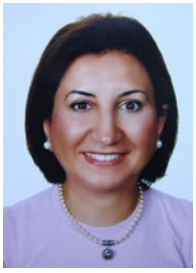
Fusun Ozer

A retrospective survey on long-term survival of osterior zirconia and porcelain-fused-to-metal crowns in private practice

Fusun Ozer, DMD, PhD[1]/Francis K. Mante, BDS, DMD, PhD[2]/Gerard Chiche, DDS[3]/Najeed Saleh, DMD[4]/Takuro Takeichi, DDS, PhD[5]/Markus B. Blatz, DMD, PhD[6]

Objectives: This retrospective survey assessed the clinical survival of zirconia-based crowns (PFZ) and conventional porcelain-fused-to-metal (PFM) crowns on posterior teeth in private practice. **Method and Materials:** A print survey of 13 private practitioners was conducted to assess the long-term survival of previously placed full-coverage crowns. The practitioners reported a total of 2,182 premolar (n = 881) and molar (n = 1,301) full-coverage single crowns, 1,102 PFZ and 1,080 PFM, fabricated by one dental laboratory (Cusp, Boston) and followed over 7.4 years. All post-cementation complications (eg, porcelain fractures and chippings) were recorded as failures. In the PFZ group, one veneering porcelain (CZR, Kuraray Noritake) was used in combination with three coping systems (Lava, 3M ESPE; Procera, Nobelbiocare; Katana, Kuraray Noritake). Kaplan-Meier survival analysis was used for statistical analyses. **Results:** The probability of survival of posterior crowns investigated over the period of study (7.4 years) was 99.3% for PFM and 99.2% for PFZ restorations. There was no statistically significant difference ($P = .614$) between PFZ and PFM groups. In the PFZ group, probability of survival was 97.7% for Lava, 100% for Procera, and 99.5% for Katana. There were no statistically significant differences ($P = .034$) between the three PFZ systems or the location of the crowns (premolar or molar; $P = .454$). **Conclusion:** PFZ crowns fabricated with CZR and three commercial zirconia coping systems revealed excellent long-term success rates. Survival times and survival probabilities of posterior PFZ crowns did not differ from PFM crowns and were independent of type of coping system and location (molar or premolar teeth). *(Quintessence Int 201#;##:5–12; doi: ##.####/j.qi.a#####)*

Key words: crowns, long-term survival, PFM, private practice, zirconia

For full-coverage restoration of severely compromised teeth, porcelain-fused-to-metal (PFM) crowns are considered the "gold standard" due their reliability and clinical use for more than 30 years. A skilled dental technician can mask the underlying cast-metal coping with an adequate veneering porcelain and create a tooth-like restoration. However, the gray color and

[1] Clinical Associate, Department of Preventive and Restorative Sciences, School of Dental Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA.

[2] Associate Professor, Department of Preventive and Restorative Sciences, School of Dental Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA.

[3] Professor, Department of Prosthodontics, School of Dentistry, Georgia Health Sciences University, Augusta, Georgia, USA.

[4] Clinical Professor, Department of Preventive and Restorative Sciences, School of Dental Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA.

[5] Assistant Professor, Department of Preventive and Restorative Sciences, School of Dental Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA; and Department of Fixed Prosthodontics, School of Dentistry, Aichi Gakuin University, Nagoya, Japan.

[6] Professor and Chair, Department of Preventive and Restorative Sciences, School of Dental Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA.

Correspondence: Dr Fusun Ozer, Department of Preventive and Restorative Sciences, University of Pennsylvania School of Dental Medicine, 240 S. 40th Street, Evans Building S6, Philadelphia, PA 19104, USA. Email: ozerf@dental.upenn.edu

Fig 1 Intaglio aspects of a posterior PFM and a PFZ crown. The gray color of the metal-alloy coping in PFM restorations makes the creation of a natural tooth-like appearance a challenge.

Fig 2 Application of veneering porcelain (CZR, Kuraray Noritake) to zirconia coping (Katana, Kuraray Noritake). Proper selection, application, and firing of veneering porcelain with physical and thermal properties adapted to zirconia framework material seem key for long-term clinical success of PFZ crowns.

Fig 3 Modern zirconia systems offer copings in a variety of shades. Note the anatomic shape of the copings for optimal support of the veneering porcelain.

Fig 4 The translucent properties of high-strength zirconia copings are obvious when placed on a light source.

Fig 5 and 6 The appearance of natural teeth can be mimicked closely with adequate materials and techniques, even in posterior areas.

Fig 7 Completed molar PFZ crown on top of a light source demonstrates tooth-like optical properties.

complete opacity of the metal requires a thick opaque layer and make it difficult to fully emulate esthetics as inherent in a natural tooth.[1,2] Today, all-ceramic crowns are becoming increasingly popular as a more esthetic and biocompatible solution in full-coverage restoration cases, even in the posterior areas of the jaws (Fig 1). All-ceramic crowns provide excellent properties of esthetic capability, color stability, wear resistance, chemical resistance, and biocompatibility.[3,4] They can be fabricated from one material (monolithic) or, similar to PFM restorations, in a bilayered configuration where a coping, made from a high-strength ceramic material, is veneered with a matching veneering porcelain (Fig 2). Zirconium-dioxide (zirconia) offers several advantages as a core material for full coverage porcelain-fused-to-zirconia (PFZ) crowns due to its esthetic characteristics,

mechanical properties, and biocompatibility.[5] Depending on the temperature, zirconia has several crystalline structure phases. In dentistry, however, it is most commonly used in forms of yttria-stabilized tetragonal polycrystals (Y-TZP), which provide high flexural strength and a distinctive property called "transformation toughening".[6-10] Due to the unique combination of strength and optical properties, PFZ restorations are indicated for all areas in the mouth, even in the posterior (Figs 3 to 7).

Modern computer-aided design/computer-assisted manufacture (CAD/CAM) technology simplifies the production process of precise and predictable all-ceramic restorations and has enabled their rapidly increasing, widespread use in clinical practice. Excellent long-term success rates were reported for CAD/CAM-fabricated aluminum-oxide-based crowns.[11,12] Clinical reports for zirconia-based restorations have indicated varying degrees of success.[13,14] A literature search was conducted to assess the scientific evidence on clinical success of PFZ and PFM crowns on natural teeth. Following a systematic search strategy, four scientific clinical studies were found for PFZ crowns[15-18] and 15 studies on PFM crowns.[19-33] The clinical studies on PFZ crowns had observation times of 2 to 3 years, while PFM studies had follow-up times of up to 25 years, indicating the lack of comparable clinical long-term data on zirconia-based restorations. The main reason for restoration failures in both crown groups was chipping and/or fracture of the veneering porcelain.[34] Early clinical reports and studies on multiple-unit zirconia-based fixed partial dentures (FPDs) indicate a pronounced incidence of veneer chippings.[1] Framework design, surface quality, and firing parameters during the veneering process were discussed as causes for porcelain chippings. An optimized substructure design with increased occlusal support and an even thickness of the veneering porcelain reduces the number and surface area of chipping incidents.[35,36] Other possible causes for veneer failure include incompatible coefficients of thermal expansion (CTE) between the core material and the veneering porcelain, residual thermal stresses in the core and its effect on firing parameters, quality of CAD/CAM software, design defects, and different moduli of elasticity.[37-40] Therefore, proper selection and application of a superior veneering porcelain in respect to CTE, modulus of elasticity, and flexural strength are crucial for functional success and clinical longevity of bilayer all-ceramic restorations.[40] Clinical and technical handling aspects in terms of knowledge and experience of the treating dentist and the dental laboratory with a specific procedure and material are additional factors that fundamentally influence clinical success.

Randomized clinical trials conducted in a standardized and controlled environment provide a high level of scientific evidence. However, there is an increasing emphasis on the importance and relevance of clinical information gathered from private practices, where new materials are being introduced at a fast pace and restorations are being inserted in large numbers.[41]

The aim of this retrospective print survey was to assess and compare the clinical long-term performance of PFZ and PFM posterior tooth-supported crowns in dental practices. Based on the available evidence, we hypothesized that there are no significant differences in the clinical long-term survival between PFZ and PFM posterior crowns.

METHOD AND MATERIALS

This survey was conducted in accordance with the Helsinki Declaration of 1975 and as revised in 2000 and approved by the local ethics committee. Thirteen dentists, 7 prosthodontists, and 6 general practitioners from the Greater Boston area and adjacent states (including New York and Maine), participated in this retrospective survey to evaluate the clinical survival of single PFZ and PFM crowns previously placed on posterior teeth in their private practices. All restorations were fabricated by one dental laboratory (Cusp Dental Research, Boston, MA) with a long experience with the specific laboratory manufacturing parameters required for zirconia-based restorations.

The practitioners reported a total of 2,182 posterior PFZ (n = 1,102) and PFM (n = 1,080) crowns followed over 7.4 years. Of those, 881 crowns were placed on pre-

molar and 1,301 on molar teeth. There were 777 molar and 303 premolar crowns in the PFM group, as well as 524 molar and 578 premolar crowns in the PFZ group.

In the PFZ group, one veneering porcelain (CZR, Kuraray Noritake) was used in combination with three zirconia coping systems: Lava (3M ESPE; n = 214), Procera (Nobel Biocare; n = 36), and Katana (Kuraray Noritake; n = 852). One veneering porcelain (EX-3, Kuraray Noritake) was used for all PFM crowns (n = 1,080) in combination with a precious alloy (52% Au). The private practitioners were asked to indicate any post-cementation complications on the print survey sheet. Any complications, including small porcelain chippings, were considered failures. A calibration meeting was held with the participating practitioners before the survey was sent to them. Kaplan-Meier survival analysis was used for statistical analyses. Multiple comparison procedures (Holm-Sidak method) were used for pairwise comparisons with the overall significance level set at .05.

RESULTS

The results of this survey on posterior crowns revealed a mean survival time of 7.4 years with a survival probability of 99.2% for PFZ crowns and 99.3% for PFM crowns (2,694 days mean survival). There was no significant difference between the two modalities for the time interval studied ($P = .614$). Survival probabilities of individual zirconia coping systems were 97.7% for Lava (2,637 days mean survival), 100% for Procera (2,706 days mean survival), and 99.5% for Katana (2,233 days mean survival), which were not significantly different from each other ($P = .034$). Seven of the 1,080 PFM crowns and nine out of 1,102 PFZ crowns were reported as failures.

Overall, there was no statistically significant difference between molar and premolar crowns ($P = .454$). In addition, when analyzing each material group independently, there were significant differences between molar and premolar crowns in the PFM ($P = .418$) or in the PFZ ($P = .617$).

Detailed results are listed in Tables 1 and 2, and illustrated in Fig 8.

DISCUSSION

The results of this survey support our hypothesis that there are no differences in the clinical long-term survival between PFZ and PFM posterior crowns. In addition, there was no difference between the three zirconia coping systems or location of the crowns (molar or premolar teeth). The survival rates in all groups were high despite the long study interval of 7.4 years.

When assessing the scientific literature on the clinical success of PFZ and PFM crowns, the lack of long-term data for PFZ restorations is obvious. Only four studies[15-18] evaluating single PFZ crowns were found, published in 2009 and 2010. In those studies, a total of 300 single crowns, 82 in the anterior and 218 in the posterior jaw, were inserted. The average observation time ranged from 2 to 3.2 years with survival rates between 92.7% and 100%. The estimated cumulative survival rate calculated from these results was 95.9% (range 91% to 100%) after 3 years. A total of 3,321 single PFM crowns were evaluated in 15 studies published from 1991 through 2011.[19-33] The mean observation time ranged from 2.8 to 24.8 years showing survival rates of 70% to 100% after 12 to 298 months. The estimated cumulative survival rate was 95.4% (range 84.1% to 100%) after 3 years. These studies were conducted by dentists in universities,[15,17-19,22,28,30-33] public services,[20,26,27] or private practices.[16,21,23-25,27,29] Survival rates among these sites were comparable. The short-term results were comparable for both types of crowns, with slightly better results for the PFZ crowns. The calculated 3-year cumulative survival rates showed insignificant differences between the PFZ (95.9%) and PFM crowns (95.4%).

The current survey study provides a long-term assessment and comparison of both PFM and PFZ crowns, which, based on our and other literature reviews, was not previously available.[34] Similar to the survival estimates extrapolated from studies published in the literature, there were no differences between the two types of crowns placed on posterior teeth. A recent systematic review on clinical fracture rates of all-ceramic crowns comes to a similar conclusion.[34] In this

Table 1 Survival analysis of posterior PFZ and PFM crowns

Group	Total no. of crowns	Mean survival [SE] (days)	Probability of survival [%]
CZR Katana	852	2232 [4]	99.5
CZR Lava	214	2638 [25]	97.7
CZR Procera ZR	36		100.0
PFZ Total	1102	2684 [6]	99.2
EX-3 52% Au	1080	2694 [5]	99.3
PFM Total	1080	2694 [5]	99.3

Table 2 Detailed results and tooth distribution

Molars/premolars	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar	Total
CZR Katana	179	252	309	112	0	852
CZR Lava	54	70	72	18	0	214
CZR Procera	11	12	10	3	0	36
PFZ Total	244	334	391	133		1102
Failures	2	2	3	2		9
EX-3 52% Au	113	190	505	270	2	1080
PFM Total	113	190	505	270	2	1080
Failures	0	1	4	2	0	7

review, the authors calculated 5-year incidence of ceramic fracture or chipping was about 5.7% for PFMs and 3.0% for all-ceramic crowns.[2,34] It was noted, however, that more long-term clinical trials on zirconia-based crowns are needed.[34] Since success rates from only one crown type are difficult to assess and compare without a reference, a study evaluating and comparing both PFM and PFZ restorations placed in the same clinical settings seemed most valuable. While the overall survival rates are higher than in other studies, the most important conclusion from this study is that, by comparison, both crown types fared equally well.

Location of the crowns on either premolar or molar teeth did not significantly influence clinical survival. Significant differences in survival of all-ceramic crowns in relation to restored tooth type were found in a systematic review.[34] However, these differences were mainly due to the large variety of ceramic materials and systems assessed: glass-ceramic materials and feldspathic ceramic crowns revealed much greater depen-

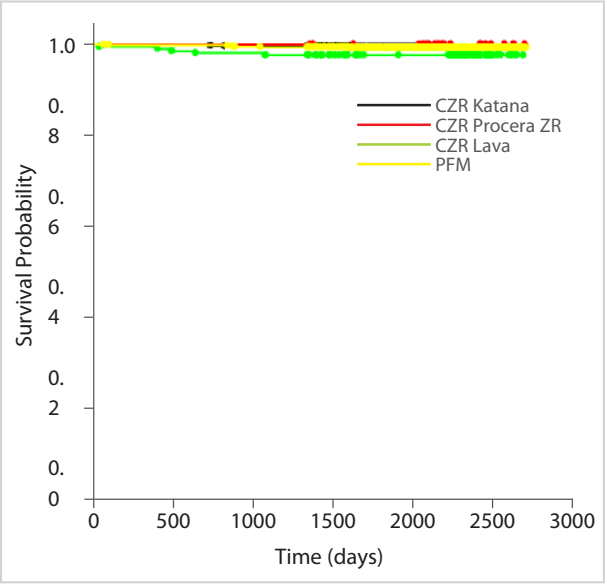

Fig 8 Survival analysis of posterior PFM and PFZ (CZR Katana, CZR Procera ZR, and CZR Lava).

dency on tooth location and substantially higher fracture rates in molar than in premolar teeth. Bilayer all-ceramic crowns with a high-strength ceramic core did not demonstrate a strong dependency on tooth type. Core fractures in PFZ single crowns were "noticeably infrequently reported" and veneer fractures ranged from 0% to 5.9% over 1- to 3-year follow-ups.[34] The authors also cite a lack of clinical trials on long-term PFZ crown performance, which makes accurate comparisons difficult.[34]

The high success rates found in the present study may be due to multiple reasons. The type of evaluation, a retrospective print survey of various practitioners, is not ideal in terms of standardization, reliability, and objectivity and does not provide the level of scientific evidence revealed by prospective randomized clinical trials. Since there was no blinding or separation of the procedures and the clinicians/evaluators, bias cannot be excluded. The thoroughness and correctness of the information provided by the practitioners cannot be determined either. The outcomes of this survey have to be viewed in light of these limitations. However, since the economic and clinical success of the practitioners is directly related to the performance of their restorations and respective materials, it is highly unlikely that there would be an unreasonably positive or negative bias towards either one of the crown restoration material groups. Despite the shortcomings of retrospective surveys and practice-based research, there is a rapidly increasing trend and grant funding geared towards gaining relevant information on dental interventions from dental clinicians in private offices and practice-based research networks.[41]

Clinical success rates of crowns are directly related to the quality of the clinician and the dental laboratory, as well as the materials used. All private practitioners who participated in this survey are experienced clinicians in successful practices, most of them with advanced specialty training certificate in prosthodontics. Adequate treatment planning as well as knowledge and clinical experience with full-coverage restorations may be contributing factors to the high success rates reported in this survey.

Several in-vitro studies have demonstrated that knowledge and proper application of adequate fabrication parameters are key to the success of zirconia-based restorations.[35-40] These parameters include an anatomically shaped substructure framework design that provides increased occlusal support and ensures an even thickness layer of the veneering porcelain.[35,36] The unique physical and thermal properties of zirconia require specific surface treatment procedures as well as adapted veneering porcelain layering, firing, and cooling protocols that substantially differ from the ones applied for metal-alloy copings and frameworks.[37,38,40] The actual veneering porcelain has to complement the properties of the core material and is, therefore, crucial for clinical success and longevity. CTE values of dental metal alloys generally range between 13 and 15 ppm, which is very different from zirconia with a CTE of about 10. The CTE of the veneering ceramic should be slightly lower than that of the core material to create favorable, internal compressive stresses during the cooling process.[40] Other influencing factors include modulus of elasticity, flexural strength, and hardness of the veneering porcelain. For all PFZ restorations followed in this survey, only one veneering porcelain (CZR) was used for all zirconia cores by one dental laboratory, strictly following manufacturer's instructions. CZR has a CTE of about 9.1 and has demonstrated superior physical properties and bond strengths in laboratory investigations.[40] Similarly, PFM crowns were fabricated by the same laboratory with a matching veneering porcelain. The high clinical long-term success rates found in this study may well be influenced by the selection and appropriate use of the veneering ceramic. Conversely, high veneering porcelain chipping rates found in other studies may be due to inadequate veneering material selection and handling.[1]

Several in-vitro studies have demonstrated the unique material and handling requirements for PFZ restorations, which differ substantially from the ones applied for traditional PFM restorations. Better knowledge of these parameters and constantly improving fabrication protocols, materials, and guidelines ensure superior clinical quality, reliability, and longevity. This

retrospective survey study revealed that posterior teeth restored with either PFZ and PFM single crowns can be equally successful in private practice after many years of service. Additional studies, especially randomized controlled clinical trials, are necessary to confirm these findings.

CONCLUSION

PFZ crowns fabricated with CZR and three commercial zirconia coping systems revealed excellent long-term success rates. Survival times and survival probabilities of posterior PFZ crowns did not differ from PFM crowns and were independent of type of coping system and location (molar or premolar teeth).

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CONFLICT OF INTEREST

Dr Blatz has received research grants and speaking honoraria from Nobel Biocare, 3M Espe, and Kuraray Noritake. Dr Chiche is a paid consultant of Kuraray Noritake.

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