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Clinical performance of metal-free polymer crowns after 3 years in service

Peter Rammelsberg[a,*], Katrin Spiegl[b], Grit Eickemeyer[b], Marc Schmitter[a]

[a]*Department of Prosthetic Dentistry, Ruprecht Karls University, Im Neuenheimer Feld 400, D-69120 Heidelberg, Germany*
[b]*Department of Prosthetic Dentistry, Ludwig Maximilians University, Munich, Germany*

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Summary *Objective*. To investigate the influence of location and preparation design on the survival and complication rate of metal-free polymer crowns within a prospective clinical study.

Methods. After randomization, a total of 114 (68 posterior and 46 anterior) single crowns were prepared, either with a chamfer finishing line or with a shoulder combined with occlusal reduction of at least 1 mm. Build-ups were made with a composite material, using the corresponding dentin adhesive. After making impressions with polyether material, polymer crowns were manufactured on stone dies and adhesively luted with resin cement. Follow-ups were scheduled after 1 month, 1 year, 2 years and 3 years. Documentation included failures and other complications, as well as ratings of esthetic and functional performance. After 3 years, data from 100 single crowns were statistically evaluated.

Results. Within a minimal observation period of 3 years, 10 complications occurred, including 3 total fractures, 3 partial fractures and 3 decementations. Only 4 crowns (3 total fractures +1 partial fracture) had to be replaced, whereas 2 partial fractures could be repaired and all loosened crowns could be recemented. Kaplan-Meier survival analysis did not show any influence of location or preparation design on the complication rate. Esthetic and functional evaluation by the patients revealed a high acceptance of single polymer crowns, indicated by medians of 9–10 on a 10-point-scale.

Conclusion. Within the 3 year observation period, it can be concluded that 0.5 mm chamfer and shoulder preparation ensure that the stability of metal-free polymer crowns for anterior and posterior teeth is acceptable. Long-term stability and wear behavior has still to be evaluated.

Introduction

Metal ceramic crowns have been the major type of restoration used in fixed prosthodontics in recent decades. Their success is based on clinical longevity

* Corresponding author. Tel.: +49 6221 566031; fax: +49 6221 565371.
E-mail address: peter_rammelsberg@med.uni-heidelberg.de (P. Rammelsberg).

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and acceptable esthetic performance; Coornaert et al.[1] has reported a 3-year survival rate of 98.3% and Leempoel et al.[2] a 5-year survival rate of 95%. In a separate evaluation of anterior metal ceramic crowns, Kerschbaum et al.[3] calculated a 5-year survival rate of 93.7%. The 6-year survival rate of Galvano crowns veneered with ceramic (89.8%)[4] and the 5-year survival rate of acrylic resin-veneered crowns were clearly lower (86.5%).[3]

All-ceramic crowns have been developed to improve the esthetic performance, which is often better without underlying metal. However, early all-ceramic systems had higher failure rates, which were predominantly caused by crown fractures. Data from clinical studies revealed 2-year survival rates of 95% for anterior and 88% for posterior Dicor (Dentsply, York, PA, USA) crowns.[5] After 4.5 years, anterior crowns showed a probability of survival of 71% and molar crowns 76%.[6] Another study reported survival rates of 84.1% for anterior and 72.9% for posterior crowns after 6 years.[4] Most of the failures were caused by fractures of the crown, although an extremely invasive 1.5 mm shoulder preparation was recommended for Dicor crowns.

Meanwhile, several all-ceramic systems with improved fracture resistance have been introduced. Recent studies on all ceramic Empress (Ivoclar-Vivadent, Schaan, Liechtenstein) crowns have yielded more promising results. A review of three clinical studies[7–9] reported survival rates of 92–99% after 3–3.5 years.[10] Edelhoff et al.[11] also reported a minimal risk of failure for Empress crowns of 2.1% after 4 years. Crown fractures were the most frequent reason for failures of Empress crowns, where the majority of fractures occurred in posterior quadrants. All-ceramic systems combining high strength core materials with a porcelain veneer gave a 5-year survival rate of 97.7% for Procera (Nobel Biocare, Yorba Linda, CA, USA)[12] and a 3-year survival rate of 96% for InCeram (Vita, Bad Säckingen, Germany).[13]

High fabrication costs and an invasive tooth preparation design have limited an extensive use of all-ceramic crowns. Therefore, current research has focused on other metal-free alternatives. Meanwhile, initial results from clinical studies on metal-free polymer crowns have been published.[14–16] A clinical study on posterior polymer crowns with an observation period of up to 4 years reported variable results, depending on the polymer system.[15] Behr et al.[16] estimated a cumulative survival rate of 82% after 3 years for 16 fiber reinforced molar crowns.[16] Since the fiber network has to be covered by composite veneering material, these crowns had to be prepared invasively to preserve adequate space. However, previous in-vitro studies revealed that the fracture resistance of metal free polymer crowns prepared without a fiber network is not a limiting factor for clinical use. Even in combination with a minimally invasive 0.5 mm shoulder preparation, minimal fracture loads above 1000 N were found for adhesively cemented molar crowns.[17] However, the stability of these crowns under clinical conditions and the influence of preparation design and location on the survival rate are still unknown.

The objective of this prospective clinical study was to evaluate the clinical performance of metal free Artglass (Heraeus Kulzer, Wehrheim, Germany) crowns placed in the anterior and posterior quadrants.

Material and methods

Ethical approval for the study was obtained from the local ethics committee. Seventy-one patients, from 20 to 81 years of age (mean: 50.5 years, 66% female) were selected for this study. The inclusion criteria were: the necessity to cap a tooth (because of the carious destruction of a tooth), age of consent and informed consent. Six experienced dentists previously trained in standardized crown preparation participated in this study. The variable preparation design (either 0.5 mm shoulder or 0.5 mm chamfer) was randomized using one randomization list for all six dentists. One hundred crowns of a total of 114 could be re-evaluated after three years in service. The drop out rate was less than 5% per year (mean age of the drop out patients: 50.4 years, 59% female).

Clinical treatment and laboratory procedures followed a standardized scheme. After the removal of old restorative materials and caries excavation, the teeth were built up with Charisma (Heraeus Kulzer, Wehrheim, Germany), using the corresponding Dentin bonding agent (Dentinadhesive, Heraeus Kulzer, Wehrheim, Germany). The minimal occlusal reduction was 1 mm and followed the anatomical contours of the abutment teeth. The minimal axial reduction was set at 0.5 mm for both preparations designs, chamfer and shoulder. Impressions were made with polyether material (Provide name and manufacturer of impression material). Stone casts were mounted in an articulator and the crowns were fabricated directly on the cast, in accordance with the manufacturers' recommendations.

After try in and occlusal adjustment, the crowns were repolished, using the Artglass tool kit at low speeds. Immediately prior to cementation,

the inner surface was sandblasted with 50 μm aluminum oxide and then activated with Artglass liquid for at least 30 s under protection from ambient light. 2bond2 base (Heraeus Kulzer, Wehrheim, Germany) without catalyst was used for cementation. In patients with supragingival margins, the crowns were cemented under a rubber dam. If fixation of the rubber dam was impossible, cotton rolls and retraction cords were placed, to avoid contamination with saliva or sulcus fluid. The abutment teeth were etched with 20% phosphoric acid for 20 s, rinsed and then gently air dried. The primer Solid bond P (Heraeus Kulzer, Wehrheim, Germany) was applied for 30 s, then gently air dried. The dentin adhesive Solid bond C (Heraeus Kulzer, Wehrheim, Germany) was applied for 10 s, then again gently air dried. 2bond2 base without catalyst was placed into the crowns and the crowns were positioned under finger pressure. The excess cement was removed and the margins were covered with air block gel. Then, each surface was light cured for 40 s. The date on which the crowns were cemented was recorded as 'baseline'.

Recalls were scheduled after 1 month, 1 year, 2 years and 3 years. Documentation included vitality and percussion tests and recording occlusal contacts and complications. The esthetic and functional performance of the Artglass crowns was evaluated subjectively by visual rating scales (VAS), from 0 (completely inadequate) to 10 (perfect). The patients were blinded to their previous results when they rated their crowns without any support from other persons. Distributions of the VAS data were displayed as box- and whisker-plots, with the box representing the 25th and 75th percentiles. Whiskers are drawn to 1.5×interquartile range beyond the 25th and 75th percentiles. Values outside 1.5 widths or outside 3 widths of the box are marked as outliers ("o") or as extremes ("x"), respectively. Kaplan–Meier curves were calculated for the survival and complication rates (number of complications). The influence of the variables preparation design (shoulder and chamfer) and location (anterior and posterior) were statistically analyzed using the Cox regression model, including all crowns in service. All statistical analyses were performed using the SPSS program (SPSS Inc., Chicago, IL, USA).

Results

43 patients received two single Artglass (Heraeus Kulzer, Wehrheim, Germany) crowns (32 crowns on anterior teeth and 54 crowns on posterior teeth) and 28 patients received one Artglass crown, where 14 crowns were placed on anterior teeth and 14 crowns on posterior teeth After one year 9 crowns and after two/three years 10 crowns could not be re-assessed (patients were at an unknown address, did not agree to further examinations, etc).

During the 3 year observation period, a total of 10 complications occurred. Three total fractures, three partial fractures and three loosened crowns were observed. Furthermore, one crown exhibited a small hole at the occlusal surface. A total of four crowns had to be replaced (three total fractures and one partial fracture). All loosened crowns could be recemented, and two partial fractures were polished intra-orally. The crown with a hole was also repaired with composite material. Calculation of the Kaplan–Meier survival curve on the basis of total failures indicated a probability of survival of 96% after 3 years (Fig. 1). The four total failures provided insufficient data for a reliable investigation of the effects of the variables preparation design and location. Table 1 demonstrates that the complications were evenly distributed between anterior and posterior crowns. However, more complications were observed in the molar region, predominantly in the maxilla. In the mandible, only posterior crowns (first and second molars) showed complications. Separate Kaplan–Meier curves for shoulder and chamfer preparation (Fig. 2) showed that the complication rate in the chamfer preparation was higher than with the shoulder preparation from 1 year onwards. However, Cox regression analysis including preparation design

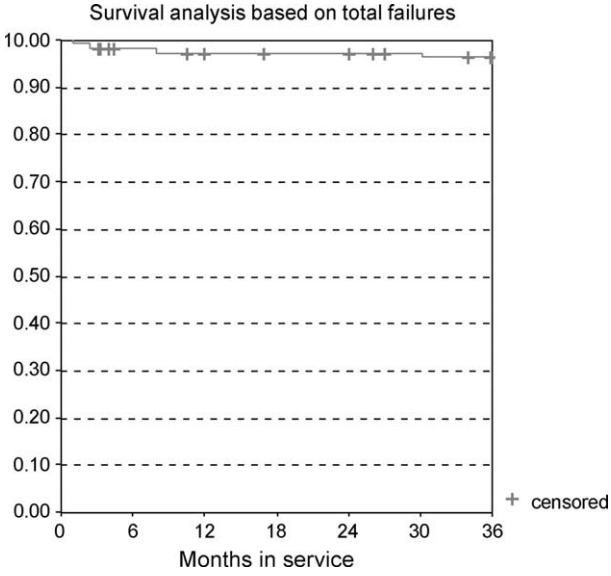

Figure 1 Kaplan–Meier survival curve for all Artglass crowns based on total failures.

Table 1 Location of the Artglass crowns and of the complications after three years.

	Number of complications	
	Maxilla	Mandible
Central incisor	1	0
Lateral incisor	2	0
Canine	0	0
First premolar	1	0
Second premolar	1	0
First molar	2	1
Second molar	1	1

($P=0.301$, confidence interval for Exp(B): 0.127–1.895) and location ($P=0.701$, confidence interval for Exp(B): 0.335–5.080) as possible risk factors revealed no significant effect of these variables on the complication rate. As both *P*-values were >0.05, no statistical significance would have been expected for the analysis of any interactions between the location (anterior, posterior) and preparation design. Use of a correlation matrix for the regression coefficients for preparation and location confirmed this assumption (correlation coefficient = 0.027).

The functional performance was evaluated on rating scales from 0 to 10, reflecting the patients' subjective point of view. Some patients did not mark the rating at different points and therefore there are some missing values. For anterior crowns, the median was 10 for the observation period from 1 month to 3 years. Values below eight were exclusively recorded as outliers and extreme values for anterior crowns (Fig. 3). The medians for posterior crowns ranged from 9.5 after 1 month, to 9 after 1 and 2 years, to 10 after 3 years.

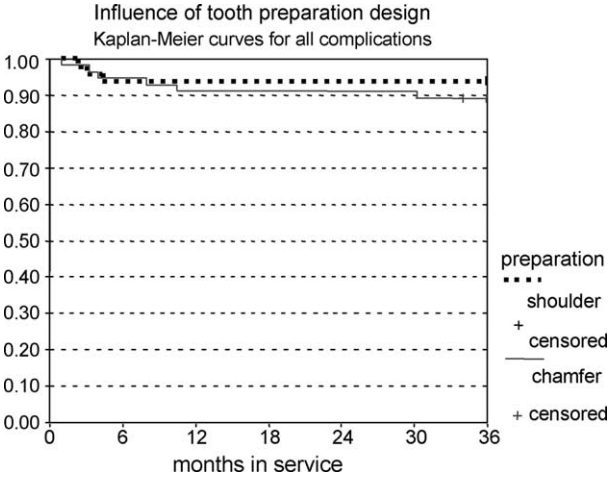

Figure 2 Effects of the preparation design (0.5 mm shoulder vs. 0.5 mm chamfer) on the complication rate.

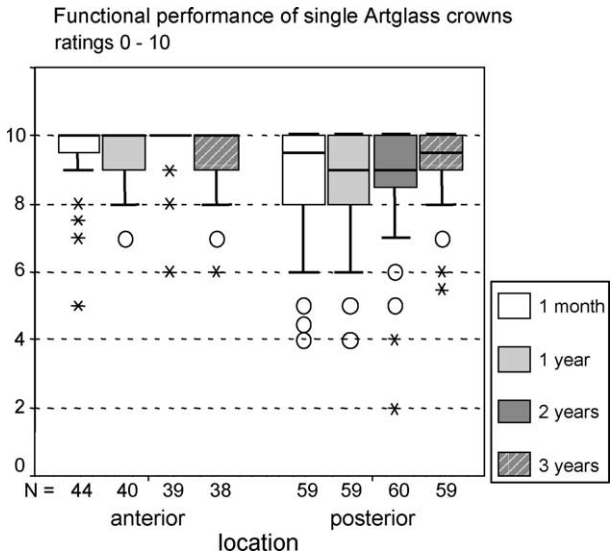

Figure 3 Distribution of the VAS data with respect to functional performance of the Artglass crowns in anterior and posterior location. Patients' ratings on a 0–10 scale. As there were some missing values, the number of rated crowns *n* varies.

The subjective ratings for the esthetic performance exhibited constant medians of 10 for anterior crowns and medians from 9 to 10 for posterior crowns. Once again, anterior crowns gave slightly higher ratings and displayed a smaller variation of the ratings than posterior crowns (Fig. 4). The occlusal stability of posterior crowns was assessed,

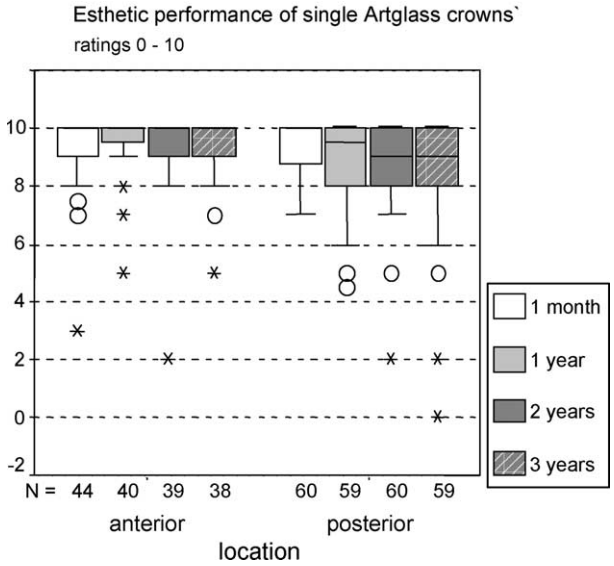

Figure 4 Distribution of the VAS data with respect to esthetic performance of the Artglass crowns in anterior and posterior location. Patients' ratings on a 0–10 scale. As there were some missing values, the number of rated crowns *n* varies.

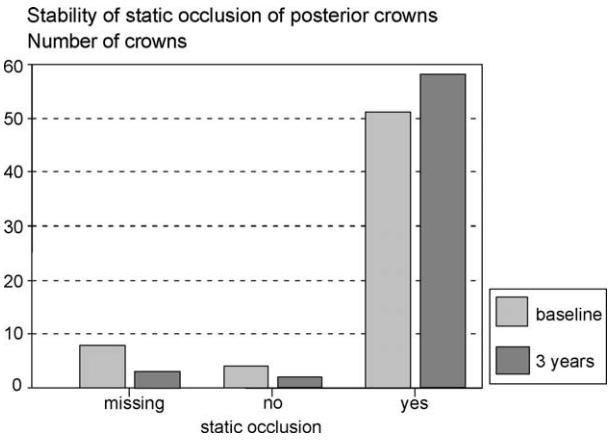

Figure 5 Presence and absence of occlusal contacts in centric occlusion for posterior crowns at baseline and after 3 years. Only crowns under observation after 3 years are displayed.

to evaluate functional problems that might arise from excessive wear of the resin material. At baseline, four posterior crowns had no occlusal contact on centric occlusion (Fig. 5). Within 3 years, this number decreased to two crowns. The number of posterior crowns with stable contacts increased from 51 to 58 at the 3-year follow-up. This means that at 3 years there were three missing values compared to 8 missing values at baseline.

Discussion

During this prospective clinical study, 114 single Artglass crowns were placed under controlled conditions and re-evaluated after 1 month, 1, 2 and 3 years. The drop out rate was less than 5% per year, giving a sample of 100 crowns for the 3 year follow-up. In contrast to early all-ceramic systems, metal-free Artglass crowns exhibited an acceptable survival rate of 96% within the 3-year observation period. Kaplan–Meier survival curves from all ceramic Dicor crowns exhibited lower 3-year survival rates, of 92% for anterior and 82% for posterior crowns.[4] Erpenstein et al.[5] calculated a 2-year survival rate of 88% for posterior and 95% for anterior Dicor crowns. Short term observations from a prospective clinical study on feldspathic porcelain (Vitadur Alpha) crowns on anterior teeth found cracks in 6% and fractures in 2% after 1 year.[18]

All-ceramic systems with improved mechanical properties gave significantly better clinical performance. A review of all-ceramic Empress crowns found survival rates of between 92 and 99% after 3–3.5 years.[7–10] These data are almost in the range for full metal crowns, which have a 5-year survival rate of 97%.[1,19–21] Comparable data have been reported from clinical studies using all-ceramic systems with high strength cores. Procera crowns exhibited a 5-year survival rate of 97.7%[12] and InCeram a 3-year survival rate of 96%.[13]

In this study, three of the four total failures were caused by total fractures and one by a partial fracture. Crown fractures have also been reported as the main reason for failures of all ceramic crowns (Dicor, Empress), whereas partial fractures occurred predominantly in metal ceramic crowns.[4] Six additional complications could be solved without replacement of the crowns. Three recementations (3%) and three repairs (one hole and polishing of two partial fractures) led to a total complication rate (including total failures) of 10% within 3 years. Partial fractures in metal ceramic crowns and in all-ceramic crowns with a high strength core often do not require replacement. In the present study, some patients received two crowns. Therefore, the assumption of independence of the crowns in the statistical analysis is not strictly true. However, as all complications occurred in different patients (no patients with two crowns had a complication in both), this statistical bias seems to be acceptable. Borchard et al.[4] reported that six of eight partial fractures observed for Galvano crowns were not replaced. Ödman and Andersson[12] reported a comparable proportion of partial fractures (four partial and four total fractures of a total of 87 Procera crowns within 10 years) in all-ceramic crowns with high strength ceramic cores.

A significantly higher decementation rate of 37% within 1 year has been reported for posterior Artglass crowns bonded with Denthesive II.[14] Clinical data from a clinical study on 6 different resin crown systems[15] placed by 46 dentists revealed that the type of complication depended on the resin material. The most frequent complications of fiber reinforced resin crowns were delaminations, whereas Artglass crowns predominantly exhibited chipping (28% after 4 years) and bulk fractures (5%). The pattern of complications in the latter study[15] was comparable to our study, but the complication rate was remarkably higher. Improvement of the resin cement (2bond2 vs. Denthesive II) and restriction to four trained dentists and three dental technicians in a single center (versus 46 dentists in dental practices and seven dental technicians) are possible explanations for the improved performance. In the present study, only six dentists were included. However, variations in the preparation design could not be prevented, although calibration training was performed.

It must be emphasized that the preparation techniques used in this study (0.5 mm shoulder or

0.5 mm chamfer) were less invasive than for metal ceramic and all-ceramic crowns. The available clinical data support the results of previous in-vitro studies that the fracture resistance of these crowns was not a critical factor.[17] Therefore, low thickness of the crowns because of the reduced axial preparation seemed to be uncritical. However, care was taken that the minimal reduction was at least 0.5 mm. Significant differences between the shoulder and the chamfer preparation were not found, whereas the occlusal thickness (1.3 mm) was important for the stability of these crowns.

Data from a clinical study on 250 Empress crowns indicate that the invasiveness of axial preparation can also be reduced for all-ceramic crowns. Empress crowns gave a minimal fracture rate of 2.1% after 4 years, although 65% of the crowns were prepared with a less invasive 0.8 mm chamfer.[11]

The factors location (anterior versus posterior) and preparation design (shoulder versus chamfer) could not be isolated as significant risk factors by Cox regression analysis. However, the small proportion of crowns on mandibular incisors in the present study has to be considered.

Consistently high functional and esthetic ratings throughout the observation period indicate good acceptance of metal-free Artglass crowns. However, these data only reflect the patients' perspective. As the patients seem to be more satisfied with their posterior crowns with respect to functional performance after two and three years, it could be assumed that they had to accustom themselves to new crowns, especially in the posterior region responsible for functional performance e.g. chewing. Since excessive wear of resin crowns might cause functional problems, the stability of occlusion was clinically examined at follow-ups. Posterior crowns did not exhibit loss of occlusal support in centric occlusion within three years. However, numerical data on the extent of wear in this study are not yet available. A field study on 61 posterior Artglass crowns reported mean wear rates of 117 μm after 3 years.[15] If the wear data and the observed occlusal stability are both considered, it is conceivable that material loss will be balanced by tooth eruption. Long-term stability and wear behavior have still to be evaluated before polymer crowns can be generally recommended for permanent restorations.

Conclusions

- Metal free polymer crowns placed in anterior and posterior quadrants exhibit an acceptable short-time survival rate of 96% after 3 years.
- The findings on failure resistance suggest that both 0.5 mm chamfer and 0.5 mm shoulder preparation are suitable for clinical use.

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