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ORIGINAL ARTICLE

# Three-year clinical performance of cast gold vs ceramic partial crowns

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**Abstract** Cast gold partial crowns (CGPC) and partial ceramic crowns (PCC) are both accepted for restoring posterior teeth with extended lesions today. However, as esthetics in dentistry becomes increasingly important, CGPC are being progressively replaced by PCC. The aim of the present prospective split-mouth study was the comparison of the clinical performance of PCC and CGPC after 3 years of clinical service. Twenty-eight patients (11 men and 17 women) participated in the 3-year recall with a total of 56 restorations. In each patient, one CGPC (Degulor C) and one PCC (Vita Mark II ceramic/Cerec III) had been inserted at baseline. CGPC were placed using a zinc phosphate cement (Harvard); PCC were adhesively luted (Variolink II/Excite). All restorations were clinically assessed using modified US Public Health Service (USPHS) criteria at baseline, 1 year, 2 years, and 3 years after insertion. Twenty-eight CGPC and 14 PCC were placed in molars, and 14 PCC were placed in premolars. Early data were reported previously under the same study design. After 3 years, the evaluation according to USPHS criteria revealed no statistically significant differences between both types of restorations with the exception of marginal adaptation and marginal discoloration: A statistically significant difference *within* the PCC group (baseline/3 years) was determined for the criterion marginal adaptation. For the 3-year recall period, overall failure was 0% for CGPC and 6.9% for PCC. At 3 years, PCC meet American Dental Association Acceptance Guidelines criteria for tooth-colored restorative materials for posterior teeth.

**Keywords** Partial ceramic crowns · Cast gold partial crowns · Clinical evaluation · USPHS criteria · CEREC III

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## Introduction

Restoration of posterior teeth with cast gold partial crowns (CGPC) is considered an accepted treatment option. CGPC are adequate for the restoration of large defects in particular, whereas direct adhesive filling techniques should be used for the restoration of less extended lesions [28, 30]. According to Pelka et al. [19], indirect restorations like CGPC are superior to direct fillings when the design of proximal contacts, polishing, and marginal adaptation is considered. Additionally, indirect restorations—whether cast gold inlays or partial crowns—obtain higher survival rates than amalgam and composite restorations [10, 30]. Compared to full-crown restorations which require the circumferential removal of sound tooth tissue, partial crowns can be considered to be less invasive [5, 6, 34].

Esthetic in dentistry is an increasing demand of the patients. Therefore, ceramic restorations are becoming increasingly important [14]. These esthetic restorations became available through the development of new dental ceramics with improved material properties [23], dual-curing luting materials, and adhesive systems. All-ceramic inlay restorations show good long-term clinical performance and can be regarded as a standard procedure [28]. However, clinical data for the performance and longevity of partial ceramic crowns (PCC) are comparatively rare [3, 5, 7, 34].

According to the current literature, most studies investigated the longevity and clinical performance either of CGPC [19, 26, 30, 32] or PCC [7, 12, 31, 34] alone but rarely in combination [5]. One retrospective study investigated the clinical performance and survival rate of CGPC and compared the data to those reported for PCC in a second investigation [7, 35]. Both kinds of restorations had been placed by the same operator in the same dental practice but in different patients. Although not statistically significant, the survival rate for CGPC was 96±4% and thus slightly higher than that for PCC (81±15%) after 7 years in situ. To the best of our knowledge, no study has investigated the clinical performance of CGPC and PCC using a prospective split-mouth design. It was hypothesized that no difference between PCC and CGPC as the currently accepted "golden standard" is to be expected after 3 years of clinical service. Therefore, the aim of the present prospective study was to investigate the clinical performance and longevity of CGPC and PCC using a split-mouth design. In the present evaluation, the 3-year results are reported.

## Materials and methods

The present study is a prospective controlled clinical split-mouth study comparing the clinical performance of CGPC (control group) and PCC (test group; Fig. 1). One- and 2-year results were reported previously [5]. The study design was approved by the ethics committee of the University of Regensburg in accordance to the Declarations of Helsinki (1975) and Tokyo (1983). All patients received a detailed description of the proposed treatment for informed consent. At baseline, the study comprised 29 patients (12 men and 17 women) with a median age of 38 years (range 25–54). All patients originated from the patient pool of the Department of Operative Dentistry and Periodontology of the University of Regensburg and displayed large defects of the dental hard tissues. Application of the rubber dam was possible, and tooth mobility was, at most, degree 1 (movability of the tooth is not visible but noticeable) [20]. Oral hygiene of all patients was good (i.e., papillary bleeding index, PBI≤35%) [25]. One tooth for ceramics and one tooth for alloy restoration was selected per patient. The preparation and restoration of the selected teeth were performed by clinical students in the final stages of their dental training program (Department of Operative Dentistry and Periodontology of the University of Regensburg) supervised by one experienced dentist, who designed the cavity preparation to each individual and checked it clinically. The preparation for CGPC followed standard guidelines: functional cusps were covered by means of a butt-joint preparation with a bevel, whereas nonfunctional cusps were beveled (Fig. 2). Temporary restorations (Luxatemp, DMG, Hamburg, Germany) were cemented with a Eugenol free cement (Temp Bond NE, Kerr, Scafati, Italy). Silaplast/-soft (Detax, Ettlingen, Germany) was used for impression taking. All CGPC were manufactured using Degulor C (Degussa, Düsseldorf, Germany) according to standard laboratory techniques. The restorations were inserted with zinc phosphate cement (Harvard, Harvard Dental, Berlin, Germany).

For the PCC, a modified cavity preparation was performed (Fig. 2) with slight modifications adapted to the given situation in the particular patient and after the findings of an in vitro investigation [6]. Nonfunctional cusps were left uncovered if applicable. After impression taking and temporization according to the procedure described for CGPC, all PCC were machined indirectly using a die cast with the Cerec III system [Sirona Cerec III Software version 1.0 (600/800), Sirona, Bensheim, Germany]. The PCC were

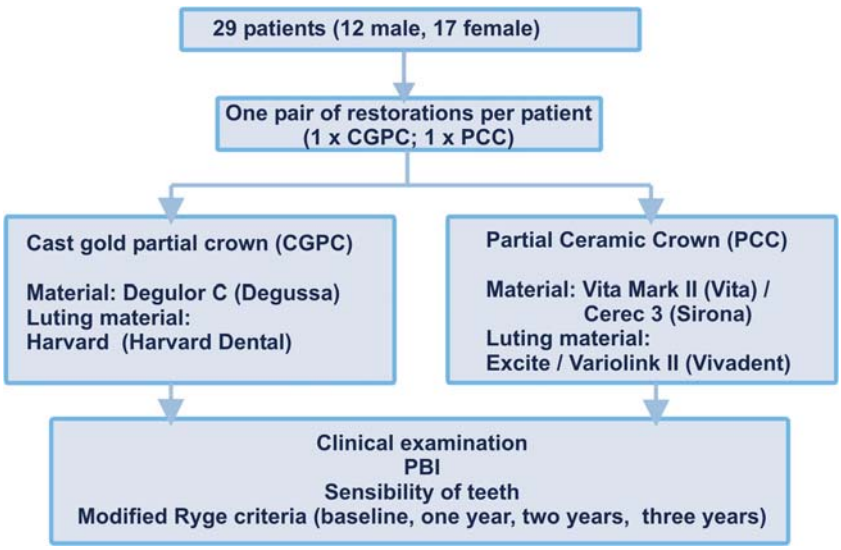


**Fig. 1** Study design

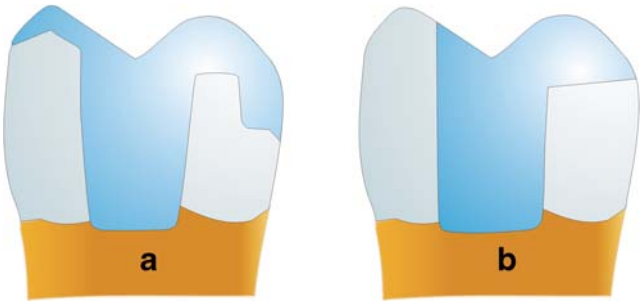


**Fig. 2** Preparation design: **a** CGPC, **b** PCC

milled out of an industrially fabricated ceramic block (Vita 3D Master Cerec Mark II, Vita, Bad Säckingen, Germany). In a second appointment, the PCC was adhesively luted, employing Variolink II/high viscosity (Vivadent, Schaan, Liechtenstein) and using Excite (Vivadent, Schaan, Liechtenstein) as the adhesive system. After insertion, the occlusion was adjusted, and the PCC restorations were polished with the Sof-Lex disc-system (3M Espe, Seefeld, Germany).

An experienced dentist not involved in the fabrication or the insertion of the restorations evaluated the CGPC and PCC at baseline, 1, 2 [5], and 3 years using US Public Health Service (USPHS) criteria [2] modified by Krejci et al. [13] and Mörmann et al. [17] (Table 1). The following parameters were assessed: sensitivity to cold of the restored teeth was investigated using the ice-spray test (Endo-Frost, Roeko/Coltene/Whaledent, Langenau, Germany). Postoperative hypersensitivities were determined by asking the patients. According to modified USPHS criteria, anatomic form, marginal adaptation, marginal discoloration, surface texture, and recurrent caries were evaluated (Figs. 3, 4, 5, and 6). Examination of the margin quality and recurrent caries was performed using a dental probe (EX 9, HuFriedy, Chicago, USA). The PBI according to Saxer and Mühlemann was employed for evaluation of the patients' oral hygiene [25]. The percentage of failure for the 3-year recall was calculated as defined in the American Dental Association ([% failure = (previous failures + current failures/previous failures + number of restorations at current recall) × 100] [1]. For statistical analysis, the chi-square test was applied ($\alpha$=0.05).

## Results

The total of 29 patients attended the examinations at baseline (immediately after placement) and the 1- and 2-year recalls (±1month). Twenty-eight patients attended their appointment for the 3-year evaluation (±1 month). One patient, whose PCC restoration had been rated delta at the 2-year recall due to debonding, refused to attend any further recall appointments. For statistical treatment of the data in the present report, 28 CGPC and 28 PCC restorations in 28 patients were considered as baseline and for the 3-year recall, referring to all restorations still under risk at the 3-year recall.

Approximately 28 of the CGPC and 14 of the PCC had been placed in molars, and 14 of the PCC had been placed

**Table 1** Modified USPHS criteria

| Modified Ryge criteria | | |
|---|---|---|
| Postoperative sensitivity | Alfa[a] | No postoperative sensitivity |
| | Bravo | Postoperative sensitivity |
| | Charlie | Postoperative sensitivity with treatment need |
| Anatomic form | Alfa | Correct contour |
| | Bravo | Slightly under- or overcontoured |
| | Charlie | Distinctly under- or overcontoured |
| | Delta | Restoration fractured or mobile |
| Marginal adaptation | Alfa | Margin not discernible, probe does not catch |
| | Bravo | Probe catches on margin but no gap; dentin or liner exposed |
| | Charlie | Probe catches on margin and gap on probing, dentin or liner exposed |
| | Delta | Restoration fractured or missing |
| Marginal discoloration | Alfa | No marginal discoloration |
| | Bravo | Marginal discoloration, not penetrated toward pulp |
| | Charlie | Marginal discoloration penetrated toward pulp |
| Surface texture | Alfa | Smooth, glazed, or glossy surface |
| | Bravo | Slightly rough or dull surface |
| | Charlie | Surface with deep pores, cannot be refinished |
| Recurrent caries | Alfa | No recurrent caries |
| | Bravo | Caries without treatment need |
| | Charlie | Caries with treatment need |

[a] According to Ryge [24]

**Fig. 3** CGPC at baseline

**Fig. 5** PCC at baseline

in premolars. The PBI indicating the quality of oral hygiene of the patients was less than 20% in 21 patients (baseline) and 26 patients (3 years). The remaining patients had a PBI between 20 and 35%. At baseline, one (3.6%) tooth of the CGPC group and five (17.9%) teeth of the PCC group showed no sensitivity to cold due to endodontic treatment before the restoration of the respective teeth. During the observation period of 3 years, no additional endodontic treatment had to be performed. For PCC as well as for the CGPC, no recurrent caries was detected 3 years after placement. The results for the modified USPHS criteria evaluation are summarized in Table 2.

Postoperative hypersensitivity

At baseline, postoperative hypersensitivity was rated alfa for 25 (89.3%) teeth and bravo for three (10.7%) teeth in each group. Three years after placement, all teeth were rated alfa for the CGPC group. In the PCC group, alfa rating increased to 27 (96.4%) teeth, and bravo decreased to one (3.6%) tooth after 3 years. No statistically significant differences could be found between the two types of restorations and the two dates of recall (baseline/3 years) regarding postoperative hypersensitivity (Table 2).

Anatomic form

At baseline, anatomic form was rated alfa for 27 (96.4%) CGPC and for 26 (92.6%) PCC. One (3.6%) CGPC and two (7.1%) PCC were rated bravo. Three years after placement, anatomic form was rated alfa for all CGPC and for 23 (82.1%) PCC; three (10.7%) PCC were rated bravo, one (3.6%) charlie without the need for intervention, and one (3.6%) delta. The delta-rated PCC showed severe chipping in the area of the marginal ridge/proximal contact and had to be replaced after the 3-year investigation. The differences between CGPC and PCC as well as the data for both materials between baseline and 3 years were not statistically significant regarding the criterion anatomic form (Table 2).

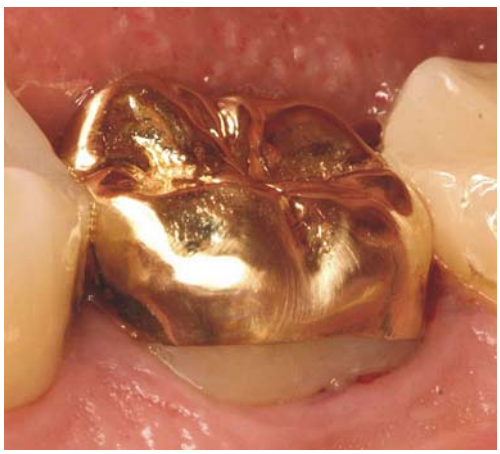

**Fig. 4** CGPC after 3 years

**Fig. 6** PCC after 3 years

**Table 2** Results at baseline and 3 years after placement in relation to modified USPHS criteria

| Material | Time | | Postoperative hypersensitivity | | | Anatomic form | | | | Marginal adaptation | | | | Marginal discoloration | | | | Surface texture | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | A | B | C | D | A | B | C | D | A | B1 | B2 | C | A | B | C |
| Gold | BL* | *n* | 25 | 3 | 0 | 27 | 1 | 0 | 0 | 25 | 3 | 0 | 0 | 28 | 0 | 0 | 0 | 28 | 0 | 0 |
| | | % | 89.3 | 10.7 | 0 | 96.4 | 3.6 | 0 | 0 | 89.3 | 10.7 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 |
| Gold | 3-Y | *n* | 28 | 0 | 0 | 28 | 0 | 0 | 0 | 27[b] | 1[b] | 0 | 0 | 27 | 1 | 0 | 0 | 28 | 0 | 0 |
| | | % | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 96.4 | 3.6 | 0 | 0 | 96.4 | 3.6 | 0 | 0 | 100 | 0 | 0 |
| Ceramic | BL* | *n* | 25 | 3 | 0 | 26 | 2 | 0 | 0 | 27[a] | 1[a] | 0 | 0 | 28[a] | 0[a] | 0 | 0 | 28 | 0 | 0 |
| | | % | 89.3 | 10.7 | 0 | 92.6 | 7.1 | 0 | 0 | 96.4 | 3.6 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 |
| Ceramic | 3-Y | *n* | 27 | 1 | 0 | 23 | 3 | 1 | 1 | 22[a,b] | 6[a,b] | 0 | 0 | 24[a] | 4[a] | 0 | 0 | 27 | 0 | 1 |
| | | % | 96.4 | 3.6 | 0 | 82.1 | 10.7 | 3.6 | 3.6 | 78.6 | 21.4 | 0 | 0 | 85.7 | 14.3 | 0 | 0 | 96.4 | 0 | 3.6 |

*BL* Baseline investigation; *3-Y* investigation 3 years after placement; *n* number of restorations; *%* percentage of restorations
[a] Significant difference between baseline and 3-year investigation ($p \leq 0.05$)
[b] Significant difference between gold and ceramic ($p \leq 0.05$)
*Only 28 patients were left because one partial ceramic crown failed and had to be replaced after 2 years in situ. The matching patient did not want to continue the study at all.

### Marginal adaptation

At baseline, marginal adaptation was rated alfa in 25 (89.3%) cases of CGPC and in 27 (96.4%) cases of PCC; all other restorations were rated bravo. Three years after insertion of the restorations, alfa ratings increased to 27 (96.4%) for CGPC and decreased to 22 (78.6%) for PCC, with the remaining restorations being rated bravo. A statistically significant difference ($p=0.043$) occurred between baseline and the 3-year results for the PCC. Additionally, a weak statistically significant difference ($p=0.051$) could be determined between the two types of restorations regarding marginal adaptation after 3 years (Table 2).

### Marginal discoloration

At baseline, marginal discoloration was rated alfa for all restorations in each group. Three years after placement, alfa ratings decreased to 27 (96.4%) cases for CGPC and to 24 (85.7%) cases for PCC. One (3.6%) CGPC and four (14.3%) PCC were rated bravo. Regarding marginal discoloration, a weak statistically significant difference ($p=0.052$) could only be found for the PCC between the two investigated dates of data assessment at baseline and 3 years (Table 2).

### Surface texture

At baseline, surface texture was rated alfa for all restorations in each group. Three years after placement, all restorations of the CGPC group and 27 (96.4%) of the PCC group were rated alfa. One (3.6%) PCC was rated charlie due to an infracture noticed in the ceramic surface but without the need for intervention. No statistically significant differences could be detected between the two types of restorations and the two dates of data assessment regarding surface texture (Table 2).

## Discussion

### Study design

In the present study, a comparison of the clinical performance of cast gold partial crowns and partial ceramic crowns was approached in a prospective split-mouth design. The study design closely followed the ADA Acceptance Program Guidelines for tooth-colored restorative materials in the posterior region suggested for application in clinical trials [1] and the recommendations for conducting clinical studies of dental restorative materials [10].

The study population included 28 pairs of restorations in 28 patients, 20 pairs of restorations in 20 patients being the minimum ADA requirements [1]. The irregular distribution of types of teeth restored within the treatment groups may be considered a limitation: no CGPC was placed in a premolar but 14 PCC were. However, a randomization of PCC and CGPC to different tooth types was not possible due to the patients' demands for esthetics.

Although the clinical comparison of CGPC and PCC is the main focus of the investigation, parameters such as the nature of the ceramic and its processing, luting procedure, and luting materials must also be taken into consideration as factors influencing clinical performance. For example, any pulp reaction may originate from either material toxicity or insufficient sealing, possibly resulting in bacterial leakage. Therefore, commonly used luting materials with comprehensive evidence for clinical acceptance

were used in the present study [1, 27, 29]. The advantages associated with this approach are reflected; e.g., in the data on postoperative hypersensitivity (decrease), allowing for the clinical comparison of a rather subjective parameter between the two treatment modalities in the same patient.

## Clinical results

### *Failure rate/survival rate*

Besides the restoration that had been considered a failure at the 2-year recall, one restoration was rated delta at the 3-year recall and had to be renewed. In the current literature, so-called "half-moon" fractures—the fracture mode assigned to the respective failure at 3 years—were reported as early as 2 years [12].

In a survey on the longevity of restorations in posterior teeth and reasons for failure, Hickel and Manhart [9] report an annual failure rate for ceramic restorations of 0–7.5% and of 0–4.4% for CAD/CAM restorations. ADA guidelines require that there cannot be more than 10% unacceptable restorations as the minimum standard for acceptance of the quality of the restorations at 3 years [1]. Survival rates reported in the literature for ceramic inlays and onlays range between 81 and 92% [8, 12, 21, 34, 35]; those for CGPC are reported to range from 86 to 96% [35], all studies covering observation periods of 5 years and more. No statistically significant differences were reported between survival functions of CGPC and PCC.

At 3 years, the results of the present investigation are in accordance with the ADA requirements for both kinds of restorations, CGPC (0% unacceptable restorations) and PCC (6.9% failure within 3 years) and with data published in the literature.

### *Clinical criteria*

*Sensitivity to cold/recurrent caries* In the present study, teeth that tested negative to cold at baseline and after 3 years had been treated endodontically *before* placing the respective restorations. No further endodontic treatment became necessary within 3 years. In contrast, in a comparison between CGPC and PCC, Wagner et al. [35] reported that one tooth in the PCC group and 7% of the cases in the CGPC group had to be treated endodontically within the considerably longer observation period of 51 months. Studer et al. [32] found that none of the teeth investigated in their study (CGPC) had to undergo endodontic treatment after restoration for a mean observation period of 18.7±9.5 years, but the authors reported recurrent caries in 40% within an observation period of up to 30 years for CGPC and in 2% for PCC within an observation period of up to 2 years [31]. Van Dijken et al. [34] reported that endodontic treatment became necessary in one case (7.7%) of their patient population within the first year of the 5-year observation period of PCC. They also reported recurrent caries in three cases (23.1%) within the 5-year observation period [34]. Considering that most of the studies reported in the literature cover observation periods exceeding 3 years, the results of the present investigation are in accordance with the cited literature and show no apparent adverse effect of the treatment on pulp vitality.

*Postoperative hypersensitivity/anatomic form/surface texture* Postoperative hypersensitivity declined over the 3-year observation period for both CGPC and PCC. Results for postoperative hypersensitivity in the present investigation and in the current literature reveal similar findings for CGPC and PCC [4, 31, 32, 35]. This seems to be particularly interesting because in the present split-mouth study, each patient could directly compare the reaction to the two different treatment procedures [33].

With respect to anatomic form, all CGPC were rated alfa 3 years after placement. Wagner et al. [35], however, reported lower alfa ratings and higher bravo ratings for CGPC. Furthermore, they found distinctly under- or over-contoured CGPC (charlie ratings) in 33% of the cases. The differences between their data and the data of the present study may be due to the longer observation period.

In the PCC group, alfa ratings referring to anatomic form decreased after 3 years; PCC with bravo ratings increased to three cases. Additionally, one charlie rating and one delta rating occurred. Van Dijken et al. [34] reported similar results. The results are also supported by the findings of Krämer and Frankenberger [12], who reported significant differences over time for the criterion anatomic form. In the present investigation, one PCC restoration was rated charlie for the criterion surface texture after 3 years due to an infraction in the ceramic surface but without the need for intervention. Shortcomings in surface texture of PCC due to intraoral finishing and polishing as mandatory with the Cerec method [11] are not reflected in the results. Differences between the results of the present investigation and the data reported in the literature may be attributed to the limited observation periods of the present study.

*Marginal adaptation/marginal discoloration* Alfa ratings for marginal adaptation of CGPC slightly increased from 89.3 to 96.4% of the cases after 3 years. Donly et al. [4] found alfa ratings in 78% of their cast gold restorations, bravo in 6%, and clinically not acceptable ratings (charlie) in 17% after 13 years. Another retrospective study reported alfa ratings in 65% and bravo ratings in 35% of the CGPC after 7 years [35]. The lower alfa ratings and the high

charlie ratings compared to our study may emerge from the longer observation periods.

For PCC, a statistically significant difference ($p$=0.043) was determined for the criterion marginal adaptation between baseline and the 3-year recall, as well as between PCC and CGPC at the 3-year evaluation ($p$=0.051). Alfa ratings decreased from 96.4 to 78.6%. In accordance with the findings of the present investigation, a decrease in marginal adaptation of ceramic restorations with time due to wear of the luting composite and increasing submargination is reported in the current literature [16, 18, 22]. Krämer and Frankenberger [12] found a statistically significant distinct deterioration over time regarding the criterion marginal integrity. The authors also indicated that after an evaluation period of 8 years, 98% of the surviving restorations exhibited marginal deficiencies. Marginal deterioration observed especially with PCC may be attributed to insufficient bonding to the hard tooth tissues and to degradation of the luting composite in the luting space due to wear and fatigue [12, 15].

For PCC, the criterion marginal adaptation is closely correlated with the criterion marginal discoloration. For this criterion, too, a weak statistically significant difference ($p$=0.052) was determined for PCC between baseline and the 3-year recall. Due to the nature of the luting material and the luting space, an increase in marginal discoloration may be expected in PCC rather than in CGPC. This must be attributed to the width of the luting space on the one hand, which in CGPC is reduced due to a bevel preparation, and to the capacity for staining of the exposed luting composite on the other hand. Other reasons for marginal discoloration are, e.g., marginal excess of the luting material, wear of luting composite, and increasing marginal deterioration [16, 18, 22].

## Conclusions

1. At 3 years, PCC meet ADA Acceptance Guidelines criteria for tooth-colored restorative materials for posterior teeth.
2. No statistically significant differences between PCC and CGPC were found in all USPHS clinical rating parameters with the exception of *marginal adaptation* and *marginal discoloration*.
3. PCC can be recommended for clinical use, with the luting material apparently being a major aim of further improvement.

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