (repair), and 1 is unacceptable (replacement).

The periodontal status was assessed by determining the Plaque Index (PI), Gingival Index (GI), Marginal Index (MI), and the pocket depth of the abutment and control teeth. All control teeth were free from caries and FDPs and were either contralateral to or opposing the abutment tooth. Finally, radiographs of the abutment teeth and clinical photographs of the restorations were taken.

Statistical Analysis

Descriptive statistics were applied to all variables to determine clinical survival. Furthermore, the Wilcoxon rank sum test was used to compare variables and incremental variables, and the Wilcoxon signed-rank test was used to compare moments. Survival rates were determined on the basis of the CDA criteria. All parameters regarding the periodontal status were



Figs 3a to 3c CDA criteria for zirconia restorations. **(a)** Anatomical form; **(b)** marginal integrity; **(c)** surface and color.

described by assigning a score of 0 to 3 (PI and GI) or 1 to 4 (MI and pocket depth). The level of significance was set at $P < .05$. The SAS 9.1 statistical software package (SAS Institute) was used for all calculations.

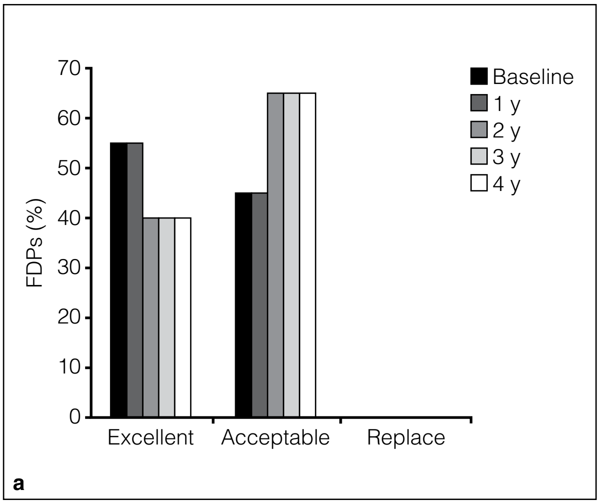
Results

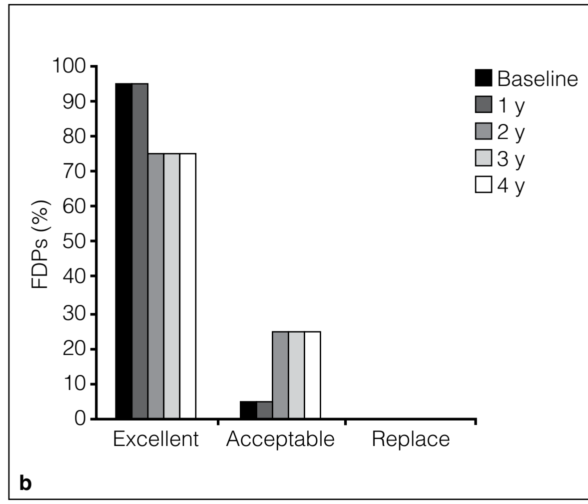
A total of 37 patients received 40 three-unit FDPs, all of which had full occlusal contact with the teeth in the opposing arch. Three abutment teeth were endodontically treated and 7 were vital. None of the patients were lost to follow-up during the observation period (mean: 50 ± 2.4 months).

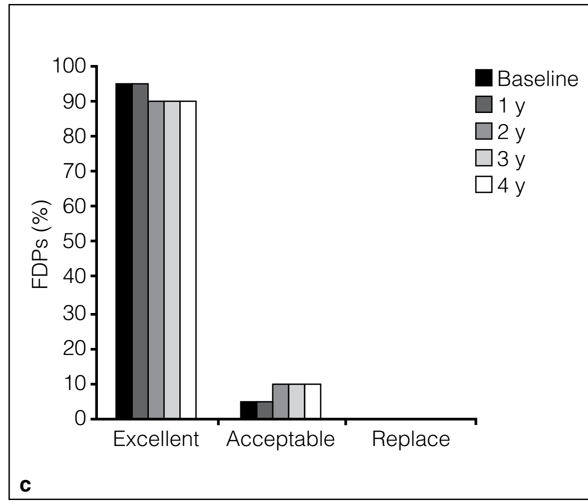
The clinical survival for the metal-ceramic restorations was 100%, whereas that for the zirconia restorations was 95%. One biologic complication resulting from the vertical fracture of an abutment tooth, which had to be removed, was noted at the 3-year follow-up. No fractures of the zirconia or metal frameworks were observed during the observation period.

All restorations from both groups were assessed as satisfactory by both assessors. The deviations from an "excellent" rating can be seen in Figs 3 and 4. A rough surface was observed for two metal-ceramic restorations (10%) and five zirconia restorations (25%). Chipping of the veneering ceramic was observed in two zirconia restorations, although the zirconia framework remained covered. Statistically significant differences were observed between the two groups ($P = .03$).

Thus, in terms of anatomical form, it was observed that 10 (50%) ceramic restorations and 12 (60%) metal-ceramic restorations dropped from excellent to acceptable at the 4-year follow-up. These changes were the result of excessive wear at the occlusal surface of both types of restorations and slightly open contact points in the metal-ceramic FDPs. There were no significant differences between the two groups. There was no significant change within each group from baseline to the 4-year follow-up.







Figs 4a to 4c CDA criteria for metal-ceramic restorations. **(a)** Anatomical form; **(b)** marginal integrity; **(c)** surface and color.

The marginal integrity at the 4-year follow-up was assessed as excellent for 85% of zirconia restorations and 75% of metal-ceramic restorations. The reasons for the change from excellent to acceptable in both groups were the observation of a color difference between the tooth and restoration and the presence of a small marginal discrepancy with no evidence of caries. No FDP was assessed as being clinically unacceptable. No significant differences were observed between the two groups. There was no significant change within each group from baseline to the 4-year follow-up.

No significant differences were observed between the abutment teeth and their corresponding contralateral teeth for either type of restoration or within groups with regard to PI, GI, and pocket depth (Table 2). As far as MI was concerned, an increase in the number of restorations with isogingival and supragingival margins was observed during the follow-up period, with significant differences between the two groups (P = .02). Thus, 10% of zirconia restoration margins were subgingival, 60% were isogingival, and 30% were supragingival, whereas 50% of metal-ceramic restoration margins were subgingival, 35% were isogingival, and 15% were supragingival (Table 3).

Discussion

The results of this study show that posterior FDPs prepared from zirconia frameworks present acceptable survival rates. Thus, the survival rate for zirconia-based restorations after 4 years of use was 95%, and that for metal-ceramic restorations was 100%. One zirconia FDP was lost because of a biologic complication as a result of a longitudinal root fracture of the endodontically treated mesial abutment. No fracture of the zirconia or metal frameworks was observed in any FDP, thus indicating a survival rate of 100%. However, it is important to differentiate between the survival of the zirconia frameworks in the posterior

Table 2 Gingival Index (GI) and Plaque Index (PI) Scores at Baseline and 4 Years for Both Types of FDPs

	GI				PI			
	Baseline		4 y		Baseline		4 y	
Score*	Zirconia	MC	Zirconia	MC	Zirconia	MC	Zirconia	MC
0	12	7	6	4	8	13	8	11
1	8	12	14	13	12	6	12	8
2	0	1	0	3	0	1	0	1
3	0	0	0	0	0	0	0	0
P	.225		.052		.186		.556	

MC = metal-ceramic.
*GI: 0 = normal gingiva; 1 = light inflammation; 2 = moderate inflammation; 3 = severe inflammation. PI: 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 between teeth.

Table 3 Marginal Index Scores at Baseline and 4 Years for Both Types of FDPs

	Baseline		4 y	
Score*	Zirconia	MC	Zirconia	MC
1	0	0	0	0
2	0	2	6	3
3	11	6	12	7
4	9	12	2	10
P	.573		.021	

MC = metal-ceramic.
*1 = supragingival, > 2 mm; 2 = supragingival, < 2 mm; 3 = isogingival; 4 = subgingival.

sectors of the mouth and that of the restorations themselves—in other words, the number of restorations that failed because of fracture of the zirconia framework and the number of restorations that failed because of biologic problems. Three- and 5-year follow-up studies have shown survival rates for the former to be in the range 97.8% to 100%.[10–13,16,19–21] This rate decreases to 73.9% if biologic complications are taken into account.[10] No statistically significant differences were observed between the two groups for any of the technical parameters except for chipping of the veneering ceramic, which occurred more frequently for ceramic FDPs.

The promising results of this study are in accordance with those of other clinical studies involving the Lava system.[14,19,20] They also agree with those of other authors[10-13,16,21,22] who studied similar zirconia-based ceramic systems with follow-up periods of between 2 and 5 years. Likewise, these results improve those achieved with other ceramic systems such as lithium disilicate,[23,24] In-Ceram Zirconia (VITA Zahnfabrik),[25,26] and In-Ceram Alumina (VITA Zahnfabrik).[27]

The marginal accuracy obtained in this study is satisfactory from a clinical point of view for both types of restorations, with no significant differences, and is similar to that obtained previously.[11–13,28] Only one study[10] obtained worse marginal adjustment values for zirconia FDPs other than those reported in the literature, probably resulting from the direct ceramic machining (DCM) prototype used in the study, whereas the other studies used fully developed systems.

The quality assessment on the basis of the CDA criteria performed for both types of restorations at the 4-year follow-up was less favorable for all parameters since a large number of restorations dropped from excellent to acceptable. These results are in accordance with those reported by other authors, who noted a decrease in the evaluation for all variables as the length of clinical follow-up increased.[10,12,13,19]

One of the main complications of zirconia-based FDPs is chipping or fracture of the veneering ceramic. In this study, chipping was observed in two ceramic restorations (10%). These results are similar to those obtained by other authors, who reported chipping rates of between 2% and 30%.[10,11,14,16,19,22,23,26,28] To the best of the authors' knowledge, there is only one study[12] in which no chipping of the veneering ceramic of Denzir FDPs was observed over a follow-up period of 5 years, possibly as a result of the frameworks being anatomically designed to provide solid support for the veneering ceramic.

No chipping of the veneering ceramic was observed for the metal-ceramic FDPs. These results are better than those obtained with ceramic FDPs and in accordance with those reported in the literature, where chipping rates for the veneering ceramic in metal-ceramic restorations are in the range 2.5% to 8% at 5 years,[4] 19.4% at 3 years,[13] and 18.1% at 20 years.[7]

In a systematic review on survival of zirconia and metal-supported FDPs, it was revealed that veneer chipping of zirconia FDPs was on average 7% higher compared to metal-ceramic restorations.[29] The reason for the higher chipping of the zirconia restorations needs to be clarified, but different investigations have shown that several factors may be involved:

- Different coefficients between the veneer and zirconia core (generally the veneer material has a higher coefficient than the core).[30,31]
- Flexural strength of the veneering ceramic. The excessive stress in metal-ceramic systems may be compensated for by an elastic or plastic deformation of the framework, whereas the framework in zirconia systems is rigid and therefore cannot undergo such a deformation.[17]
- Inadequate support for the veneering ceramic. The core must be designed anatomically to provide enough support to the veneer material and to avoid the risk of veneer chipping.[12,32]
- Bond strength between veneering ceramic and zirconia frameworks.[33]
- Different surface treatments of the frameworks.[34]
- Inadequate thickness of the veneer. When the thickness of the veneer exceeds that of the framework, the risk of veneer chipping is greater.[35]

Chipping was observed in FDPs that presented a rough surface resulting from occlusal contacts, indicating that this clinical factor could be associated with the chipping, as was reported previously,[12–14] although fractographic examination was not done. Furthermore, the anatomical design of the frameworks and the adequate thickness of the veneer ceramic in both groups cannot be considered critical factors for chipping in the zirconia group. The high chipping rate for the veneering ceramic in zirconia restorations indicates that this problem must be resolved in the future.

A resin-based cement was used for zirconia restorations, as recommended by the manufacturer, whereas a conventional glass-ionomer cement was used for metal-ceramic restorations, as is typical in clinical settings. No problems such as decementation or abutment sensitivity were observed in either group. This was consistent with the findings of previous studies[14,22] but in contrast with others that reported loss of retention for the zirconia abutments with different luting agents.[10–12,16]

No significant differences were found between abutment and control teeth or within the groups analyzed in terms of the periodontal parameters PI, GI, and pocket depth at the first and fourth year, thus indicating no adverse reactions to zirconia restorations for the gingival tissue. These results are in accordance with those obtained in previous studies.[10–14] Only slight increases in GI and PI were observed for both groups after 4 years of follow-up. These results are in accordance with those reported by other authors who noted that the risk of gingivitis is always slightly higher in the vicinity of a fixed prosthesis.[22] Likewise, in accordance with previous reports, a slight increase in PI was observed for both groups as well as for the contralateral teeth.[28]

The results obtained are comparable to those obtained with conventional metal-ceramic FDPs[5–7] and could be a result of the good marginal fit and high biocompatibility of the Lava system.

Conclusions

Considering the limitations of the observational period, the excellent survival rate of zirconia restorations fabricated using the Lava system indicates this type of ceramic to be an alternative to metal-ceramic restorations in the posterior region. No framework fracture was observed, and the gingival tissue showed an excellent response to the zirconia restorations. However, a longer observation period is required to validate these medium-term results, and further studies are necessary with more units in function.

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