The Clinical Performance of Porcelain-Fused-to-Metal Precious Alloy Single Crowns: Chipping, Recurrent Caries, Periodontitis, and Loss of Retention

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Purpose: This retrospective study investigated the frequency and time history of chipping and facing failures, recurrent caries (RC), periodontitis (PE), and loss of retention (LR) of porcelain-fused-to-metal (PFM) single crowns. ***Materials and Methods:*** A total of 997 PFM single crowns had been inserted according to a standardized treatment protocol from January 1984 to May 2009. The frequency and time history of chipping and facing failures were evaluated, as were possible risk factors from historical clinical data. Risk factors were bruxism, the type of antagonist, and the location of crowns (mandible, maxilla, anterior, posterior). The survival times of crowns were estimated using Kaplan-Meier (KM) analysis. ***Results:*** The median follow-up time calculated with the inverse KM method was 4.33 years. Anterior and posterior PFM crowns showed 5-year survival rates (time to crown replacement) of 96.4% and 97.5% and 10-year survival rates of 92.3% and 95.9%, respectively. Chipping was found in 17 (1.7%) of the 997 PFM crowns. According to the KM method, the 5- and 10-year free-of-event-rates for chipping of anterior crowns were both 98.9%, and the rates for posterior crowns were 98.2% for 5 years and 97.3% for 10 years. Thirteen patients showed RC (1.3%) and 144 (14.4%) PE. The 5-year free-of-event-rate for RC was 98.7% and the 10-year free-of-event rate was 97.2%. For PE, the 5-year free-of-event-rate was 85.8% and the 10-year free-of-event rate was 72.2%. The 5- and 10-year free-of-event-rates for LR were 92.2% each for anterior teeth and 97.1% each for posterior teeth. ***Conclusions:*** Patients with PFM crowns may expect long-term survival for their restoration. Clinical complications are rare. Chipping of the veneer or loss of retention may occur during the first few years. While chipping of the veneer may occur during the first few years, the frequency of caries or periodontitis increases with the length of oral service and with age. *Int J Prosthodont 2014;27:153–160. doi: 10.11607/ijp.3440*

Porcelain-fused-to-metal (PFM) crowns are the most frequently used type of restoration in dentistry. For more than five decades, these devices have been successfully inserted in the oral cavity. Many clinicians seem to prefer PFM crowns because of their clinically measurable longevity, which is much higher than that of previous generations of all-ceramic crowns. However, the literature contains only a few long-term clinical reports on PFM crowns[1–6] as most clinical studies focus on fixed partial dentures, implant-supported restorations, or various all-ceramic systems.[7–12] A comparison between recently presented all-ceramics systems, such as zirconia, and the established PFM restorations necessitates more data on PFM restorations.

This retrospective study aimed at collecting such data on PFM crowns. The crowns had been inserted at the Department of Prosthodontics, Regensburg University Medical Center, from 1984 to 2009. The study focused on clinical outcomes, such as the frequency of chipping or failure of the ceramic veneer, the frequency of recurrent caries, periodontitis, and loss of retention of the crowns. Survival and hazard rates were calculated.

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Table 1 Description of the Sample

Sex	
Female	n = 546 (54.8%)
Male	n = 451 (45.2%)
Mean age	52.5 y (SD: 13 y)
Location	
Anterior	n = 309 (31%); implant-supported restorations: n = 12 (3.8%)
Posterior	n = 688 (69%); implant-supported restorations: n = 21 (3.0%)
Maxilla (61.6%)	n = 662 (66.3%); anterior: n = 261 (39.4%); posterior: n = 401 (61.6%)
Mandible (85.7%)	n = 335 (33.7%); anterior: n = 48 (14.3%); posterior: n = 287 (85.7%)
Luting agent	
Zinc oxide–phosphate cement	n = 669 (67.1%)
Glass-ionomer cement	n = 12 (1.2%)
Zinc oxide–eugenol cement	n = 258 (25.8%)
Zinc oxide–eugenol-free cement	n = 20 (2.0%)
Composite cement	n = 5 (0.5%)
Self-adhesive composite	n = 32 (3.2%)
Posts/cores	
No posts	n = 735 (73.7%)
Posts	n = 262 (26.3%)
No root filling	n = 643 (64.6%)
Root filling	n = 353 (35.4%)

Materials and Methods

Only PFM single crowns made of precious alloy were included. The PFM crowns were selected using the search tool of a dental software (Report Smith of Highdent Plus, Systema). Many patients received more than one crown during an appointment. Only the first crown documented in the clinical data was chosen for this investigation, which allowed the consideration of each patient as a statistically independent case. Other crowns of a patient were excluded. Furthermore, patients with incomplete records and crowns made of nonprecious alloy, glass fiber–reinforced composite, and all-ceramic were excluded (n = 472).

Therefore, 997 PFM precious alloy crowns that had been inserted at the Department of Prosthodontics of the Regensburg University Medical Center between 1984 and 2009 were analyzed. Table 1 and Fig 1 show further details from this sample. The crowns had been made according to a standardized treatment protocol by full-time staff of the department.[13] After insertion of the crown, the patients were instructed to come to a follow-up examination at least once per year.

The frequency and time point of chipping or facings failures, as well as possible risk factors on the basis of historical clinical data, were retrospectively evaluated. Risk factors were bruxism, implant-supported restorations, the type of antagonist (fixed vs removable dentures), and crown location (mandible, maxilla, anterior, posterior).

Chipping was defined as any loss of substance of the ceramic facing that could not be attributed to any forms of wear. In case of intolerable or unrepairable substance loss, a new crown had to be made. Such cases were rated as a failure, and the decision was made by a clinician.

The frequency of recurrent caries defects, the occurrence of periodontitis, or loss of cementation (re-cementation necessary) based on the historical clinical data were also evaluated. In case of more than one event, for instance, loss of cementation and caries, the event mentioned first was evaluated in the historical clinical data.

Recurrent caries was diagnosed using metal probes or a caries detector (GC), or both. If a cervical filling could be made, the case was rated as recurrent caries. Cases were considered as a failure when caries defects were so severe that the abutment tooth was in danger; in such cases, a new crown was made.

The diagnostic tool for periodontitis changed during the observation time.[14,15] A case was rated as periodontitis when the historical clinical data stated a Bleeding Index or any treatment typically conducted in case of periodontitis. Loss of cementation was noted when a luting agent lost its function and a crown could be removed from the abutment by gentle pulling.

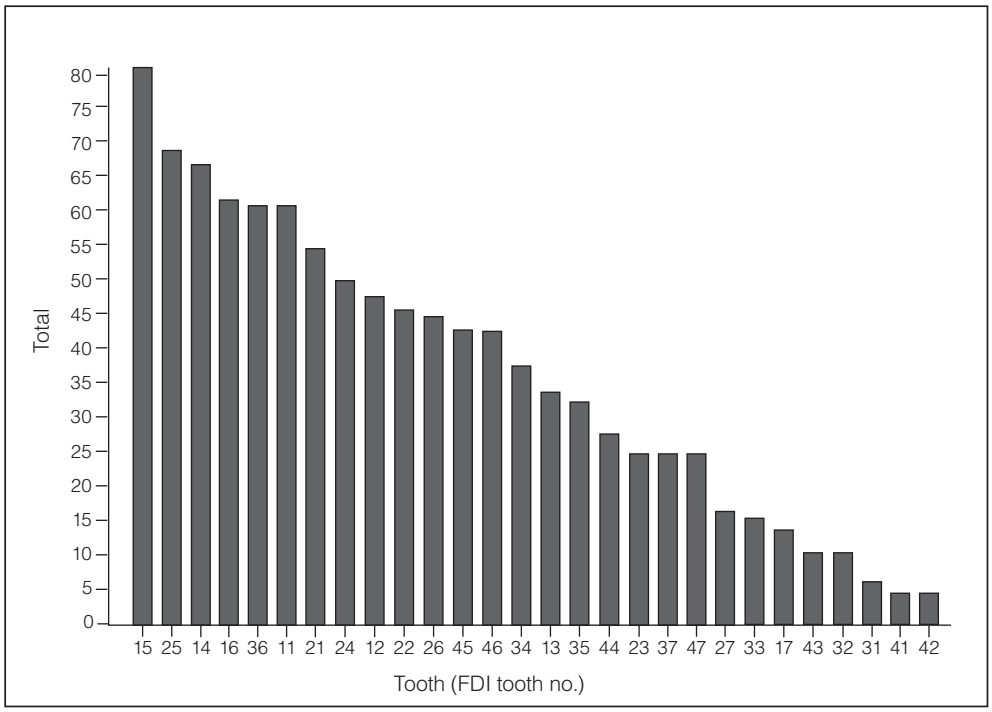

Fig 1 Teeth treated with PFM crowns.

Statistical Analysis

Continuous variables are presented as means and SDs and categorical variables as absolute numbers and proportions. The survival time of the PFM crowns was calculated by means of the Kaplan-Meier (KM) analysis.[16] Statistical differences between the subgroup levels were determined with the logrank test ($\alpha = .05$).[16–18] A case was rated as "termination due to failure" (= event) when a crown/tooth lost its function and a new one had to be made. This decision was made by a full-time clinician of the department. Crowns that were not replaced or did not fail at their final examination were classified as censored. A univariate or multivariate Cox regression analysis determined the impact of each covariate, such as the type of antagonist, bruxism, location (maxilla or mandible), anterior or posterior area, core build-up material, implant-supported restoration, and luting agent. Subcategories including fewer than 10 cases were excluded.[19]

Clinicians wish to know at what time point chipping and facings failures, recurrent caries, or periodontitis may be expected. This calculation was based on clinical cases with only one event; therefore, the time considered was not based on the entire observation time but on the event-related time.

The hazard rate λ[18] was estimated on a biennial basis within specific time intervals by dividing the total survival period into time segments, counting the number of events occurring during the time segment, and dividing the number of events by the number of patients at risk during that segment (Table 2). The biennial time interval was chosen because the number of events in an annual time interval was low, and trends were easier to detect on a biennial basis. Few events may be an advantage from the clinical point of view but not from the view of the statistician.

All data entries and calculations were made with the software package PASW Statistics version 18.0 (SPSS, IBM). All reported *P* values are two-sided, and *P* values of .05 were considered the threshold of statistical significance. Since this investigation was an exploratory study, no adjustments for multiple testing were made.

Results

Survival Rate

The median follow-up time calculated with the inverse KM method[20] was 4.33 years. Anterior and posterior PFM crowns showed 5-year survival rates (time to crown replacement) of 96.4% and 97.5%, respectively, and 10-year survival rates of 92.3% and 95.9%, respectively (Fig 2). No significant difference between anterior and posterior crowns could be found (log rank: $P = .206$).

Table 2 Calculation of the Hazard Rate λ

Example: first 2-year interval
TTE = time to event (mo)
TTC = time to censoring (mo)
ET = exposure time (mo)
$f_1 = \Sigma$ TTE first 2 years = ET cases with event
$F_1 = \Sigma$ TTC first 2 years + n remaining cases after 2 years * 24 = ET cases without event in the first 2 years
d_1 = Number of events in the first 2 years
Total exposure during the first 2 years for all patients: $f_1 + F_1$
Hazard rate: $\lambda_1 = \frac{d_1}{(f_1 + F_1)}$ (ie, the risk of having an event in 1 month under the condition to be event-free at the beginning of this month for the first 2 years)
λ_1 * 24 is the hazard rate on a biennial basis for the first 2 years.

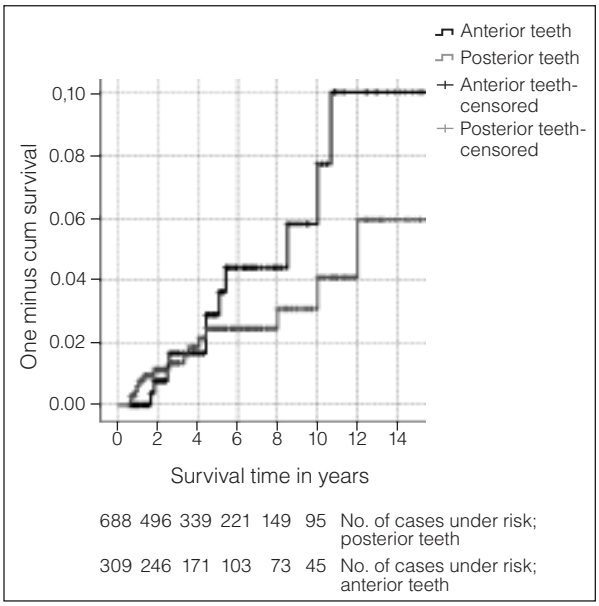

Fig 2 One minus survival was calculated with the Kaplan-Meier estimation. A case was rated termination due to failure when a crown lost its function and a new one had to be made. Crowns that were not replaced or did not fail at their final examination were classified as censored. The number of cases under risk at a specified time is depicted. For example, after 8 years, 149 cases of posterior teeth were still under risk.

Fig 3 One minus survival of the event chipping was calculated using the Kaplan-Meier estimation. The number of cases under risk at a specified time is depicted. For example, after 8 years, 149 cases of posterior teeth were still under risk.

Chipping and Facing Failures

Chipping was found in 17 (1.7%) of 997 PFM crowns (anterior: n = 5, 1.9%; posterior: n = 12, 1.8%). According to the KM method, the 5- and 10-year free-of-event-rates for chipping of anterior crowns were both 98.9%; the rates for posterior crowns were 98.2% for 5 years and 97.3% for 10 years (Fig 3). No significant difference between anterior and posterior crowns could be found (logrank: $P = .778$). Possible risk factors, such as bruxism, type of antagonist, maxilla, mandible, posterior or anterior area, or implant-supported restorations had no significant influence on chipping and facing failures. On a biennial basis, the hazard rate of chipping in the first 2 years was 0.012, ie, 1.2 of 100 person-years of exposure showed chipping. For the next three intervals, the hazard rates dropped to 0.005, 0.003, and 0.004; therefore, about 3 to 5 of 1,000 person-years of exposure showed chipping (Fig 4).

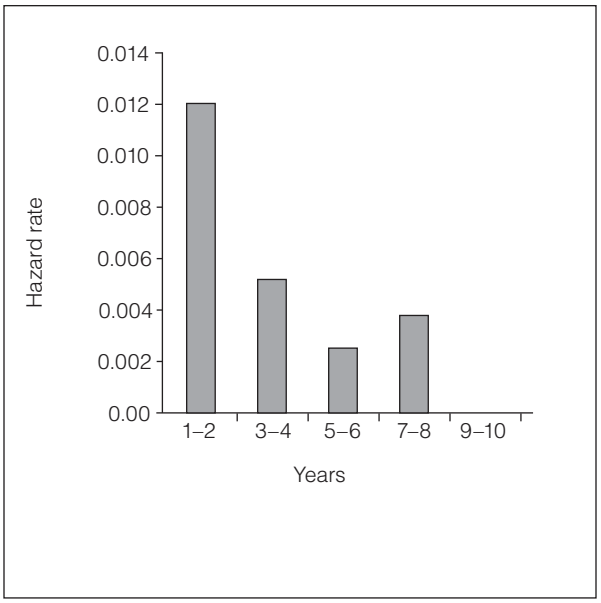

Fig 4 Hazard rate of chipping on a biennial basis. For example, the hazard rate of chipping on a biennial basis was 0.012 in the first 2 years, ie, 1.2 of 100 person-years of exposure showed chipping.

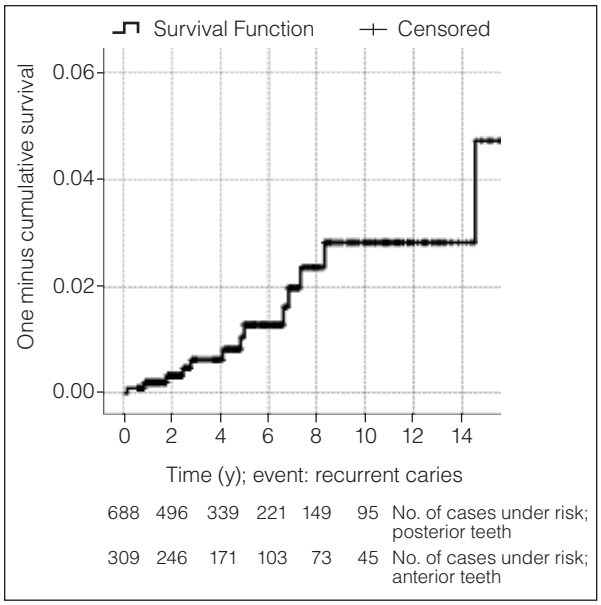

Fig 5 One minus survival of the event recurrent caries was calculated using the Kaplan-Meier estimation. The number of cases under risk at a specified time is depicted. For example, after 8 years, 149 cases of posterior teeth were still under risk.

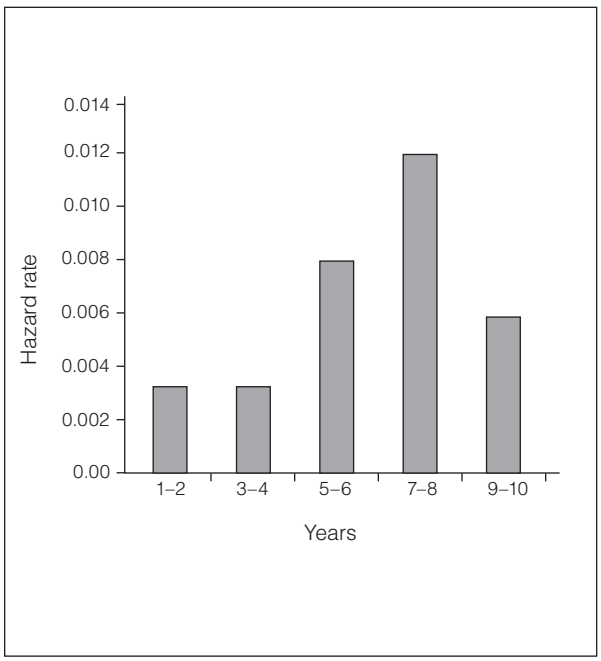

Fig 6 Hazard rate of recurrent caries on a biennial basis. For example, the hazard rate of recurrent caries on a biennial basis was 0.004 during the first 2 years, ie, 4 of 1,000 person-years of exposure showed recurrent caries for the first 2 years.

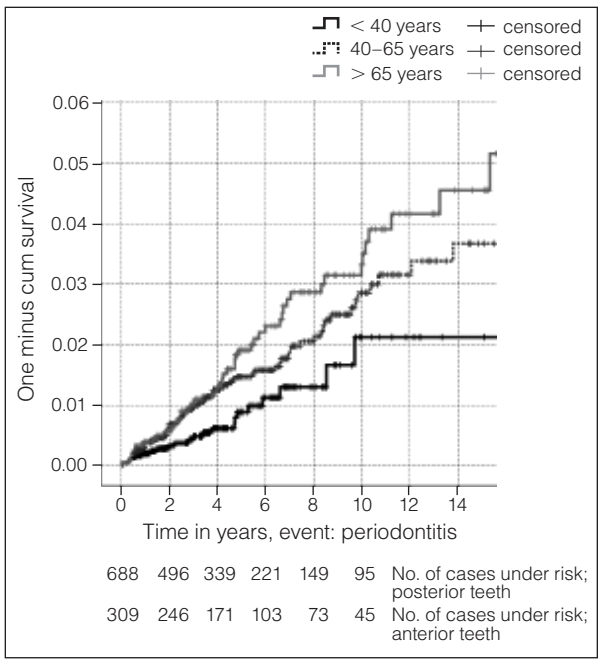

Fig 7 One minus survival of the event periodontitis was calculated using the Kaplan-Meier estimation. The number of cases under risk at specified time is depicted. For example, after 8 years, 149 cases of posterior teeth were still under risk.

Recurrent Caries (RC)/Periodontitis (PE)

Thirteen patients showed RC (1.3%) and 144 (14.4%) exhibited PE. According to KM, the 5-year free-of-event-rate for RC was 98.7% and the 10-year free-of-event rate was 97.2% (Fig 5). For PE, the 5-year free-of-event-rate was 85.8% and the 10-year free-of-event rate was 72.2% (Fig 7). In the first 2-year interval, the hazard rate of recurrent caries of PFM on a biennial basis was 0.004, ie, 4 of 1,000 person-years of exposure had RC for the first 2 years (Fig 6). The rate increased to 0.012 in the 7- and 8-year intervals.

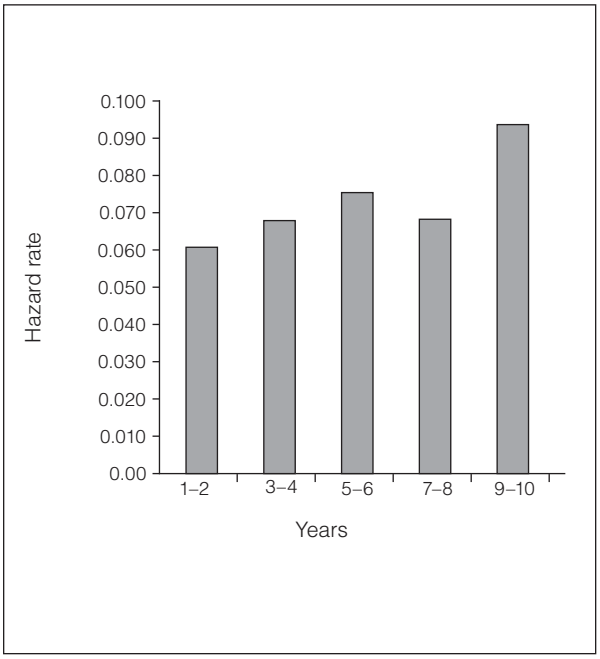

Fig 8 Hazard rate of periodontitis on a biennial basis. For example, the hazard rate of periodontitis was 0.06 in the first 2-year interval, ie, 6 of 100 person-years of exposure showed periodontitis for the first 2 years.

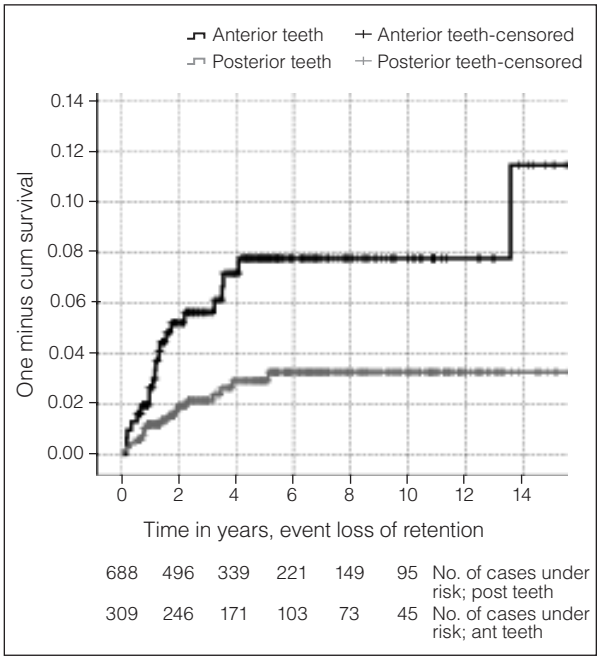

Fig 9 One minus survival of the event loss of retention was calculated using the Kaplan-Meier estimation. The number of cases under risk at a specified time is depicted. For example, after 8 years, 149 cases of posterior teeth were still under risk. The logrank test showed a significant difference between anterior and posterior teeth.

The hazard rate of periodontitis was 0.06 in the first 2-year interval, increasing to 0.1 in the 11- and 12-year intervals. After that, the rate dropped (Fig 8).

Loss of Retention

The 5- and 10-year free-of-event-rates for loss of retention were 92.2% each for anterior teeth and 97.1% each for posterior teeth. Loss of retention only occurred in the first 5 years (Fig 9). Comparing the risk of loss of retention between posterior and anterior teeth at any time point, the logrank test showed a significant difference (logrank: $P = .002$) with a hazard ratio of 2.66 (95% confidence interval [CI]: 1.40–5.05). Thus, the chance of loss of retention was 2.66 times higher for anterior than for posterior crowns. The Cox regression model could not show the impact of any risk factors on the event loss of retention.

Discussion

The perspective of retrospective studies is limited because such studies are based on already existing data. Analyzing the data of more than 20 years from medical histories requires several generations of staff. Thus, despite the fact that all crowns had been inserted according to a standardized treatment protocol, different opinions and decisions of the staff members may have influenced the results. For example, the decision to rate a crown as a failure may lead to bias. Scurria et al emphasized that misclassifications or undetailed classifications could result in either overestimating or underestimating the survival of restorations.[7] They stated that the "objective category of failure" as the removal of the crown overstates the survival of crowns, as many are found in situ but in need of replacement. Patients may sometimes have desired the removal of a crown for esthetic or personal reasons. Therefore, removal of the crown was defined as a decision made by a member of staff. Such decisions were based on clinical facts, such as whether a facing failure was not reparable or severe caries defects or marginal misfits might be a risk for the survival of an abutment tooth.

A further limitation of this study was the decrease in the number of cases along with observation time. Mean observation time was 50 months. After more than 10 years of service, the number of cases under risk reduced from 997 to 140. That means that events occurring after 10 years of service may lead to overestimated hazard rates. Therefore, only hazard rates up to 12 years were calculated.[17,18] Because of the low number of events, the hazard rate was determined on a biennial base. This way, trends were easier to detect.

Data Interpretation

PFM crowns showed an excellent survival rate. After 5 years, 96.4% of the anterior and 97.5% of the posterior teeth were still under risk. The results coincide with the literature. Pjetursson et al reported in a systematic review of 34 studies that 95.5% (CI: 92.4% to 97.5%) of all metal-ceramic crowns had survived after 5 years.[10] Reitemeier et al found that 96.1% of PFM crowns made of noble alloy had survived after 5 years (interpolation from survival plot).[5] After 10 years, the present survival rate dropped slightly to 92.3% (anterior) and 95.5% (posterior). No significant differences were found. Walton reported a 94% survival rate for single tooth-supported crowns after 10 years.[6] Survival rates of single crowns were generally higher than those of three-unit or four-unit fixed partial dentures made of PFM.

Chipping or facings failure of PFM crowns is a rare event. In this study, such an event only occurred in 1.7% (n = 17) of all clinical cases. The 10-year free-of-event-rate of chipping was 98.2% for anterior and 97.3% for posterior crowns. A higher incidence of 3% of veneer failure was found by Goodacre et al in a review of English–language publications covering the past 50 years.[4] Reitemeier and coauthors reported only one case with a metal-ceramic defect in a population of 95 patients with noble alloy PFM crowns.[5] Walton et al described less favorable results in their 1986 publication.[3] They stated that metal-ceramic crowns also showed a relatively short period of service at 6.5 years, needing replacement primarily because of porcelain failure or poor esthetics. As already mentioned by Scurria et al,[7] a direct comparison between the studies is difficult. Most studies reported complications, such as chipping, as simple proportions associated with the mean patient follow-up time instead of the mean complication follow-up time. Furthermore, the studies did not differentiate between framework failures and ceramic failures. Different materials, such as precious or nonprecious alloys, were mixed in the data. Some studies showed that the risk of facings failure of PFM fixed partial dentures made with nonprecious alloy could be higher than that of PFM fixed partial dentures made with precious alloy. Walter et al reported that titanium-based restorations showed considerably more chipping or facings failures (45.5%; $P = .0049$) over 6 years than high gold alloy restorations (0.04%).[21] In a retrospective study lasting 3 to 7 years, Eliasson and colleagues found 17.6% of ceramic fractures in cobalt-chromium alloy-based fixed partial dentures.[22] All in all, these data indicate that the risk of chipping or facings failure is lowest when porcelain is fused to high precious alloys.

The Cox regression model could not show any potential risk factors for chipping, such as bruxism, location of the restoration, or the type of antagonist. This finding was rather unexpected because a study by Kinsel showed a seven-times higher risk of porcelain fractures for patients with bruxism.[11] The same high odds ratio was calculated for patients when comparing implant-supported restorations with natural teeth. Kinsel[11] supposed that the absence of a neurosenory mechanism, which adequately compensates for the periodontal ligament's proprioception and compressibility, leads to the higher incidence of porcelain fractures. The authors could not confirm Kinsel's observation with implant-supported and tooth-supported single crowns. In this study, no chipping or facing failure was noted for implant-supported crowns, yet this absence might have been due to the low number of cases.

Figure 4 shows that chipping or facings failures occurred most frequently during the first biennial interval after insertion. These ceramic failures were not caused by any fatigue phenomena due to long-lasting overload procedures within the increasing observation time. In the authors' opinion, such early failures reflect errors made during the manufacturing process, such as nonanatomical framework design, wrong firing temperature, or lack of sufficient cooling during occlusal adjustment.

The present patients rarely showed recurrent caries (1.3%) or loss of retention (3.8%). No correlation could be found between the type of luting agent and these two events. The number of events was too low for a sufficient statistical analysis. Goodacre et al identified caries (2%) and loss of retention (2%) as the most common complications for single crowns.[4] Other authors found comparable low rates of these complications. However, the percentage of patients with periodontitis was rather high (14.4%). Periodontal tissue response to the insertion of metal-based crowns is well known. Marginal misfit or oxides from the alloys are considered to be responsible for the tissue inflammation.[23–25] Even noble alloys for metal-ceramic reconstructions contain a small amount of nonprecious elements, such as iron, indium, or tin.[26] These elements secure the bond between the metal copping and the ceramic facing material. A too high content of nonprecious elements can be agglomerated at the crown margin due to mistakes during the casting procedure or the final polishing and adjustment procedure.[26] The impact on the inflammation of the gingival tissue may be higher with nonprecious alloys or gold-reduced alloys. However, Kancyper and Koka concluded in their study on different types of alloy and all-ceramics that suitable oral hygiene had

a greater impact than the type of alloy used for the restoration.[24] The authors agree with this opinion because a significant correlation was found between the incidence of periodontitis and age group. The older the age group, the higher the number of patients with periodontitis. Many elderly patients seemed to have more problems adhering to a suitable oral hygiene regimen. This study fails to support the "oxide-thesis" because no data on the content of the alloys were available in the clinical history. However, an age-dependent influence on the occurrence of inflammation of the periodontal tissue was shown.

Conclusions

Patients with PFM crowns may expect long-term survival for their restoration. Clinical complications, such as chipping of the facing, recurrent caries, and loss of retention, are rare. Age-dependent periodontitis was the most frequently observed clinical complication with PFM single crowns made of noble alloys.

Acknowledgment

The authors reported no conflicts of interest related to this study.

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