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ORIGINAL ARTICLE

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Two-year clinical performance of cast gold vs ceramic partial crowns

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Abstract Cast gold partial crowns (CGPC) are an accepted means of restoring posterior teeth with extended lesions. However, for esthetic reasons, CGPC are being increasingly substituted with partial ceramic crowns (PCC). The aim of the present prospective split-mouth study was to compare the clinical performance of PCC and CGPC. There were 29 patients (male 12, female 17) who participated in the investigation for a total of 58 restorations. In each patient, one CGPC (Degulor C) and one PCC (Vita MarkII/Cerec III) were placed. CGPC were inserted using conventional zinc-phosphate cement (Harvard); PCC were adhesively luted to the cavities (Variolink II/Excite). The restorations were clinically rated using modified United States Public Health Service (USPHS) criteria at baseline and 1 and 2 years after placement. The median patient age was 38 years (range 25–54). There were 29 of the CGPC and 14 PCC placed in molars, while 15 PCC were placed in premolars. All patients were available for the 1- and the 2-year recall. One PCC (1.7%) failed and had to be replaced after 2 years in situ. The rest of the restorations were functional without need of replacement. The evaluation using USPHS criteria revealed no statistically significant differences between CGPC and PCC with the exception of anatomic form: PCC showed occlusal chipping in two cases without need of replacement. From these data, it can be concluded that PCC may provide an esthetic and tissue-conservative alternative to CGPC. However, long-term studies comparing the clinical performance and longevity of cast gold and ceramic partial crowns for posterior teeth are desirable.

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

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Introduction

The restoration of posterior teeth with cast gold partial crowns (CGPC) is considered to be effective and long lasting. Sound tooth structures can be conserved using partial crowns for the restoration of defects in the posterior region [8]. Cast gold partial crowns can be recommended especially for large defects, whereas direct adhesive filling techniques should be used for restoring small defects [33]. According to Pelka et al. [20], indirect restorations like CGPC are superior to direct filling materials considering the design of the proximal contact areas, polishing, and marginal adaptation. Furthermore, cast gold inlays and partial crowns showed higher survival rates than amalgam and composite restorations [33].

Due to the aesthetic needs of patients, gold restorations are being increasingly substituted with all-ceramic systems [14]. This aesthetic way of restoration became available due to the development of new dental ceramics with improved material properties [25], dual-curing luting materials, and dentin adhesive systems. Both gold and ceramic restorations are regarded as excellent as far as conservation of tooth structure and biocompatibility are concerned [6]. The restoration of defects with ceramic inlays shows good long-term clinical performance and can be regarded as a standard procedure [30]. However, clinical data about the performance and longevity of partial ceramic crowns are comparatively rare [7, 8, 12, 22, 34, 37].

According to the current literature on partial crowns, most studies investigated the longevity and clinical per-

formance of CGPC and PCC separately [7, 12, 20, 28, 33–35]. However, it is well established that the clinical success of dental restorations to a large extent depends upon the dentist performing the treatment on the one hand and the patient receiving the restoration on the other hand. One study investigated retrospectively the clinical performance and survival of CGPC and compared the data to those reported for PCC, with both restoration types being placed by the same operator in the same dental practice [38] but the CGPC and the PCC being placed in different patients. Although not statistically significant, the survival rate for CGPC was 96±4%, slightly higher than that for PPC (81±15%) after 7 years in situ. This might be due to the differences between patients. 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 there is no difference between PCC and CGPC as the currently accepted "golden standard". The aim of the present study was to investigate prospectively the clinical performance of CGPC and PCC using a split-mouth design.

Materials and methods

This study was designed as a prospective, controlled clinical split-mouth study comparing the clinical performance of cast gold partial crowns (control group) and partial ceramic crowns (test group) (Fig. 1). The study design was approved by the ethics committee of the University of Regensburg in accordance with the Declarations of Helsinki (1975) and Tokyo (1983). All patients received a detailed description of the proposed treatment for informed consent. The study comprised 29 patients (12 male, 17 female) with a median age of 38 years (range 25–54). All patients were recruited from the patient contingent of the Department of Operative Dentistry and Periodontology of the University of Regensburg and were suffering from large defects of the dental hard tissues with the need of restoration by partial crowns. The application of a rubberdam was possible and tooth mobility was lower or equal to degree 1 (movability of the crown of the tooth is not visible but noticeable [21]). All patients had good oral hygiene (i.e., papillary bleeding index ≤35%). One tooth for the ceramic and one tooth for the alloy restoration were selected per patient. The preparation and restoration of the selected teeth were performed by clinical students (one GCPC and one PCC per clinical student) at the end of their dental training program (Department of Operative Dentistry and Periodontology of the University of Regensburg). Before the study, the students had successfully accomplished a training course on CGPC and on PCC. During the study, the students were supervised by one experienced dentist, who designed the cavity preparation to each individual, trained the students with respect to the individual cavity preparation (casts), checked it clinically, and finally accepted it. The preparation of teeth for cast gold partial crowns followed generally accepted 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 an Eugenol free cement (Temp Bond NE, Kerr, Scafati, Italy). Silaplast/-soft (Detax, Ettlingen, Germany) was used for impression taking. All CGPC were fabricated

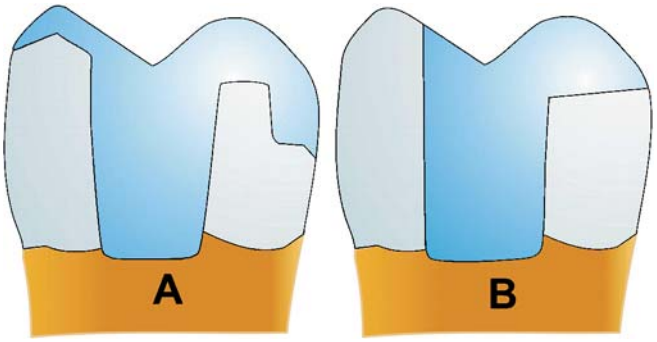

Fig. 2 Preparation design: preparation A, CGPC; preparation B, PCC

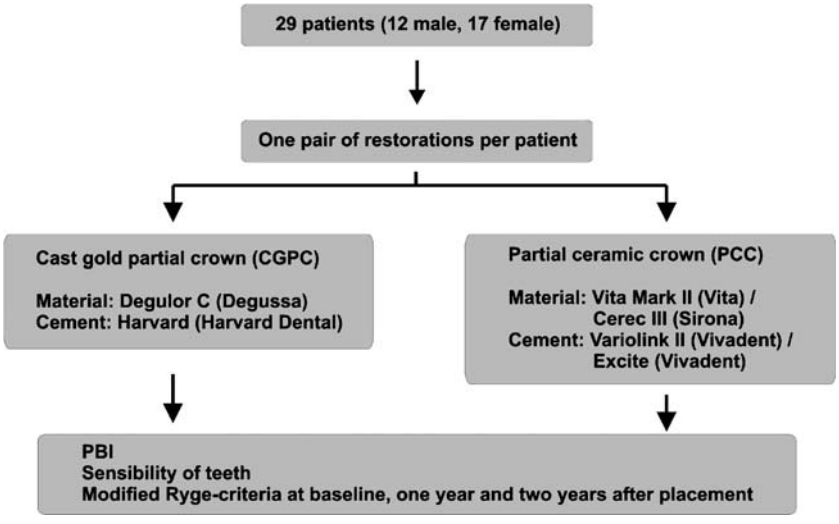

Fig. 1 Study design

using Degulor C (Degussa, Düsseldorf, Germany) according to standard laboratory techniques. The restorations were luted with conventional zinc phosphate cement (Harvard, Harvard Dental, Berlin, Germany).

For the partial ceramic crown, a modified cavity preparation was performed (Fig. 2) with slight modifications according to the given situation in a single patient. Nonfunctional cusps were not covered. After impression taking and temporization in the same way as for CGPC, all PCC were machined indirectly with the CEREC III system (CEREC III Software Version 1.0 (600/800), Sirona, Bensheim, Germany), using a cast. The PCC were milled out of an industrially fabricated ceramic body (Vita 3D Master CEREC Mark II, Vita, Bad Säckingen, Germany). In a second appointment, the PCC was adhesively luted with Variolink II/high viscosity (Vivadent, Schaan, Liechtenstein) using Excite (Vivadent, Schaan, Liechtenstein) as the adhesive system. After placement, the occlusion was adjusted and the PCC restorations were polished with the Sof-Lex disc system (3M Espe, Seefeld, Germany). There were 29 of the CGPC and 14 of the PCC placed in molars and 15 of the PCC were placed in premolars. Endodontic treatment had been performed on two teeth in the CGPC group and on six teeth in the PCC group before including the teeth into the investigation.

An experienced dentist who was not involved in making or placing the restorations rated the CGPC and PCC using the United States Public Health Service (USPHS) criteria [26] modified by Krejci et al. [13] and Mörmann et al. [17] (Table 1). All of the 29 patients attended the examinations at baseline (immediately after placement), 1 year (±1 month), and 2 years (±1 month) after placement. Sensitivity to cold of the restored teeth was tested using Endo-Frost spray (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. For the examination of the margin quality and recurrent caries, a dental probe (EX 9, HuFriedy, Chicago, IL, USA) was used. The papilla bleeding index (PBI) according to Saxer and Mühlemann [27] was used for evaluating patients' oral hygiene. For statistical analysis of differences between the two treatment modalities, the Chi-square test was applied (α=0.05).

Results

The PBI indicating the quality of oral hygiene of the 29 patients under study was less than 20% in 21 patients (baseline), 24 patients (1 year), and 25 patients (2 years). The rest of the patients had a PBI between 20 and 35%. At baseline and 1 and 2 years after placement, two (6.9%) teeth of the CGPC group and six (20.7%) teeth of the PCC group showed no sensitivity to cold due to endodontic treatment before placement. One PCC was lost due to adhesion failure within the 2-year examination period (25 months). No recurrent caries was detected 1 and 2 years after placement. The results of the clinical evaluation regarding modified USPHS criteria are summarized in Table 2.

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 towards pulp
	Charlie	Marginal discoloration penetrated towards 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 "Clinical criteria" of G. Ryge (1980)

Table 2 Results 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* (%)	26 (89.7)	3 (10.3)	0 (0)	28 (96.6)	1 (3.4)	0 (0)	0 (0)	26 (89.7)	3 (10.3)	0 (0)	0 (0)	29 (100)	0 (0)	0 (0)	0 (0)	29 (100)	0 (0)	0 (0)
Gold	1-Y	*n* (%)	28 (96.6)	1 (3.4)	0 (0)	29[a] (100)	0 (0)	0 (0)	0 (0)	25 (86.2)	4 (13.8)	0 (0)	0 (0)	29 (100)	0 (0)	0 (0)	0 (0)	28 (96.6)	1 (3.4)	0 (0)
Gold	2-Y	*n* (%)	28 (96.6)	1 (3.4)	0 (0)	29[a] (100)	0 (0)	0 (0)	0 (0)	25 (86.2)	4 (13.8)	0 (0)	0 (0)	28 (96.6)	1 (3.4)	0 (0)	0 (0)	29 (100)	0 (0)	0 (0)
Ceramic	BL	*n* (%)	26 (89.7)	3 (10.3)	0 (0)	27 (93.1)	2 (6.9)	0 (0)	0 (0)	28 (96.6)	1 (3.4)	0 (0)	0 (0)	29 100	0 (0)	0 (0)	0 (0)	29 (100)	0 (0)	0 (0)
Ceramic	1-Y	*n* (%)	28 (96.6)	1 (3.4)	0 (0)	25[a] (86.2)	4 (13.8)	0 (0)	0 (0)	27 (93.1)	2 (6.9)	0 (0)	0 (0)	29 (100)	0 (0)	0 (0)	0 (0)	28 (96.6)	1 (3.4)	0 (0)
Ceramic	2-Y[b]	*n* (%)	29 (100)	0 (0)	0 (0)	22[a] (75.9)	4 (13.8)	2 (6.9)	1 (3.4)	22 (75.9)	6 (20.7)	0 (0)	1 (3.4)	26 (92.9)	2 (7.1)	0 (0)	0 (0)	27 (96.4)	1 (3.6)	0 (0)

BL Baseline investigation, *1-Y* investigation 1 year after placement, *2-Y* investigation 2 years after placement, *n* number of restorations, *%* percentage of restorations
[a] $p \leq 0.05$ (gold vs ceramic)
[b] One lost ceramic restoration

Postoperative hypersensitivity

At baseline, postoperative hypersensitivity was rated alfa for 26 (89.7%) teeth and bravo for 3 (10.3%) teeth in each group. One year after placement, alfa rating increased to 28 (96.6%) teeth and bravo decreased to 1 (3.4%) tooth in each group. The same result was observed 2 years after placement for the CGPC teeth; in the PCC group, all teeth were rated alfa. No statistically significant differences could be detected between the two types of restoration regarding postoperative hypersensitivity (Table 2).

Anatomic form

At baseline, anatomic form was rated alfa for 28 (96.6%) CGPC and for 27 (93.1%) PCC. One (3.4%) CGPC and two (6.9%) PCC were rated bravo. One year after placement, anatomic form was rated alfa for all CGPC (Fig. 3) and for 25 (86.2%) PCC; four (13.8%) PCC were rated bravo. Two years after placement, the anatomic form was again rated alfa for all CGPC and for 22 (75.9%) PCC. Four (13.8%) PCC were rated bravo, two (6.9%) restorations charlie due to chipping of the ceramic leading to an undercontoured PCC, and one (3.4%) delta due to the loss of the restoration. The differences between CGPC and PCC were statistically significant 1 and 2 years after placement regarding anatomic form. No statistically significant difference between the 1- and the 2-year results in the PCC group could be observed (Table 2).

Marginal adaptation

At baseline, marginal adaptation was rated alfa in 26 (89.7%) cases of CGPC and in 28 (96.6%) cases of PCC (Fig. 4); all other restorations were rated bravo. One year after placement, alfa ratings decreased to 25 (86.2%) for CGPC and to 27 (93.1%) for PCC, with again the other

Fig. 3 CGPC with anatomic form rated alfa

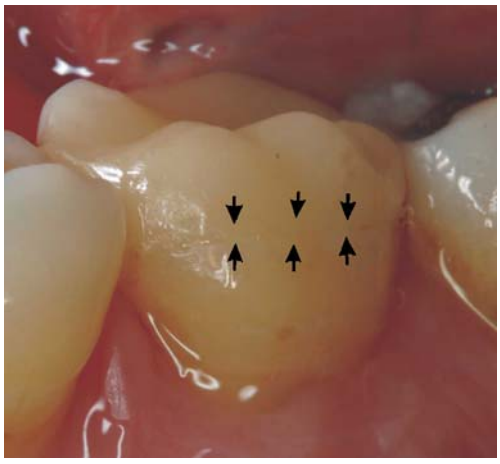

Fig. 4 PCC with marginal adaptation rated alfa (*arrows* indicate margin)

restorations being rated bravo. Two years after placement, no changes were observed for CGPC, but 22 (75.9%) PCC were rated alfa and six (20.7%) PCC bravo. In the PCC group, one (3.4%) case was rated delta due to the loss of the restoration. No statistically significant differences could be detected between the two types of restoration regarding marginal adaptation. Furthermore, no statistically significant difference between the 1- and the 2-year results in the PCC group could be observed (Table 2).

Marginal discoloration

At baseline and 1 year after placement, marginal discoloration was rated alfa for all restorations in each group. Two years after placement, alfa rating decreased to 28 (96.6%) cases for CGPC and to 26 (92.9%) cases for PCC. One (3.4%) CGPC and two (7.1%) PCC were rated bravo. No statistically significant differences could be detected between the two types of restoration regarding marginal discoloration (Table 2).

Surface texture

At baseline, surface texture was rated alfa for all restorations in each group. One year after placement, alfa rating decreased to 28 (96.6%) restorations, with one (3.4%) restoration in each group being rated bravo. Two years after placement, all restorations of the CGPC group and 27 (96.4%) of the PCC group were rated alfa. In the PCC group, one (3.6%) case was rated bravo due to a pore in the ceramic surface. No statistically significant differences could be detected between the two types of restoration regarding surface texture (Table 2).

Discussion

Study design

The present study compared the clinical performance of partial ceramic crowns and cast gold partial crowns in a prospective split-mouth approach. The limitations of prospective studies are generally a selected patient population, a limited observation period, and a comparatively small number of treatments [12, 22, 34].

In the present study, no CGPC was placed in premolars, but 15 PCC were. A random distribution of gold and ceramic restorations to different tooth types was not possible due to the patients' demands for esthetic ceramic restorations in premolars. Another disadvantage of the present study was that the preparation and restoration of selected teeth was not performed by one operator. It is known that parameters "operator" or "clinical experience" may influence the clinical success rate of the restorations [14]. The group of patients, however, was very homogenous, and the restorations placed in each patient had the same age. A main advantage of split-mouth trials is that test and control restorations are placed in the same patient. Patient factors influencing longevity of partial crowns like oral hygiene and diet are the same for the test and the control group. Furthermore, the patients' subjective sensations; e.g., hypersensitivities, in relation to the different treatment modalities could be better assessed because the patients were able to compare the two types of restorations in their mouth. Therefore, prospective split-mouth studies are reported as highly suitable for comparing treatment modalities [36], and they are encouraged in the American Dental Association (ADA) Acceptance Program Guidelines [1]. The study population meets the requirements outlined in the ADA Acceptance Program Guidelines for Tooth-Colored Restorative Materials for Posterior Teeth [1]. Furthermore, all 29 pairs of restorations in 29 patients were examined at both follow-up appointments.

Although the main focus of this study was directed to clinically compare CGPC and PCC, it should be kept in mind that the luting procedure and the luting materials play a decisive role in the clinical behavior of the restorations. For example, pulp reaction may be caused by either material toxicity or insufficient sealing, resulting in bacterial leakage. Therefore, in the present study, widely used luting materials (zinc-phosphate cement for CGPC and a dual curing luting composite for PCC), for which ample evidence exists that they are clinically acceptable, were applied [29, 31].

The CEREC III system was used for fabricating the partial ceramic crowns. The CEREC method enables the dentist to fabricate all-ceramic restorations chairside [2]. However, in the present study, the CEREC restorations were machined indirectly using a cast to make it more

convenient for the supervising operator to additionally control the preparation and the marginal fit of the milled restorations on the cast before placement.

Clinical results

Regarding the PCC, the data of the present study are in line with a recent, non-controlled prospective study over 10 years [32] which showed a 10-year survival rate of 77% (dual-cured resin composite-luted) and 100% (chemically cured resin composite-luted) for CEREC inlays. According to these data, the authors concluded that the patient satisfaction with and the acceptance of CEREC inlays are high, and the performance after 10 years of clinical service was acceptable. Other studies confirmed these findings [15, 18]. Compared to laboratory-manufactured ceramic inlays, CEREC inlays showed similar clinical results after 7 years [9]. Reiss and Walther [23] reported a survival rate of 90% after 10 years and of 84.9% after 11.8 years for all-ceramic CEREC inlays and onlays. Only scarce clinical data are available concerning PCC [3].

One PCC was lost due to adhesion failure. The restored tooth had been treated endodontically before the placement of the all-ceramic restoration. Reiss and Walther [23] showed in their investigation of 1,010 full-ceramic inlays and onlays that restorations on non-vital teeth showed worse results than those on vital teeth.

All eight teeth that were tested negative to cold in the follow-up appointments had been treated endodontically before placing the restorations, and no more endodontic treatment became necessary after placement of CGPC or PCC. In contrast, Wagner et al. [38] found one tooth in the PCC group and 7% of the cases in the CGPC group which needed endodontic treatment after placement of the restorations. Studer et al. [35] found no tooth having to undergo endodontic treatment after restoration for a mean observation time of 18.7±9.5 years. The results of the present investigation and the current literature gave no indication of severe pulp damage within the limited observation period.

With respect to postoperative hypersensitivity, it can be stated that, 2 years after placement, only one tooth restored with a CGPC and no tooth of the PCC group showed postoperative hypersensitivity. Wagner et al. [38] found less postoperative hypersensitivities (2% in the CGPC group and none in the PCC group). Donly et al. [5] also found postoperative hypersensitivities in 3% of the cases with cast gold restorations, which declined to 0% up to 4 years after placement. Studer et al. [34] reported in their investigation of 130 all-ceramic IPS-Empress inlays one patient suffering from minor sensitivity. However, Studer et al. [35] also reported postoperative hypersensitivities in 24% of the cases with cast gold partial crowns, which disappeared after several months. The data from the present study are apparently of the same order of magnitude as those reported in the literature. CGPC and PCC can be rated as similar. This seems to be of special interest because each patient could compare the reaction to the two different treatment procedures.

Regarding anatomic form, all CGPC were rated alfa 2 years after placement. Wagner et al. [38], however, reported lower alfa ratings (12% of CGPC) and higher bravo ratings (55% of CGPC). Furthermore, they found distinct under- or overcontoured CGPC (charlie rating) in 33% cases. The differences between these data and those of the present study may be due to the longer observation period (up to 157 months for CGPC and 72 months for PCC) compared to the present study. Van Dijken et al. [37] reported similar results to those of the present study with 86.3% alfa, 6.6% bravo, 2.2% charlie (distinct under- or overcontoured partial ceramic crown), and 4.9% delta (loss of restoration) cases in their investigation of ceramic partial crowns with an observation period of 4 years.

In the present study, marginal adaptation of CGPC slightly decreased after 2 years. Donly et al. [5] found alfa ratings in 78% of cast gold restorations, bravo in only 6%, and charlie (clinically not acceptable) in 17% after 13 years of function. Another retrospective study [38] found alfa ratings in 65% and bravo ratings in 35% of the CGPC cases after an observation period of 7 years. The lower alfa ratings and the high charlie ratings compared to the present study may be explained by the longer observation periods in the cited studies. In the PCC group, alfa ratings also decreased within an observation time of 2 years. Furthermore, one case was rated delta 2 years after placement because of the loss of the restoration. Studer et al. [34] investigated 130 IPS-Empress I inlays and onlays over a mean observation period of 23.4±6.1 months. They found 87% alfa ratings, 11% bravo ratings, and 2% delta (partial or complete fracture) ratings regarding marginal adaptation. Comparing the results of Studer et al. [34] with the present study is difficult because the authors did not subdivide their restorations in inlays, onlays, or partial crowns. Similar results compared to the present study were reported by Wagner et al. [38] and Felden et al. [8] after an observation period of 7 years, although the PCC of both studies [8, 38] were luted with four different luting materials. Bindl and Mörmann [3] found lower alfa ratings (25%) and higher bravo ratings (69%) in their investigation of CEREC II PCC cemented with Tetric (Vivadent). The better results of the present study can be explained by the short observation period of 2 years and, eventually, by the use of CEREC III system with improved software. In the present investigation, the PCC group showed lower alfa ratings and higher bravo ratings 2 years after placement compared to the CGPC group. However, the differences were not statistically significant. Therefore, both types of restoration can be rated as similar regarding marginal adaptation. In accordance with findings in the literature [16, 19, 24], the margin quality of ceramic restorations decreased with time due to wear of the luting composite and increasing submargination.

Marginal discoloration was rated alfa in nearly all cases of CGPC and PCC 2 years after placement. Other studies showed a similarly low appearance of marginal discoloration [7, 10, 13].

Surface texture was rated alfa in all cases of CGPC and in 27 (96.4%) cases of PCC 2 years after placement. Donly et al. [5] reported lower alfa (78%) and higher bravo ratings (6%) for CGPC compared to the present study. The CEREC method requires surface finishing of the ceramic restoration in situ. To achieve a smooth surface of the Vita Mark II CEREC restorations in the present study, the Sof-Lex disc-system (3 M Espe, Seefeld, Germany) was used for polishing as suggested by Karapetian et al. [11]. The use of industrially sintered machinable ceramic is an important advantage compared to laboratory ceramic restorations. The technical properties of these homogenous prefabricated ceramic preforms are very similar to those of natural enamel [4]. CGPC and PCC of the present study can be rated as similar regarding the surface texture within the limitations of the criteria used. However, in the future, the evaluation of replicas taken at the recall visits should be included to provide additional information with respect to surface texture and, eventually, quantification of gap size.

Within the limitations of the present prospective clinical split-mouth study, the stated hypothesis could not be rejected. Therefore, there is evidence that PCC show a similar clinical performance as the "golden standard" CGPC.

Conclusions

Cast gold partial crowns and partial ceramic crowns generally show a similar clinical performance after an observation period of 2 years and, thus—within the limitations of the present study—partial ceramic crowns may be regarded as an alternative to cast gold partial crowns. A longer observation time is, however, desirable.

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