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A Randomized Clinical Trial Comparing Zirconia and Metal-Ceramic Three-Unit Posterior Fixed Partial Dentures: A 5-Year Follow-Up

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Abstract

Purpose: To compare the survival, success rates, and biological/technical complications of posterior metal-ceramic (MC) and zirconia fixed partial dentures (FPDs).
Materials and Methods: A total of 40 patients requiring 40 posterior FPDs were randomly assigned to receive 20 zirconia and 20 MC restorations. The restorations were examined 1 week (baseline) and 1, 3, and 5 years after the end of treatment. Technical and biological outcomes were compared. Data were statistically analyzed using the Wilcoxon signed-rank and Mann-Whitney U tests.
Results: The survival rates of both groups were 100%, and the success rates were 80% (zirconia) and 100% (MC). No biological complications were observed. Minor chipping was found in 20% of the zirconia restorations. No differences in periodontal parameters were observed between groups.
Conclusions: Zirconia FPDs exhibited the same survival rate (100%) as MC FPDs after 5 years; however, the success rate was 80%, because an increased rate of chipping was observed in zirconia restorations.

The esthetic demands of both patients and dentists have increased, even for the posterior teeth, since ceramic restorations have become more popular and natural looking. The most recently used core material for posterior ceramic FPDs is yttria-stabilized zirconia polycrystals (Y-TZP).[1,2] Zirconia exhibits excellent mechanical properties, with high fracture strength and fracture toughness.[3,4] The zirconia framework is principally manufactured using computer-aided design and computer-aided manufacturing (CAD/CAM) technology, and previous studies have demonstrated an adequate marginal integrity of zirconia FPD frameworks with or without a corresponding porcelain veneer.[2,5]

Metal-ceramic (MC) restorations are considered the gold standard for fixed prosthodontics.[1,2,6] All new materials used as alternatives must be comparable to MC, particularly regarding veneer chipping, core fractures, and marginal fit.[7] Zirconia ceramics seem to be a promising alternative for posterior FPDs.[1,6,8-14] However, despite their favorable mechanical, biological, and esthetic properties, zirconia FPDs have not been free of clinical complications.

The reasons for zirconia FPD failure primarily include biological complications, such as secondary caries, loss of vitality, abutment tooth fractures and periodontal disease,[15,16] or technical complications, mainly including chipping of the ceramic veneering.[1,8,13,14,17] Some clinical studies have presented data up to 7 years after treatment that reported a high prevalence of chipping of the veneering ceramics of zirconia FPDs (0-35%).[8,13,14,18-21] A systematic review evaluated MC versus zirconia FPDs and concluded that the frequency of veneer chipping was significantly higher in zirconia FPDs.[22] However, framework fractures have rarely been reported, and rates have ranged from 0% to 2.2%.[8-10,13,17,18,21-23] The connector size is also an important factor to minimize the fracture risk of zirconia FPDs compared to MC, and previous studies recommended a connector area for zirconia FPDs of at least 9 mm^2.[6,17]

Zirconia seems to show adequate properties to guarantee clinical serviceability when used in the posterior region and may be considered a possible alternative to a MC restoration; however, few clinical studies have reported the longevity of zirconia posterior FPDs, and even fewer are randomized controlled clinical trials or compare both types of restorations. Furthermore, the results vary due to differences in the zirconia system employed, parameters analyzed, and measurement methods used.[6,21] Thus, additional studies on zirconia posterior FPDs are necessary before they can be recommended for routine use.

In this study, we compared the survival, success, and failure rates as well as the biological and technical complications of 3-unit MC and zirconia posterior FPDs. The null hypothesis was that no between-group differences would be found among the studied parameters.

Materials and methods

Patient selection

Seventy-six patients, requiring at least one 3-unit FPD in the posterior region of the maxilla or mandible, were screened and examined from the Department of Buccofacial Prostheses (Faculty of Odontology, University Complutense of Madrid, Spain) waiting list. Forty patients (23 females, 17 males) fulfilled the inclusion criteria and were included in this study. The age of the subjects ranged from 24 to 70 years. Before treatment, patients were informed of the study objectives, clinical procedures, materials used, advantages and possible risks of the ceramic material, and other therapeutic alternatives. The following inclusion criteria were applied: one missing posterior tooth (first molar or second premolar), vital abutments or abutments with sufficient endodontic treatment, abutments not crowned previously, periodontally healthy abutments with no signs of bone resorption or periapical disease, adequate occlusogingival height for an appropriate connector area of at least 9 mm^2, and complete dentition of the opposite arch. The exclusion criteria consisted of patients who required a FPD of more than three units or who presented with poor oral hygiene, high caries activity, active periodontal disease, or bruxism. Prior to the study, participants were asked to provide written informed consent, and the study was approved by the Ethical Committee of Clinical Trials at the University Complutense of Madrid (C.P. N.E.// C.I. P-06/155).

The patients were randomly assigned into two groups (n = 20 each) to receive either zirconia or MC FPDs.[24] Therefore, 40 posterior FPDs were produced and allocated in parallel to either zirconia restorations using the IPS e.max ZirCAD system (Ivoclar Vivadent, Schäan, Liechtenstein) (n = 20), or MC restorations (n = 20). Twenty FPDs were placed in the maxilla, and 20 were placed in the mandible (Table 1). The patients did not know which treatment they were receiving.

Table 1 Missing teeth replaced

	Maxilla		Mandible		
	Second premolar	First molar	Second premolar	First molar	Total
MC FPDs	4	6	4	6	20
Zr FPDs	4	6	4	6	20
Total	8	12	8	12	40

MC FPDs: Metal-ceramic fixed partial dentures. Zr FPDs: Zirconia fixed partial dentures.

Clinical procedures

The clinical procedures were performed by two experienced clinicians. All participants received oral hygiene instructions and a professional tooth cleaning prior to prosthetic treatment.

The abutment teeth were prepared with a 0.8- to 1-mm-wide circumferential chamfer, an axial reduction of 1 to 1.5 mm, and an occlusal reduction of 1.5 to 2.0 mm. A 10° to 15° angle of convergence was achieved for the axial walls. Full-arch impressions were taken with the two-stage putty-wash technique using addition silicone (Express Penta Putty and Express Penta Light Body; 3M ESPE, Seefeld, Germany) and a Pentamix dispenser (3M ESPE). An impression was made of the opposing arch with an irreversible hydrocolloid material (CA37; Cavex Holland BV, Haarlem, Holland). Provisional FDPs (Telio CS C&B; Ivoclar Vivadent) were then made and cemented with eugenol-free zinc oxide provisional cement (Integrity TempGrip; Dentsply Sirona, Salzburg, Austria). Master casts were obtained using type IV dental stone (GC Fujirock EP; GC Europe, Leuven, Belgium) and were sent to the laboratory mounted in a semi-adjustable articulator (Articulator ARH; Dentatus, Spanga, Sweden). The appropriate shade was selected using the VITA Classic shade guide (VITA Zahnfabrik, Bad Säckingen, Germany). The inner surface of all FPDs was carefully sandblasted (CoJet; 3M ESPE), and all FPDs were cemented using a resin-based cement (RelyX Unicem, 3M ESPE). After cementation, the occlusion was adjusted, and any reshaped surfaces were polished.

Laboratory techniques

Zirconia restorations were made using the IPS e.max ZirCAD system. Abutments were digitized with the InEos scanner (Dentsply Sirona) with software used to design the morphology of the frameworks (CAD Framework 3D software; Dentsply Sirona). The frameworks were milled from presintered zirconia blanks and enlarged by approximately 20% to compensate for shrinkage during sintering in a Sintramat furnace (Ivoclar Vivadent) at 1500°C (Fig 1). The framework was tested intraorally post-sintering to evaluate the accuracy of fit (Fig 2). The zirconia frameworks were then veneered, covering all surfaces, with the corresponding hand-layered veneering ceramic (IPS e.max Ceram; Ivoclar Vivadent). All restorations were prepared by an experienced technician.

The MC restorations were prepared from a chromium-cobalt alloy (Heraenium Pw; Kulzer, Hanau, Germany) using the conventional lost-wax casting technique. The frameworks were waxed up, and a graphite-free phosphate stone (Bellavest t; Bego, Bremen, Germany) was used to invest the wax patterns. Casting was performed using a CL-IG vacuum/pressure-casting machine (Heracast; Kulzer) with induction heating. The frameworks were evaluated intraorally for accuracy of fit. Finally, the structures were veneered with compatible glass ceramic (VITA VM 13; VITA Zahnfabrik).

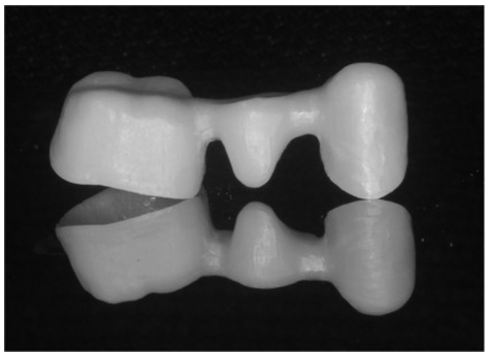

Figure 1 Representative zirconia framework fabricated according to the manufacturer's recommendations.

Figure 2 Try-in of the IPS e.max ZirCAD framework.

The minimum connector dimension was 9 mm^2 for both types of restorations, and the frameworks were manufactured with an anatomic form and a minimum thickness of at least 0.5 mm at the axial walls and 1 mm at the functional cusps. The technician verified the thickness of the veneering porcelain at different locations using a digital micrometer, so that the thickness of the veneering porcelain was approximately 1 mm in all areas.

Follow-up examination

Two calibrated examiners who were not involved in the restorative treatment evaluated the FPDs at 1 week (baseline) and 1, 3, and 5 years after the end of treatment. Each assessor evaluated the restorations independently, and the worst assessment was used in the event of discrepancies. Both examiners evaluated the quality of the surface and the color, anatomical form, and marginal integrity of the FPDs according to the California Dental Association (CDA) assessment system.[13,21,23] The periodontal condition was examined using the plaque index (PI), gingival index (GI), pocket depth, and margin index (MI)[13] of all abutment teeth. Radiographs of the abutment teeth and clinical photographs of the restorations were obtained at each evaluation.

Statistical analysis

Descriptive statistics were used to evaluate clinical outcomes. The Wilcoxon signed-rank test was used to compare variables between both groups, and the Mann-Whitney U test was used to compare variables and incremental variables. Survival rates were determined based on the CDA criteria. Each CDA criterion was ranked on a scale of 1 to 4, where 4 = excellent, 3 = good, 2 = unacceptable (repair), and 1 = unacceptable (replacement). All parameters regarding periodontal status were described by assigning a score of 0 to 3 (PI and GI) or 1 to 4 (MI and pocket depth). The cutoff value for statistical significance was set at $\alpha = 0.05$. Statistical software (SAS 9.2; SAS Institute, Cary, NC) was used for the analysis.

Table 2 Frequency (%) (number) of CDA assessments at baseline and the 1-, 3-, and 5-year follow-up evaluations for zirconia FPDs

Time	Score	Surface and color	Anatomical form	Marginal integrity
Baseline				
	4	100 (20)	54 (9)	100 (20)
	3	0	55 (11)	0
	2	0	0	0
	1	0	0	0
1 year				
	4	100 (20)	45 (9)	100 (20)
	3	0	55 (11)	0
	2	0	0	0
	1	0	0	0
3 years				
	4	80 (16)	45 (9)	100 (20)
	3	20 (4)	55 (11)	0
	2	0	0	0
	1	0	0	0
5 years				
	4	65 (14)	45 (9)	80 (16)
	3	35 (7)	55 (11)	20 (4)
	2	0	0	0
	1	0	0	0

Results

Forty patients received 40 three-unit FPDs. No patients were lost to follow-up during the observation period (mean: 63 ± 2.4 months).

No fracture of the zirconia or metal framework was observed. Both types of FPDs exhibited a 100% survival rate, and no biological complications occurred during the follow-up period. A CDA rating of satisfactory was given for 100% of the FPDs of both groups at all examinations. Deviations from the score of excellent are presented in Tables 2 and 3. Chipping of the veneering ceramic was observed on occlusal surfaces of four zirconia restorations (20%); however, remaking of the restorations was not necessary because the fractured areas could be polished, the zirconia frameworks remained covered, and the occlusal contact of the opposing tooth was not affected. The percentage of chipping increased from zero at baseline to 10% and 20% after 3 and 5 years, respectively. In terms of surface and color, statistically significant differences were observed between the two groups ($p = 0.019$). A significant change

Table 3 Frequency (%) (number) of CDA assessments at baseline and the 1-, 3-, and 5-year follow-up evaluations for metal-ceramic FPDs

Time	Score	Surface and color	Anatomical form	Marginal integrity
Baseline				
	4	95 (19)	65 (13)	100 (20)
	3	5 (1)	35 (7)	0
	2	0	0	0
	1	0	0	0
1 year				
	4	95 (19)	65 (13)	95 (19)
	3	5 (1)	35 (7)	5 (1)
	2	0	0	0
	1	0	0	0
3 years				
	4	90 (18)	50 (10)	75 (15)
	3	10 (2)	50 (10)	25 (5)
	2	0	0	0
	1	0	0	0
5 years				
	4	90 (18)	50 (10)	75(15)
	3	10 (2)	50 (10)	25 (5)
	2	0	0	0
	1	0	0	0

($p = 0.008$) was observed within the zirconia group from baseline to the 5-year follow-up evaluation.

With respect to anatomical form, 11 (55%) ceramic restorations and 10 (50%) MC restorations were assessed as acceptable at the 5-year follow-up evaluation due to slightly overcontoured restorations, wear at the occlusal surface, or a slightly lower marginal ridge. Three MC restorations (15%) decreased from excellent to acceptable at the 3-year follow-up evaluation because the contact areas were slightly opened. No significant differences were observed between the two groups, and no significant changes were found within each group from baseline to the 5-year follow-up evaluation.

The marginal integrity at the 5-year follow-up was ranked as excellent in 80% of the zirconia restorations and 75% of the MC restorations. Margin discoloration and a small marginal discrepancy with no evidence of caries were the reasons for changes from excellent to acceptable categorizations in both groups. No FPD was assessed as being clinically unacceptable. Significant differences were observed between the two groups ($p = 0.018$). A significant change ($p = 0.025$) was observed within the MC group from baseline to the 5-year follow-up evaluation.

With respect to periodontal status, a significant difference was found between the zirconia and MC groups in the GI at the 5th year of follow-up ($p = 0.010$), with worse results for the MC group (Table 4). No differences were found between the two groups with respect to PI, MI, or pocket depth. Significant differences were observed in the abutment teeth from baseline to the 5-year follow-up evaluation in the zirconia group for GI ($p = 0.003$), PI ($p = 0.02$), and MI ($p = 0.02$), and in the MC group for GI ($p = 0.0001$), PI ($p = 0.008$), and MI ($p = 0.025$).

Discussion

In this study, the survival rate of zirconia and MC FPDs was 100% after 5 years. No fractures of the ceramic or metal frameworks occurred; however, differences in the clinical outcomes of zirconia and MC posterior FPDs were observed after 5 years of function. The overall success rates were of 80% (due to veneer chipping fractures) and 100% for the zirconia and MC FPDs, respectively.

The survival rates of zirconia FPDs reported in the literature are lower than those of MC FPDs (Table 5). MC restorations have shown 5-, 10-, and 20-year survival rates of approximately 94.4% to 100%, 90%, and 66.2%, respectively.[13,21,23,25-29] Zirconia restorations have been shown to have survival rates at 3- and 7-year follow-up evaluations in the range of 83.4% to 100%,[12-14,18-21,23,25,30-36] and one study reported a cumulative survival rate of 85% up to 10 years.[37] A systematic review comparing the survival rates of zirconia and MC FPDs showed significant differences;[22] however, a more recent systematic review showed no differences.[25] Although these systematic reviews are important, their results were based on a relatively small number of studies, and the majority reported a 3- to 5-year follow-up period.[35] In addition, data were based on prospective and retrospective cohort studies rather than randomized clinical trials, which may affect the validity of the results.[38]

The main technical complication of zirconia bilayered FPDs is the chipping or fracture of the veneering ceramic. Previous studies have reported a high prevalence of chipping, with rates between 0% and 35% after up to 10 years of clinical service[12-14,18-21,23,30-34,36,37] (Table 6); however, framework fractures were rarely reported.[17] In this study, minor cohesive chipping was observed in four zirconia restorations (20%). Two occurred at the 3-year follow-up evaluation, and another two

Table 4 Frequency (%) (number) of gingiva Index (GI) at baseline and the 1-, 3-, and 5-year follow-up of both types of FPDs

	Baseline		1 year		3 years		5 years	
Score	Zirconia	MC	Zirconia	MC	Zirconia	MC	Zirconia	MC
0	85 (17)	100 (20)	65 (13)	20 (4)	50 (10)	15 (3)	25 (5)	5 (1)
1	10 (2)	0	35 (7)	65 (13)	45 (9)	60 (14)	70 (14)	80 (16)
2	5 (1)	0	0	15 (3)	5 (1)	25 (5)	5 (1)	15 (3)
3	0	0	0	0	0	0	0	0

MC: Metal-ceramic. 0 = Normal gingiva; 1 = light inflammation; 2 = moderate inflammation; 3 = severe inflammation.

Table 5 Survival rates of metal-ceramic and zirconia FPDs

Material	Reference	Percentage	Observation period
Metal-ceramic			
	Sailer et al, 2009[23]	100	3 years
	Nicolaisen et al, 2015[21]	100	3 years
	Peláez et al, 2012[13]	100	4 years
	Sailer et al, 2017[36]	100	5 years
	Pjetursson et al, 2015[25]	94.4	5 years
	Walton, 2002[26]	96	5 years
		87	10 years
		85	15 years
	Behr et al, 2012[27]	87	10 years
	De Backer et al, 2006[28]	66.2	20 years
	Holm et al, 2003[29]	53	30 years
Zirconia			
	Beuer et al, 2009[12]	90.5	
	Sailer et al, 2009[23]	100	
	Naenni et al, 2015[30]	100	3 years
	Nicolaisen et al, 2016[21]	100	
	Wolfart et al, 2009[31]	96	
	Roediger et al, 2010[32]	94	4 years
	Peláez et al, 2012[13]	95	
	Schmitt et al, 2012[33]	92	
	Sorrentino et al, 2012[34]	100	
	Raidgrodski et al, 2012[18]	83.4	
	Monaco et al, 2015[20]	94.7	5 years
	Pjetursson et al, 2015[25]	90.4	
	Le et al, 2015[35]	93.5	
	Sailer et al, 2017[36]	100	
	Rinke et al, 2013[19]	83.4	7 years
	Tartaglia et al, 2015[14]	94.7	
	Ioannidis and Bindl, 2016[37]	85	10 years

Table 6 Zirconia FPD chipping rates

Reference	Percentage	Observation period
Beuer et al, 2009[12]	0	
Sailer et al, 2009[23]	35.2	
Naenni et al, 2015[30]	20	3 years
Nicolaisen et al, 2016[21]	29.4	
Wolfart et al, 2009[31]	17.6	
Roediger et al, 2010[32]	14.2	4 years
Peláez et al, 2012[13]	10	
Raidgrodski et al, 2012[18]	22	
Sorrentino et al, 2012[34]	6.2	5 years
Schmitt et al, 2012[33]	28	
Monaco et al, 2015[20]	13.7	
Sailer et al, 2017[36]	35	
Rinke et al, 2013[19]	23.2	7 years
Tartaglia et al, 2015[14]	3.1	
Ioannidis and Bindl, 2016[37]	28	10 years

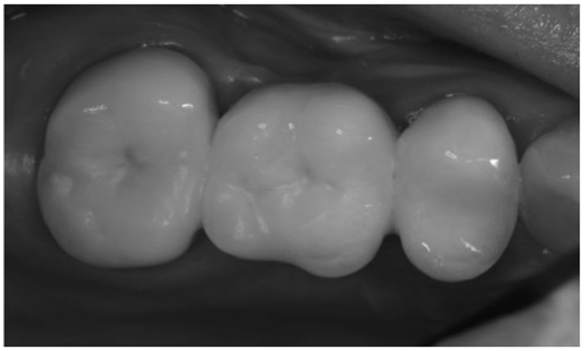

Figure 3 Occlusal cohesive chipping of the ceramic veneer in the pontic of a maxillary zirconia FPD at the 5-year follow-up evaluation.

occurred at the 5-year follow-up evaluation; however, fractures did not affect the function or esthetics, and only polishing was necessary (Fig 3). This finding was previously reported in clinical studies and systematic reviews.[1,6,17,22] In all four cases, the chipping was observed in FPDs that presented a rough surface, indicating that this clinical factor could be associated with the chipping, as was reported previously.[8,13,14,19-21,36] No chipping was observed in the MC FPDs. No differences were observed between the two groups in any of the technical parameters, except for chipping of the veneering ceramic, which occurred more frequently in zirconia FPDs.

Prior studies have shown that several factors are involved in the higher chipping rates of zirconia restorations, although additional studies are needed to clarify this problem. Among the factors analyzed in laboratory studies were the different coefficients of thermal expansion between the veneering ceramic and the framework, the surface treatments of the framework before the veneering procedure, the flexural strength of the veneering ceramic, and inadequate support of the veneering ceramic due to an inadequate framework design and a lack of veneer thickness.[13] The veneering technique also has a potential effect on chipping of the ceramic veneer.[39] In this study, hand-layered veneering ceramic was used, which could influence our results, as could grinding or occlusal function, as previously reported.[10,13,40]

According to the CDA scores recorded in this study, a change from an excellent to acceptable rating occurred during the period from baseline to the 5-year follow-up evaluation in all parameters examined in both groups, which is consistent with previous studies.[8,10,13,16,21,23] Differences in surface and color were observed between the groups due to the veneer chipping of the zirconia FPDs. The marginal integrity was satisfactory in both groups, although differences were present due to the lower scores for MC FPDs, indicating a better marginal adjustment in the zirconia group than in the MC group. This result is inconsistent with previous studies, where MC FPDs had a superior fit compared to zirconia FPDs.[21,23] A possible explanation for this finding is that the metal framework was fabricated with a gold alloy, while in this study, it was made of a chromium-cobalt alloy.

To date, only four randomized clinical studies comparing zirconia and MC posterior FPDs have been published.[13,21,23,36] Their results showed similar survival rates of both types of restorations after 3, 4, and 5 years, consistent with the results of this study.

At the 5-year time point, a slight but significant increase was observed in the periodontal parameters of GI and PI at

the abutment teeth in both groups. These results are consistent with previous studies, which reported that the risk of gingivitis is always slightly higher in the vicinity of fixed dental prostheses.[12,13,16] Significant differences were shown between the groups for GI, with zirconia restorations exhibiting better results than MC restorations, probably due to the better marginal accuracy of zirconia FPDs. With respect to the MI, significant differences were also observed in both groups from baseline, with an increase in the number of restorations with isogingival and supragingival margins; however, no significant differences were observed between the groups. This finding could be due to the increment in GI, as previously reported.[6]

Biological complications such as secondary caries, a loss of vitality, or abutment tooth fractures were not observed in this study, likely because of the inclusion/exclusion criteria applied. Likewise, no decementation or abutment sensitivity was observed in either group, which is consistent with some previous findings,[11,13] but contradictory to others.[8-10,32] In this study, a resin cement was used, and a recent systematic review[35] reported that retention loss occurred more frequently in zirconia FPDs luted with zinc phosphate or glass-ionomer cement than in those luted with resin cements. The results of this study suggest that zirconia 3-unit posterior FPDs are satisfactory at 5 years of follow-up, may serve as a restorative option for replacing a missing posterior tooth, and could be a viable alternative to MC restorations; however, additional randomized clinical studies that compare both types of restorations and have a longer follow-up period are needed to provide clinicians an optimal choice for the posterior region.

Conclusions

Within the limitations of this study, the 5-year results support previous findings and add to the body of available evidence indicating that a zirconia posterior FPD using the IPS e.max ZirCAD system may be an acceptable alternative to a MC restoration. A significant incidence of increased chipping of zirconia FPDs was observed; however, a longer observation period is required to validate these medium-term results.

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