Comparison of Metal-Ceramic and All-Ceramic Three-Unit Posterior Fixed Dental Prostheses: A 3-Year Randomized Clinical Trial

Maj H. Nicolaisen, DMD¹/Golnosh Bahrami, DMD, PhD²/Lars Schropp, DMD, PhD³/Flemming Isidor, DMD, PhD, Dr Odont⁴

**Purpose:** The aim of this randomized clinical study was to compare the 3-year clinical outcome of metal-ceramic fixed dental prostheses (MC-FDPs) and zirconia all-ceramic fixed dental prostheses (AC-FDPs) replacing a posterior tooth. **Materials and Methods:** A sample of 34 patients with a missing posterior tooth were randomly chosen to receive either a MC-FDP (n = 17) or an AC-FDP (n = 17). The FDPs were evaluated at baseline and yearly until 3 years after cementation. They were assessed using the California Dental Association assessment system. Periodontal parameters were measured at the abutment teeth, and the contralateral teeth served as control. The statistical unit was the FDP/patient. **Results:** The survival rates for MC-FDPs and AC-FDPs were 100%. The success rate was 76% and 71% for MC-FDPs and AC-FDPs, respectively. Three technical complications were observed in the MC-FDP group and five in the AC-FDP group, all chipping fractures of the ceramic veneer. Furthermore, one biologic complication in the MC-FDP group (an apical lesion) was observed. No framework fractures occurred. All patients had optimal oral hygiene and showed no bleeding on periodontal probing at any of the recalls. Only minor changes in the periodontal parameters were observed during the 3 years of observation. **Conclusions:** Three-unit posterior MC-FDPs and AC-FDPs showed similar high survival rates and acceptable success rates after 3 years of function, and ceramic veneer chipping fracture was the most frequent complication for both types of restorations. *Int J Prosthodont 2016;29:259–264. doi: 10.11607/ijp.4504*

All-ceramic systems have been introduced as a replacement for metal-ceramic for crowns and fixed dental prostheses (FDPs), mainly because they are considered to have a better esthetic outcome (tooth-resembling color and enamel-like translucency) compared to the conventional metal-ceramic systems.¹² The main shortcoming of all-ceramic systems is their inferior mechanical properties compared with metal-ceramic systems.³ However, high-strength ceramics such as yttria tetragonal zirconia polycrystal (zirconia) have been introduced.³ This contemporary ceramic material may have the potential to serve as an alternative to metals as a framework material even for posterior FDPs, but like metal frameworks zirconia frameworks need to be veneered to create an esthetically satisfactory appearance.²

Clinical studies assessing survival, success, and failure for veneered zirconia FDPs (AC-FDPs) are available and have shown promising results after follow-up periods of 2 to 5 years.⁴–¹⁰ However, there is a lack of clinical studies reporting on technical failures of metal-ceramic FDPs (MC-FDPs), although in a recent retrospective data record analysis of MC-FDPs it was found that the 10-year survival rate was 87% and the frequency of ceramic veneer chipping fractures was 6%.¹¹

A systematic review comparing MC-FDPs and AC-FDPs showed that the frequency of framework failure was 0% for MC-FDPs and < 1% for AC-FDPs.¹² The survival rates after 3 years were 97% and 90% for MC-FDPs and AC-FDPs, respectively. This difference was statistically significant.¹² Furthermore, the frequency of ceramic veneer chipping fractures in studies comparing MC-FDPs with AC-FDPs was higher for the AC-FDPs.¹² Similar results were reported in another systematic review.³ These systematic reviews are based primarily on the available prospective and retrospective cohort studies rather than randomized clinical trials (RCTs), which may affect the validity of the results.¹³

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Comparison of Metal-Ceramic and All-Ceramic Posterior FDPs

Table 1  Location of Fixed Dental Prostheses

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<th>Mandible</th>
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<tr>
<td></td>
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<td>First molar</td>
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MC-FDPs = metal-ceramic fixed dental prostheses; AC-FDPs = zirconia fixed dental prostheses.

To the authors’ knowledge, only two RCTs have been published comparing posterior FDPs made with frameworks of metal or zirconia. Both studies showed similar survival and success rates for the two types of FDPs after 3 and 4 years and, furthermore, the two studies demonstrated similar survival rates. More RCTs comparing the two systems are needed to evaluate whether posterior AC-FDPs can yield similar success and survival rates as MC-FDPs, which would allow clinicians to choose a restoration material based on clinical recommendations derived from evidence-based scientific results.

The aim of this RCT was therefore to investigate whether a three-unit AC-FDP or MC-FDP replacing a single posterior tooth will show similar clinical outcomes in terms of survival, success, and failure rates as well as technical and biologic complications.

Materials and Methods

This RCT was conducted in accordance with the Declaration of Helsinki and was approved by the Scientific Ethical Committees, Central Denmark Region (reference number M-20090196). A convenience sample was obtained from the clinic at the Department of Dentistry, Aarhus University, Denmark and by referral from private practitioners in the Aarhus area.

The patient inclusion criteria were need for replacement of a second premolar or first molar, moderate to large fillings in the teeth neighboring the edentulous area, and vertical dimensions at the treatment site allowing for a 2-mm occlusal reduction and maintaining a 4-mm preparation (in height) without risk of compromising the surrounding tissues. The exclusion criteria were general diseases, allergy to the materials used in this study, malocclusion, manifest parafunctional habits (ie, bruxism or clenching) or other temporomandibular joint disorders, apical lesion at the abutment teeth (examined with periapical radiographs using paralleling technique), endodontic treatment of abutment teeth performed < 6 months prior to enrollment, insufficient oral hygiene, periodontally involved abutment teeth (ie, bleeding on periodontal probing and probing pocket depth exceeding 4 mm), present caries activity or history of high caries incidence, present or prior xerostomia, major dental treatment (eg, prosthodontic, endodontic, orthodontic, or implant treatment; or extractions) within the last 3 months, comprehensive treatment need, and patients with fewer than 20 teeth or removable dentures.

In total, 34 patients were included in the study (21 women aged 37 to 66 years [mean age: 53 years] and 13 men aged 36 to 66 years [mean age: 49 years]). The patients were randomly allocated to receive either a MC-FDP with a high-noble metal framework (n = 17) or an AC-FDP with a zirconia framework (n = 17). Twelve second premolars and 22 first molars were replaced, equally represented in the two treatment groups (Table 1). A total of 20 FDPs were placed in the maxilla and 14 in the mandible. A total of 11 retainers were endodontically treated at the time of enrollment (6 teeth in the MC-FDP group and 5 in the AC-FDP group). Two abutments, one in each group, were already provided with a post and core.

Tooth Preparation

All treatments were performed by one experienced clinician. Shade selection was made prior to treatment under optimal conditions using VITA Toothguide 3D-master (VITA Zahnfabrik).

The tooth preparation was done with a high-speed handpiece under copious water irrigation, and new diamond burs were used for each preparation. The preparation was performed with a standardized set of diamond burs. The preparation of abutment teeth for the MC-FDPs included a 1-mm-wide shoulder on the facial aspect and a 0.6-mm-deep chamfer at the remaining circumference. The abutment teeth for the AC-FDPs were prepared with a 0.8-mm-deep circumferential chamfer. For both types of abutment preparations a 2.0- to 2.5-mm occlusal tooth reduction with a 120-degree occlusal cusp indentation was made. The axial convergence was 15 degrees, and the finish line was placed supragingivally when possible.

Full-arch impressions were made with a customized tray (NovoTray, Dansk Edelmet) using a single-step, two-phase technique with a silicone impression material (Extrude Wash and Heavy, Kerr). The impressions were examined under a microscope (Mantis, Vision Engineering) at ×8 magnification and approved by both operator (M.H.N) and dental technician. An impression with an irreversible hydrocolloid material (Aroma Fine Plus, GC) was made of the opposing dental arch, and interocclusal records were made of wax. The impressions were poured with a high-strength dental stone (Nova Die Stone, BK Giulini). The metal frameworks were cast with high noble gold-platinum (Au-Pt) alloy (BioPontoStar, BEGO) using the lost-wax
technique. The high-strength dental stone dies of the AC-FDP preparations were scanned with a dental laboratory scanner (3Shape). The zirconia frameworks were milled (Medical Scan- und Designcenter, BEGO) from presintered zirconia blocks (BeCe CAD Zirkon+, BEGO). The minimum connector dimension was 9 mm² and 16 mm² for the metal and zirconia frameworks, respectively, and the framework thickness at least 0.5 mm measured at 10 points for each retainer with an Ivanson Measuring Calibre. All frameworks were manufactured by one experienced technician and the veneering was performed by another technician by hand-layering technique. Both the metal and zirconia frameworks were tried-in before adding the veneering ceramic.

The veneering ceramics VITA VM 13 and VITA VM 9 (VITA Zahnfabrik) were used for the metal and zirconia frameworks, respectively. The veneering ceramic had an overall thickness of 1.0 to 1.5 mm on the axial walls and 1.5 to 2.0 mm occlusally, again measured at 10 points with an Ivanson Measuring Calibre.

At try-in, occlusion, articulation, and proximal contacts were checked and adjusted as needed under copious water irrigation. Occlusal adjustment and corrections regarding the pontic contact to the mucosa as well as any color adjustments were done before the final glaze firing. The FDPs were cemented using a resin-enhanced glass-ionomer cement (Ketac Cem Plus, 3M ESPE) using static finger pressure for 7 minutes. Following removal of the excess cement, the margins were polished with a slow-speed rubber polisher. All patients were recalled 2 weeks and 3 months after cementation.

The FDPs were examined at baseline (day of cementation), after 6 months, and after 1, 2, and 3 years. The assessed clinical outcomes were success (FDP remaining in situ without requiring modification), failure (loss of the FDP caused by technical or biologic complications), survival (FDP remaining in situ after complications requiring modifications), technical complications (ceramic veneer chipping fracture, marginal ditching or discoloration, loss of retention, framework fracture, or post/core fracture), and biologic complications (presence of plaque, pocket probing depth as measured to the nearest mm, bleeding on periodontal probing, marginal bone level on bite-wings, postcementation pain, dental caries, apical periodontitis on periapical radiographs, and abutment or root fracture). Surface and color, anatomical form, and marginal integrity of the FDPs were evaluated with a modified California Dental Association (CDA) assessment system. One score, the most severe for each parameter, was recorded for the individual FDP. The evaluations were performed by the operator and another clinician who had not been involved in the treatments. (M.H.N. and G.B.)

**Statistical Analysis**

The statistical unit was the FDP/patient. Analyses of the 3-year survival rate and technical success rate were performed by means of Kaplan-Meier survival analysis (log-rank), and life tables were developed. Survival curves were derived from life table analysis. Statistical analyses of data reported as frequencies were performed with Fisher Exact Test. Differences between two groups were analyzed with t test or, when appropriate, paired t test. When the data failed normality test, a nonparametric test was used. To assess associations between parameters, Pearson product-moment correlation was used. Interexaminer agreement concerning CDA was analyzed using Wilcoxon signed rank test and Spearman rank order correlation. The significance level was set to .05. The computer program package SigmaPlot 11 (Systat) was used for the statistical analysis.

**Results**

At the 3-year recall, all 34 FDPs were still in function (100% survival). Of these FDPs, 25 (13 MC-FDPs and 12 AC-FDPs) were considered successful (74%), and 9 required clinical intervention.

At the 2-week recall, one patient in the MC-FDP group and two in the AC-FDP group experienced postcementation sensitivity. Nine patients (two in the MC-FDP group and seven in the AC-FDP group) felt that chewing was slightly unnatural. This difference was not statistically significant. None of the patients reported any discomfort at any of the later recalls.

Three MC-FDPs showed technical complications (chipping fractures of the veneering ceramic on occlusal surfaces). Two occlusally located cohesive fractures (one on a posterior retainer and one on a pontic) were polished (Grade 1 according to the classification for veneer chipping fractures proposed by Anusavice16), and one adhesive fracture occlusally located on a pontic (Fig 1) was repaired with composite resin (Grade 2). In the AC-FDP group, five technical complications, all chipping fractures of the veneering ceramic, were identified. Four cohesive fractures, one located occlusally on an anterior retainer, one on a pontic (Fig 2), and two at the margin of anterior retainers (Fig 3), were polished (Grade 1). One adhesive fracture on the occlusal surface of a pontic was repaired with composite resin (Grade 2). Both Grade 2 chipping fractures were identified as having a void at the interface between the framework and veneering ceramic. Consequently, the rate of FDPs without ceramic veneer chipping fractures was 82% and 71% for MC-FDPs and AC-FDPs, respectively (Fig 4). This difference was not statistically significant (P = .44).
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All chipping fractures involved a surface area smaller than $2 \times 2$ mm, and all patients were unconcerned by these. An even distribution of ceramic veneer chipping fractures was observed irrespective of replaced tooth type, jaw, or sex.

One biologic complication (radiographic apical lesion) in the MC-FDP group was observed 6 months after treatment. This abutment tooth was successfully endodontically treated through the retainer of the FDP and the access hole was sealed with resin composite.

The average probing pocket depth at the abutment teeth and at the contralateral control teeth was similar before treatment and < 4 mm in both treatment groups. After 3 years, a small increase was observed in the average probing pocket depth of 0.1 mm and 0.2 mm at abutment teeth of MC-FDPs and AC-FDPs, respectively. The increase was statistically significant ($P = .01$) for the AC-FDP group.

At baseline, just after cementation of the FDPs, the average distance from the margin of the FDP to the marginal bone was 1.8 mm at abutment teeth in the MC-FDP group and 1.7 mm at abutment teeth in the AC-FDP group. Three years after treatment, a statistically significant ($P < .02$) loss of marginal bone was observed at MC-FDPs (0.9 ± 1.2 mm) and at AC-FDPs (0.7 ± 0.8 mm). The difference between the groups was not statistically significant. A statistically significant relationship between decreasing distances from the margin of a FDP to the marginal bone at baseline and increasing marginal bone loss assessed 3 years later was observed for the AC-FDPs ($r_s = 0.56; P = .02$), but not in the MC-FDP group ($r_s = 0.28; P = .28$).

No statistically significant differences between the two CDA assessors were observed for any of the parameters either at baseline or after 3 years, and their assessments demonstrated statistically significant ($P < .01$) correlation coefficients varying from 0.5 to 0.9. Consequently, only the scores for the clinician not involved in the treatments are presented. Both at baseline and at the 3-year follow-up almost all CDA scores were one of the two top grades, namely excellent or good (Table 2).

At baseline the distribution of surface and color scores for the two types of FDPs were similar. After 3 years of observation, more inferior scores were given in both groups. However, the AC-FDPs obtained statistically significant ($P = .04$) superior scores compared with the MC-FDPs. Regarding anatomical form, no differences were observed between the two groups at baseline or after 3 years. At the 3-year follow-up more inferior scores were observed in both groups, but only within the AC-FDP group ($P = .04$). At baseline and at the 3-year follow-up, the MC-FDPs had a superior marginal fit than the AC-FDPs although the difference was only statistically significant ($P < .001$) after 3 years.

All patients presented optimal oral hygiene, showing no presence of plaque and no bleeding on periodontal probing at all recalls. Furthermore, no clinical or radiographic signs of secondary caries lesions were observed. There were no obvious clinical signs...
of wear on the opposing dentition in any of the patients, and none of the FDPs needed further adjustment of occlusion or articulation at any recall.

Discussion

All the FDPs included in this study survived 3 years and experienced mainly technical complications, namely ceramic veneer chipping fractures, resulting in an overall success rate of 76% and 71% for the MC-FDPs and AC-FDPs, respectively.

The chipping fractures in this study were all identified as relatively small areas of missing ceramic veneer, which did not compromise esthetics, occlusion, or function and did not necessitate replacement of the FDP. Six out of eight chipping fractures were primarily superficial within the ceramic veneer (cohesive) and were polished. The two remaining adhesive chipping fractures were successfully repaired. The ceramic veneer chipping fractures all occurred during the first 2 years (Fig 1).

The frequency of ceramic veneer chipping fractures for AC-FDPs was similar to that observed in several other studies, although fewer ceramic veneer chipping fractures have also been reported.6,10,17 In this study, slightly more chipping fractures were observed among AC-FDPs compared with MC-FDPs. A similar result was reported in two other RCTs comparing posterior FDPs with frameworks of either metal or zirconia.14,15 Hand-layered veneering ceramic, as used in this study, has shown a higher chipping incidence than pressed veneer ceramic.6,17 Similarly, few fractures of the ceramic material have been observed in posterior FDPs fabricated of monolithic lithium disilicate.18

In the present study, an even distribution of ceramic veneer chipping fractures was observed irrespective of replaced tooth type, jaw, or sex. One systematic review reported an increased frequency of ceramic veneer chipping fractures in the maxilla compared to the mandible among AC-FDPs, but similar to the present study no differences were found when comparing tooth type (molar or premolar) or sex.12

Rekow et al proposed the following possible reasons for ceramic veneer chipping fractures: mismatch of coefficient of thermal expansion between framework material and veneer ceramic, lack of framework support, veneer thickness, inadequate experience with ceramics, firing and cooling rate errors, surface damage from CAD/CAM production, or sliding contact fatigue during oral function.19

The two adhesive ceramic veneer chipping fractures may be related to a handling flaw during the veneer layering process causing development of a material void at the interface between the framework and veneering ceramic during firing. The resulting unsupported area of ceramic veneer ultimately may lead to premature failure.

The number of FDPs rated as excellent with the CDA for both surface and color and anatomical form decreased in both groups from baseline to the 3-year follow-up, but only for the AC-FDP group was the deterioration in anatomical form statistically significant. This observation can possibly be ascribed to the ceramic veneer chipping fractures and the repair. In other studies, a decrease in the frequency of excellent ratings for surface and color and anatomical form has also been observed.10,15

The MC-FDPs had a superior marginal fit compared to AC-FDPs both at baseline and at the 3-year follow-up. This result corroborates the findings reported by Sailor et al.14 In both studies, the metal framework was fabricated of gold alloy. In the AC-FDP group in the present study, a small but statistically significant increase in average probing pocket depth was registered from baseline to the 3-year follow-up. This increase is probably without clinical consequence. Furthermore, an average marginal bone loss at the abutment teeth of < 1 mm was observed in both groups. This is probably a result of the restorative procedures, since the oral hygiene was optimal and no bleeding on probing was recorded at any of the recalls. An increased marginal bone loss at teeth with crowns or FDPs has been observed in a Danish population study.20 In the present study, a statistically significant negative relationship was observed between the distance from the

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<th>Marginal fit</th>
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Scoring was performed by a clinician not involved in the treatments. 4 = excellent, 3 = good, 2 = acceptable (repair), and 1 = unacceptable (replacement).

Table 2 Number and Frequency (%) of CDA Assessments at Baseline and 3-Year Follow-Up for MC-FDPs and AC-FDPs

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margin of the AC-FDP to the marginal bone at baseline and the marginal bone loss assessed 3 years later.

Aside from the transient biologic complications related to the treatment procedures (postcementation sensitivity and discomfort in chewing) biologic complications in the present study were rare; only a radiographic apical lesion at one abutment tooth was seen. This relatively low frequency of biologic complications may be attributed to the strict case selection.

The clinical outcomes in this study were similar in the two treatment groups. Therefore, both three-unit MC-FDPs and three-unit AC-FDPs can be used in replacing a posterior tooth. The observation period was only 3 years, and more complications and a lower survival rate may be expected with an extended observation period. Extended observation also might reveal differences in outcome success between the two types of restorations. To further evaluate the treatment outcomes regarding survival, success, and failure rates, the patients will be recalled at 5 and 10 years.

Conclusions

With the applied designs of FDPs and within the limitations of the observation period it can be concluded that both MC-FDPs and AC-FDPs have a high survival rate (100%), although technical complications in the form of veneer chipping fractures were rather frequent (≈ 25%). However, biologic complications were rare (3%). The overall clinical performance of the two types of FDPs was similar.

Acknowledgments

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