Journal of Dentistry 43 (2015) 1076–1082

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.intl.elsevierhealth.com/journals/jden

Clinical performance of CEREC AC Bluecam conservative ceramic restorations after five years—A retrospective study

Farahnaz Nejatidanesh[a], Mehrak Amjadi[b], Mohadese Akouchekian[b], Omid Savabi[c,*]

[a] Dental Materials Research Center, School of Dentistry, Isfahan University of Medical Sciences
[b] Student's Research Committee, School of Dentistry, Isfahan University of Medical Sciences
[c] Torabinejad Dental Research Center, School of Dentistry, Isfahan University of Medical Sciences

ARTICLE INFO

Article history:
Received 15 April 2015
Received in revised form 27 June 2015
Accepted 2 July 2015

Keywords:
Computer-aided design
CEREC
Dental restoration failures
Inlays
Survival analysis
Treatment outcome

ABSTRACT

Objectives: The aim of this study was to assess the clinical performance of CAD/CAM partial coverage posterior restorations made by CEREC AC Bluecam system after 5 years.
Methods: 159 ceramic partial coverage posterior restorations were placed in 109 patients in a private practice. The restorations were made using CEREC AC Bluecam with CEREC Blocs or Empress CAD blocks. The clinical performance of the restorations was evaluated with modified California Dental Association (CDA) guidelines, gingival and plaque indices, probing pocket depth, and bleeding on probing in a period of 5 years. Patients' satisfaction was assessed using visual analogue scale. The Kaplan–Meier method was used to analyze survival probability of the restorations ($\alpha = 0.05$).
Results: The restorations included 102CEREC Blocs and 57 Empress CAD. The survival rates of CEREC Blocs and Empress CAD blocks were 96.0% and 94.6%, respectively ($P = 0.67$). A total of 7 (4.5%) failures were found. The failures were not significantly influenced by restoration size, type and position of teeth. The ceramic fracture was significantly more in nonvital teeth ($P = 0.04$). The periodontal parameters were not significantly different between the restored and control teeth except plaque index. The mean score of patients' satisfaction was 94.4 ± 8.1.
Conclusions: Chair-side CEREC AC ceramic partial coverage posterior restorations were clinically successful restorations with mean survival rate of 95.5% after 5 years.
Clinical significance: Conservative chair-side CAD/CAM ceramic restorations with less reduction of tooth structure can be a successful restorative method with acceptable survival rate and patient's satisfaction.

1. Introduction

The use of ceramic restorative materials has increased significantly in the last decade due to increasing demands for esthetic and metal-free restorations [1]. While full coverage complete crown restoration requires substantial reduction of tooth structure, partial coverage preparations with reduced macro-retentive geometry, such as inlays and partial coverage ceramic crowns have been reported to remove half the amount of tooth structure compared to a complete coverage metal ceramic crown [2]. Preserving tooth structure is critical for the longevity of teeth and restorations [3]. This permits retaining more enamel and dentin and can provide better periodontal health by preservation of sound tooth structure [2].

With the development and improvement of reliable adhesive bonding techniques, minimally invasive dentistry has become a field of great interest. Bonding with resin luting agents provides a chemical bond between the cement and the tooth as well as cement and the silanized glass. This bonding can increase the strength of ceramic which results in reduced fracture rate and increased lifetime of ceramic restorations [4].

Additionally, resin cements can seal small cracks of the intaglio surface of ceramic restorations and improve ceramic strength [5]. Ceramic-resin bonding is successfully achieved through pretreatment of silica-based ceramics with acid etching followed by silanization [6,7].

The computer-aided design/computer-aided manufacturing (CAD/CAM) technology has had a significant effect on both dental laboratories and clinics. The innovations in digital optical

* Corresponding author at: #400-Sheikhsadoogh Shomali St., Sheikhsadoogh Cross Road Isfahan, Iran. Fax +98 311 6625500.
E-mail address: savabi@hotmail.com (O. Savabi).

http://dx.doi.org/10.1016/j.jdent.2015.07.006
0300-5712/

impression techniques, virtual design software and precise milling machines [8,9] are rapidly improving fabrication methods. Chair-side CAD/CAM systems can be used for fabricating ceramic inlays, onlays, veneers, crowns, and fixed dental prostheses. These systems provide design and automatic production of all-ceramic monolithic restorations in one appointment. Continual development of the hardware and software have expanded the restorative capabilities significantly [10,11]. Chair-side production of restorations eliminates the need for interim restorations and decrease the risk of tooth structure fracture [12].

The ceramic restorations can be milled from prefabricated blocks with a CAD/CAM system [13]. Two types of these ceramics are CEREC Blocs (Sirona Dental Systems) and IPS Empress CAD (Ivoclar Vivadent) glass ceramics blocks. These materials are industrially manufactured in a reproducible manner in high-quality materials [13].

CEREC Blocs are fabricated from fine-grained powders that produce relatively pore free ceramic. Improved polishability, reduced enamel wear and increased strength of these blocks are partly because of their fine crystals (4 μm). They contain SiO_2 (60–64%) and Al_2O_3 (20–23%) and can be etched with hydrofluoric acid to create micromechanical retention for adhesive bonding with resin luting agents. The flextural strength of CEREC Blocs is approximately 112 or 120 MPa when polished or glazed, respectively [14].

IPS Empress CAD blocks are similar to IPS Empress Esthetic pressable materials (Ivoclar Vivadent) in structure. IPS Empress CAD blocks are made of a leucite-reinforced glass ceramic which consists of a glass and a crystal phase. Leucite crystals (5–10 μm) evenly grow in a multi-stage process directly from the amorphous glass phase. The flextural strength of IPS Empress CAD is approximately 105–125 MPa [14].

The long term longevity of dental restorations is essential for their clinical use. Survival rates for all-ceramic restorations has been reported from 88 to 100% for 2–5 years [15–17], and 84 to 97% after 5–14 years in service [18–27]. Wittneben and her colleagues [28] have been reviewed the clinical performance of CAD/CAM restorations in a systematic review. They found a total survival rate of 92.9% (95% CI: 89.3–95.3%) after 5 years for inlay/onlay CAD/CAM restorations [28].

Most of the clinical researches have been performed on restorations made by first generations of chairside CAD/CAM systems [12,15,16,18,19,21,29–31]. Introduction of new sophisticated softwares and milling machines open new era for dentistry. On the other hand Bluecam's handheld camera optics provides greater depth of field and precision. It provides a uniform field of illumination for increased accuracy. Built-in "shake control" eliminates blurry images and produces significantly more detailed images. The primary aim of this clinical study was to compare the survival, modified California Dental Association (CDA) criteria [32], and periodontal parameters of Cerec Bloc and IPS Empress CAD partial-coverage restorations over 60 months. The secondary purpose was to determine any correlation to tooth or patient characteristics with survival of the restorations. The null hypothesis was that there would be no significant difference in the clinical performance of the restorations which were made with CEREC Blocs and IPS Empress CAD blocks.

2. Materials and methods

In this retrospective study 109 patients (74 women and 35 men) with a mean age of 45.53 ± 10.67 years (range 18–70 years) who had received CAD/CAM ceramic (CEREC) partial-coverage posterior restorations between March 2009 to September 2009 were evaluated (all the patients were included). All the patients' files were screened and patients were recalled after 1 year. This research was approved by the Ethical Committee of Isfahan University of Medical Sciences (#393400).

The studied restorations consisted of 159 inlays and onlays (Table 1). Clinical treatment was performed by one prosthodontist in a private dental clinic. All patients were in good general health. The inclusion criteria consisted of having received a CEREC posterior restoration (except full crowns) from the same private practice during the aforementioned time span.

The clinician prepared, fabricated and placed all of the restorations in one appointment. The clinician prepared the tooth for all-ceramic two surface restorations with 1.5–2.0 mm pulpal floor depth, 1.0–1.5 mm axial reduction, 2.0 mm isthmus width with rounded internal line angles. The divergence of 12° was considered for proximal walls (6° each wall). For 3 surfaces restorations, the functional cusps were reduced 2 mm and nonfunctional cusps were reduced when the remaining wall thickness was less than 1.5 mm. For 4 and more surfaces restorations, in addition to cusp reduction, a shoulder preparation was extended to buccal or lingual surfaces. The gingival margin was placed entirely in enamel whenever possible. For teeth with substantial loss of tooth structure resulting from caries or fracture, the clinician used composite cores (Build-It; Pentron LLC) to create the required retention and resistance form.

After preparation, the teeth were isolated by cotton roll and saliva ejector. Retraction cord (Ultrapak; Ultradent) or paste (Expasyl; Kerr/Sybron) were used for tissue retraction. The prepared and corresponding antagonist teeth were sprayed (Optispray; Sirona) and scanned with CEREC Bluecam (CEREC AC) from occlusal view. The buccal bite was scanned for registration of occlusal relation.

The restorations were fabricated with a CEREC AC system (Sirona). The clinician designed (Version 3.85; Sirona) and milled (MCXL; Sirona) the restoration from prefabricated block of IPS Empress CAD (Ivoclar Vivadent) or CEREC Blocs (Sirona) at standard milling speed. No randomization was used for selection of blocks. After recovering the restorations from the milling chamber, proximal contacts and surfaces were checked, corrected, and polished with polishing disk (Sof-lex; 3M ESPE). The internal surface of the restorations was adjusted by diamond bur when needed.

2.1. Luting procedures

After try in, the restorations were cleaned with 96% isopropyl alcohol and the inner surfaces were treated with 9.5% hydrofluoridric acid (Porcelain Etchant; Bisco) for 1 min and then silanated (Bis-silane; Bisco). The tooth was isolated by rubber dam (Optradam; Ivoclar Vivadent) and enamel and dentine of the prepared teeth were etched with 32% phosphoric acid gel (15 s),

Table 1
Distribution of the studied posterior restorations.

	First premolar	Second premolar	First molar	Second molar	Total
Maxillary	14	22	34	14	84
Mandibular	9	16	26	24	75
Total	23	38	57	38	159

rinsed and dried. The preparation surfaces were treated with a dentin/enamel adhesive resin agent according to the instruction of manufacturer (ALL-BOND 2; Bisco). The bonding agent was applied to the cavity preparation and intaglio surface of restoration. A dual-curing composite (Duo link; Bisco) was injected into the cavity preparation and the restorations seated. The excess of luting agent was removed with a brush and dental floss. The restorations were light polymerized for 3 s (blue phase C8, LED with 800 mW/cm^2 output; Ivoclar Vivadent AG). After removing excess cement and application of OxyGuard, the restorations were light polymerized for 30 s on each side. The occlusion was refined as needed and occlusal surfaces were polished with polishing disk (Sof-lex; 3 M ESPE) and pumice paste (Fig. 1A and B).

2.2. Registrations and clinical examinations

The restorations were evaluated in the day of cementation and patients were recalled for check-up after 12, and 60 month intervals. The follow-up examinations were performed by 2 prosthodontists other than the clinician who had placed the restorations. The restorations were evaluated by both examiners. Agreement between the two clinicians for the characteristics of restorations (according to California Dental Association (CDA) guidelines) and soft tissue parameters were 92% and disagreements were resolved through discussion. Every finding (complication or failure) of restorations were additionally examined by the principal investigator. In addition, we asked the patients to call the clinic in case of any problem. If the patients had any problem they were examined between the scheduled follow up session and the data were registered.

For each patient, data were collected regarding the patient's gender, age at delivery, tooth position, occluding teeth in the opposite jaw, dynamic occlusal contacts. The California Dental Association guidelines were used to evaluate the quality of restorations regarding shade match, marginal gap, fracture, loss of retention, and hypersensitivity (Table 2) [32]. Variables Alpha and Bravo (excellent and acceptable) were defined as survive, whereas variables Charlie and Delta (not acceptable) were defined as failures. The treatment was also considered a failure when the abutment tooth was extracted following a biologic complication such as root fracture, endodontic and periodontal problems. Gingival index (GI), and plaque index (PI) were recorded for the studied restorations and contralateral sound teeth as the control.

Probing pocket depth (PPD) was analyzed by means of 4-point periodontal probing (mesial, buccal, distal, and palatal/lingual). Bleeding on probing (BOP) was evaluated with a yes-no score. Presence of pain and tenderness of temporomandibular joint and nocturnal bruxism of individuals were also recorded.

Presence of pain and tenderness of temporomandibular joints and nocturnal bruxism of individuals were also asked and recorded in the examination form.

The patients were interviewed regarding their satisfaction with their restorations (regarding general satisfaction) using a visual analogue scale (VAS) of 100 mm with the endpoints extremely dissatisfied (0) and extremely satisfied (100).

2.3. Statistical analysis

The data were evaluated using descriptive statistics. Kaplan–Meier analysis and the log rank test were used to analyze and compare the survival probabilities of different ceramic blocks. The CDA score comparison was performed using by log rank test. Because a patient could have more than one restoration, a noncluster data sample of 109 from the entire restorations (sample of 159) was identified for survival analysis. In patients who had more than one restoration, a random number table was used to randomly identify a single restoration for analysis. In patients who received only one unit, each restoration was included for analysis. Survival of randomly selected sample was analyzed and compared with the survival of entire sample [33]. In addition, a general estimation equation model (GEE; binary logistic, failure yes/no, chipping yes/no, as target variable) was produced with material of restoration (CEREC Blocs or IPS Empress CAD blocks) as covariates to support the results of the log-rank test.

Cox regression was used to evaluate hazard ratio of the effect of position, and size of restorations. Comparison between GI, PI, and PPD of studied and control teeth was made using Wilcoxon signed-rank test for paired samples. McNemar's nonparametric test was used for comparing BOP of the studied and control teeth ($\alpha = 0.05$).

3. Results

A total of 159 ceramic inlay and onlays were inserted with CEREC AC in 109 patients. These restorations included 102CEREC Blocs (in 66 patients) and 57 Empress CAD (in 43 patients). There was an average of 1.54 restorations per patient (with a maximum 8 restorations in a 48 year old woman). The participants included 35

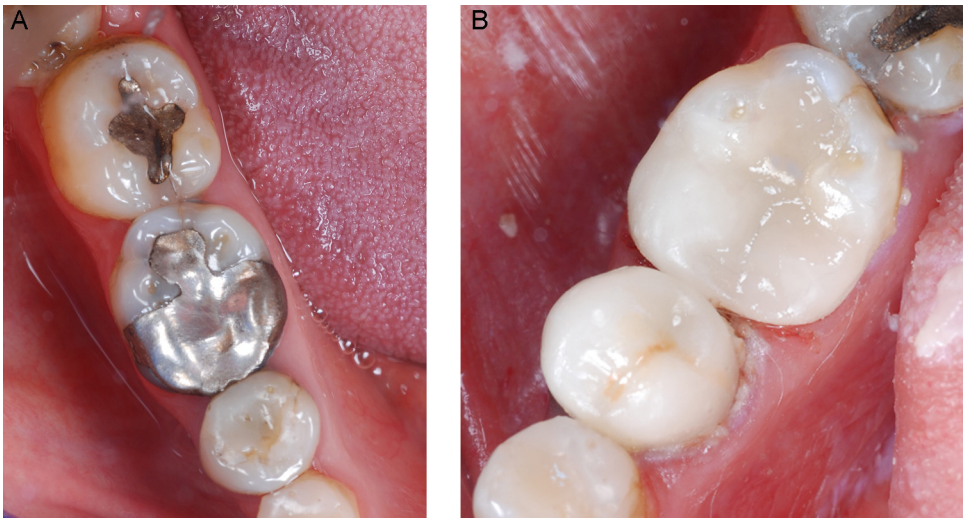

Fig. 1. A and B: Teeth 46 restored by a ceramic partial coverage restoration. Teeth no 45 restored by a crown and was not included in the study.

Table 2
Evaluation criteria based on the modified California Dental Association guidelines.

	Alfa	Bravo	Charlie	Delta
Shade match	No mismatch	Slight mismatch	Gross mismatch	Color falls outside the scale
Marginal gap	No probe catch	Slight probe catch but no gap	Gap with exposure of tooth	Restoration is mobile, fractured, or missing
Fracture	No fracture	Chipping of porcelain that does not impair esthetics or function and does not expose tooth structure	–	Chipping of porcelain impairing esthetics and function or exposing tooth structure
Loss of retention	No debonding	Debonding, may be re-cemented	–	Debonding, cannot be re-cemented
Hypersensitivity	No hypersensitivity when an air syringe is activated for 2 s at distance of 2.5 cm from the restoration	Hypersensitivity disappearing after removal of the stimulus	–	Spontaneous pain or the pain does not disappear after removal of the stimulus

men (mean age 45.37) and 74 women (mean age 45.70). Six patients who had 1 restoration did not take part in the follow up examinations (3 patients at first and 6 patient at fifth year). Thus, 103 patients have been examined in 60 months (153 restorations).

Eight patients had signs of temporomandibular disorders, and 11 individuals had bruxism. A natural opposing dentition was noted for 78.0%, a dentition with opposing fixed dental prostheses for 20.1% of restorations, and an edentulous area for 1.9% of restorations.

Table 1 shows the distribution of restored teeth and Table 3 presents the number of restorations with 2, 3, 4 and more surfaces.

Table 4 presents all failures occurred during the observation time. Fig. 2 shows the Kaplan–Meier survival rate of 5 years for restorations with CEREC Blocs (96.0%; 95% CI: 93.2–98.8%) and IPS Empress CAD (94.6%; 95% CI: 89.9–98.5%) blocks ($\chi^2 = 0.18$; $P = 0.67$). The estimated cumulative survival rates of the entire sample (94.1%) and random nonclustered sample (95.5%) were not significantly different ($\chi^2 = 0.26$; $P = 0.61$) The GEE model estimated that the risk of failure was not significantly different in two ceramic blocks (Exp (B) = 0.16, $P = 0.83$) that supported the result of log rank test. The Kaplan–Meier fracture free rates of 5 years for restorations were 99.0% (95% CI: 98.1–99.9%) for CEREC Blocs (1 fracture) and 96.4% (95% CI: 93.4–99.4%) for IPS Empress CAD blocks (2 fractures) ($\chi^2 = 1.30$; $P = 0.25$). None of the restorations on vital teeth had been fractured (no = 92) while ceramic fracture was significantly more in nonvital teeth (3 out of 67 teeth) ($\chi^2 = 4.02$; $P = 0.04$). Cox regression showed no influence in the failure rate for the following parameters: number of restoration surfaces (HR = 1.00; 95% CI: 0.87–1.18), molar or premolar teeth (HR = .07; 95% CI: 0.77–1.50), and mandible or maxilla (HR = 0.95; 95% CI: 0.66–1.31).

Table 5 and Table 6 show the CDA rating of the studied restorations after 1 and 5 years. The log rank test showed that only the color match of the restorations made with CEREC Blocs had significantly more Bravo score than Empress CAD ($\chi^2 = 8.58$; $P = 0.003$).

Tables 7 and 8 show the soft tissue conditions of restored teeth. Wilcoxon signed-rank test for paired samples showed that there is no significant difference in gingival index and pocket depth of restored and control teeth ($P = 0.32$, $P = 0.05$) but the PI was more in restored tooth than controls ($P = 0.02$). BOP of the studied and control teeth was not significantly different ($P = 0.13$). VAS evaluation of general satisfaction showed that 92 (89.3%) patients scored the restorations 90 and 100 and 11 (10.7%) patients scored them 70 and 80 (mean VAS score of 94.4 ± 8.1).

Table 3
The number of teeth with 2, 3, 4, and more surface restorations.

	2 Surface	3 Surface	4 Surface	More than 4 Surface	Total
CEREC blocs	6	43	32	21	102
Empress CAD	8	15	17	17	57
Total	14	58	49	38	159

4. Discussion

In the present study 153 chairside CAD/CAM restorations were assessed in 5 year follow up. The hypothesis that there would be no significant difference in the clinical performance of the CEREC Blocs and IPS Empress CAD blocks was rejected for one of the CDA rating criteria (shade match). But the present study could not prove significant difference in failure between 5-year survival rate of chairside CAD/CAM partial-coverage posterior restorations made from CEREC Blocs and IPS Empress CAD blocks ($\chi^2 = 0.18$; $P = 0.67$). During the follow up, only 3.7% of the restorations were unavailable for analysis because of no contact. The 5 year survival rate (Kaplan–Meier) of studied restorations was 95.5 (95% CI: 92.2–98.8). Nonvital teeth showed a significantly higher risk of fracture ($\chi^2 = 4.02$; $P = 0.04$).

Bulk fracture has been reported as the primary reason for failure of all-ceramic restorations [3,34]. In the current study, 1.89% of the restorations fractured and replaced by new CEREC restorations (emax CAD; Ivoclar Vivadent). The fracture of ceramic inlays and onlays has been reported 1–9.4% for 3–12 years [15–17,19,20,22,29,35]. The main reason for fracture was low flexural strength and fracture toughness of the material [11]. Additionally, inadequate porcelain thickness reported as one of the major contributors to the fracture of all-ceramic restorations. Another reason for weakness of the CAD/CAM ceramics is subsurface flaws produced during machining. Insufficient polishing of the occlusal surfaces after adjustment can also reduce the fracture strength of the ceramic restorations [31]. In the present study, the fracture of teeth with previous root canal treatment was significantly more. Although the number of restored surfaces had no significant effect on the fracture of restorations (HR = 1.00; 95% CI: 0.87–1.18) but all the fractures were in restorations with 4 and more surfaces (Table 4). The location of the restoration (molar or premolar) had no effect on failure risk in present study which is not in agreement with some of previous studies [19,26,35]. Since the occlusal forces in molar area are higher, careful material and patient (with parafunctional habits) selection has a critical influence in survival of restorations. For reducing the fracture rate of these restorations high strength ceramics (Lithium disilicate) can be used [25].

Among the 7 failures, 3 restored teeth (3 out of 92 vital teeth; 3.26%) needed root canal treatment because of post-operative hypersensitivity. Fasbinder [10] stated that early CEREC clinical studies reported high levels of post-operative sensitivity (13%). Introduction of new luting materials and techniques result in less post-operative sensitivity (0–3.13%) [15,19–21]. Some post-operative sensitivity may be the result of occlusal interference and can be resolved by occlusal adjustment [10]. On the other hand, cavity

Table 4
Descriptive analysis of the failures.

No.	Restoration surfaces	Block	Type of failure	Gender	Age	Restored tooth	Event (month)	In situ	Details of failure
1	3	Empress	Biologic	Male	40	Left 2nd mandibular molar	6	No	Hypersensitivity
2	4	Empress	Mechanical	Female	50	Right 2nd mandibular molar	8	No	Fracture
3	>4	CEREC	Biologic	Male	26	Left 1st mandibular molar	12	No	Hypersensitivity
4	4	Empress	Mechanical	Female	48	Right 2nd mandibular molar	12	No	Fracture
5	4	CEREC	Mechanical	Female	61	Right 2nd maxillary molar	12	No	Retention loss
6	>4	CEREC	Mechanical	Female	28	Left 2nd maxillary molar	24	No	Fracture
7	4	CEREC	Biologic	Male	61	Right 2nd maxillary premolar	36	yes	Hypersensitivity

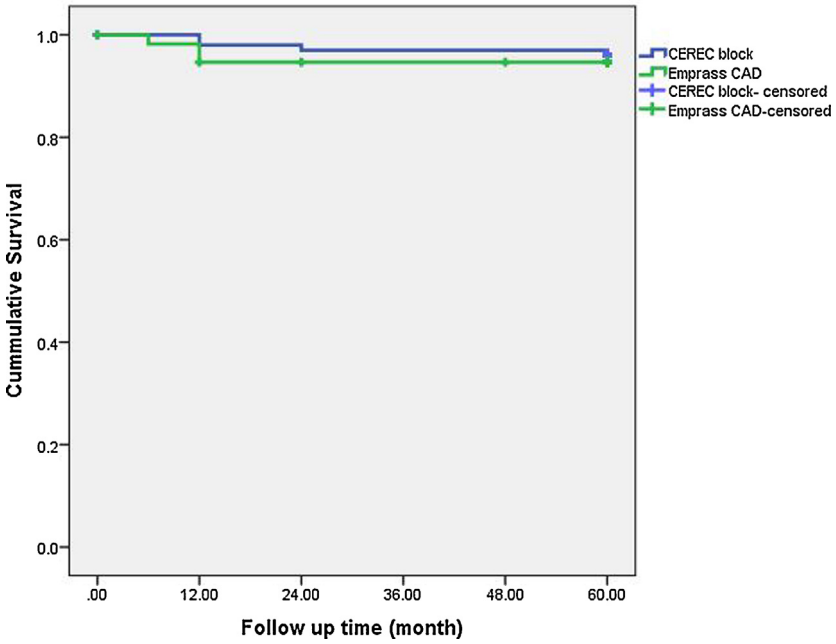

Fig. 2. Kaplan–Meier survival rate of 5 years for restorations with CEREC Blocs and IPS Empress CAD blocks.

Table 5
Modified California Dental Association rating, number and percentage (in parenthesis) of the cases in each studied groups after 1 year.

Studied feature	Excellent (Alfa)		Acceptable (Bravo)		Not acceptable (Charlie)		Not acceptable (Delta)		Total	
Material	CEREC Blocs	Empress CAD	CEREC Blocs	Empress CAD	CEREC Blocs	Empress CAD	CEREC Blocs	Empress CAD	CEREC Blocs	Empress CAD
Shade match	64 (64.0%)	49 (87.5%)	36 (36.0%)	7 (12.5%)	0	0	0	0	100	56
Marginal gap	94 (94.0%)	54 (96.4%)	6 (6.0%)	2 (3.6 %)	0	0	0	0		
Fracture	100 (100%)	54 (96.4%)	0	0	0	0	0	2 (3.6%)		
Loss of retention	100 (100%)	55 (98.2%)	0	0	0	0	0	1 (1.8%)		
Hypersensitivity[a]	59 (93.6%)	27 (93.2%)	3[b] (4.8%)	1[b] (3.4%)	0	0	1 (1.6%)	1 (3.4%)	63	29

[a] Only in vital teeth (total = 92, CEREC Blocs = 63, and Empress CAD = 29).
[b] Hypersensitivity was resolved within a few weeks.

disinfection and careful luting procedures can reduce the post-operative hypersensitivity [31].

The color match of IPS Empress CAD blocks was significantly better than CEREC Blocs ($\chi^2 = 8.58$; $P = 0.003$). This may be partly because of the special shade guide of CEREC Blocs which was not familiar for the clinician, while the classic Vita shade guide (Vita Zahnfabrik) was used for Empress CAD. Staining and glazing can be used to improve the color match of these ceramic restorations. Molin and Karlsson [15] showed that the degree of color mismatch increased by the time. Sjögren and colleagues [21] reported decrease in color match of CEREC ceramic inlays from 84% to 62% Alfa scores. This color mismatch over the time can be due to a color change in the tooth rather than the color of the restoration [10].

Table 6
Modified California Dental Association rating, number and percentage of the cases in each studied groups after 5 years.

Studied feature	Excellent (Alfa)		Acceptable (Bravo)		Not acceptable (Charlie)		Not acceptable (Delta)		
Material	CEREC Blocs	Empress CAD	CEREC Blocs	Empress CAD	CEREC Blocs	Empress CAD	CEREC Blocs	Empress CAD	Significance* (*P* value)
Shade match	63 (63.6%)	47 (87.0%)	36 (36.4%)	7 (13.0%)	0	0	0	0	$\chi^2 = 8.58$; $p = 0.003$
Marginal gap	93 (93.9%)	52 (96.3%)	6 (6.1%)	2 (3.7 %)	0	0	0	0	$\chi^2 = 0.093$; $p = 0.76$
Fracture	98 (99.0%)	52 (96.3%)	0	0	0	0	1 (1.0%)	2 (3.7%)	$\chi^2 = 1.31$; $p = 0.25$
Loss of retention	99 (100%)	53 (98.2%)	0	0	0	0	0	1 (1.8%)	$\chi^2 = 0.54$; $p = 0.46$
Hypersensitivity**	60 (95.2%)	27 (93.2%)	1 (1.6%)	1 (3.4%)	0	0	2 (3.2%)	1 (3.4%)	$\chi^2 = 0.07$; $p = 0.97$

* Log rank test.
** Only in vital teeth (total = 92, CEREC Blocs = 63, and Empress CAD = 29).

Table 7
Gingival index (GI), plaque index (PI), and bleeding on probing (BOP) scores of studied groups after 5 years (percentage in parenthesis).

	Plaque index				Gingival index			BOP	
	0	1	2	3	0	1	2	Negative	Positive
CEREC Blocs	81 (81.8)	14 (14.1)	4 (4.1)	0	93 (93.9)	6 (6.1)	0	88 (88.9)	11 (11.1)
Empress CAD	38 (70.4)	15 (27.8)	1 (1.8)	0	49 (90.7)	5 (9.3)	0	41 (75.9)	13 (24.1)
Total	119 (77.8)	29 (19.0)	5 (3.2)	0	142 (92.8)	11 (7.2)	0	129 (84.3)	24 (15.7)

Table 8
Probing pocket depth (PPD) of studied restorations after 5 years. (percentage in parenthesis).

PPD mm	CEREC Blocs	Empress CAD
1	38 (38.4)	11 (20.4)
2	58 (58.6)	42 (77.8)
3	3 (3.0)	1 (1.8)

The marginal fit of ceramic inlays is one of the most critical factors for clinical success. Large marginal gaps lead to wear of luting agent which can jeopardize the strength of the restoration [10,20]. The marginal accuracy was considered excellent (rating as Alfa) in 93.9% and 96.3% of CEREC Blocs and IPS Empress CAD restorations respectively ($\chi^2 = 0.093$; $P = 0.76$) in present study. Previous studies on Cerec 1 and 2 showed 19 to 73% of inlays or partial crowns had excellent margins [12,15,17,19,21,30]. Molin and Karlsson [15] reported that the ditching of the margins increased from 5% in the first year to 70% after 5 years. The average clinical marginal gap of 236.1 ± 96.8 μm was reported for CEREC 1 and 2 inlays by Posselt and Kerschbaum [30]. Bindl and Mörmann [12] compared the marginal adaptation of crowns fabricated with CEREC 1 and 2 and showed significantly improved margins for crowns fabricated by CEREC 2 (207 ± 63 μm) compared CEREC 1generated (308 ± 95 μm). The better result of current study may be related to newer acquisition and milling unit of the CEREC AC Bluecam.

Regards to soft tissue status, the results of present study showed that 7.2% of patients had mild to moderate inflammation (GI 1) and 22.2% had PI score of 1 and 2. On the other hand, 15.7% of them had positive BOP (Table 7). Although the pocket depth and GI of the restored teeth were not significantly different from control teeth, the greater PI may lead to future inflammation.

The patient satisfaction with CEREC restorations was generally high (mean 94.4 ± 8.1) which can be partly because of single visit treatment.

One of the limitations of present study was that the results of this study were obtained from one practitioner in a private clinic and cannot be generalized. Although the learning curve of chair-side restoration is short, the experience of clinician can highly affect the clinical success. Another limitation of the current study is the non randomized selection of the CAD/CAM blocks which was chosen according to the availability of these blocks in clinic.

5. Conclusions

Within the limitations of this study it can be concluded that:

1. Chair-side CEREC AC conservative ceramic restorations were clinically successful restorations with mean survival rate of 95.5% (95% CI: 92.2–98.8%) after 5 years.
2. There was no significant difference between survival rate of restorations made by CEREC Blocs and IPS Empress CAD blocks.
3. The fracture rate of ceramic restorations was significantly more in nonvital compare to vital teeth.

Conflict of interest

No conflict of interest.

Acknowledgements

This study was approved by Ethics Committee of Isfahan University of Medical Sciences and supported by Isfahan University of Medical Sciences (Research Grant #393400)

Based on a thesis submitted to the post graduate school of Isfahan University of Medical Sciences in partial fulfillment of the requirement for the Master of Science Degree.

References

[1] G.J. Christensen, Porcelain-fused-to-metal versus zirconia-based ceramic restorations, J. Am. Dent. Assoc. 140 (2009) 1036–1039.
[2] D. Edelhoff, J.A. Sorensen, Tooth structure removal associated with various preparation designs for posterior teeth, Int. J. Periodontics Restorative Dent. 22 (2002) 241–249.
[3] J.W. van Dijken, L. Hasselrot, A prospective 15-year evaluation of extensive dentin-enamel-bonded pressed ceramic coverages, Dent. Mater. 26 (2010) 929–939.
[4] F.E. Albert, O.M. El-Mowafy, Marginal adaptation and microleakage of Procera AllCeram crowns with four cements, Int. J. Prosthodont. 17 (2004) 529–535.

[5] M.B. Blatz, A. Sadan, M. Kern, Bonding to silica-based ceramics: clinical and laboratory guidlines, Quintessence Dent. Technol. 25 (2002) 54–62.
[6] M. Ozcan, P.K. Vallittu, Effect of surface conditioning methods on the bond strength of luting cement to ceramics, Dent. Mater. 19 (2003) 725–731.
[7] A. Della Bona, K.J. Anusavice, J.A. Hood, Effect of ceramic surface treatment on tensile bond strength to a resin cement, Int. J. Prosthodont. 15 (2002) 248–253.
[8] E.R. Batson, L.F. Cooper, I. Duqum, G. Mendonca, Clinical outcomes of three different crown systems with CAD/CAM technology, J. Prosthet. Dent. 112 (2014) 770–777.
[9] T.A. Hamza, H.A. Ezzat, M.M. El-Hossary, H.A. Katamish, T.E. Shokry, S.F. Rosenstiel, Accuracy of ceramic restorations made with two CAD/CAM systems, J. Prosthet. Dent. 109 (2013) 83–87.
[10] D.J. Fasbinder, Clinical performance of chairside CAD/CAM restorations, J. Am. Dent. Assoc. 137 (2006) 22S–31S.
[11] D.J. Fasbinder, J.B. Dennison, D. Heys, G. Neiva, A clinical evaluation of chairside lithium disilicate CAD/CAM crowns: a two-year report, J. Am. Dent. Assoc. 141 (Suppl. 2) (2010) 10s–14s.
[12] A. Bindl, W.H. Mormann, Clinical and SEM evaluation of all-ceramic chair-side CAD/CAM-generated partial crowns, Eur. J. Oral Sci. 111 (2003) 163–169.
[13] R. Giordano, Materials for chairside CAD/CAM-produced restorations, J. Am. Dent. Assoc. 137 (2006) 14S–21S.
[14] A. Vichi, M. Sedda, F. Del Siena, C. Louca, M. Ferrari, Flexural resistance of Cerec CAD/CAM system ceramic blocks. Part 1: chairside materials, Am. J. Dent. 26 (2013) 255–259.
[15] M.K. Molin, S.L. Karlsson, A randomized 5-year clinical evaluation of 3 ceramic inlay systems, Int. J. Prosthodont. 13 (2000) 194–200.
[16] M. Thordrup, F. Isidor, P. Horsted-Bindslev, A 3-year study of inlays milled from machinable ceramic blocks representing 2 different inlay systems, Quintessence Int. 30 (1999) 829–836.
[17] D.J. Fasbinder, J.B. Dennison, D.R. Heys, K. Lampe, The clinical performance of CAD/CAM-generated composite inlays, J. Am. Dent. Assoc. 136 (2005) 1714–1723.
[18] B. Reiss, Clinical results of Cerec inlays in a dental practice over a period of 18 years, Int. J. Comput. Dent. 9 (2006) 11–22.
[19] T. Otto, D. Schneider, Long-term clinical results of chairside Cerec CAD/CAM inlays and onlays: a case series, Int. J. Prosthodont. 21 (2008) 53–59.
[20] U. Pallesen, J.W. van Dijken, An 8-year evaluation of sintered ceramic and glass ceramic inlays processed by the Cerec CAD/CAM system, Eur. J. Oral Sci. 108 (2000) 239–246.
[21] G. Sjogren, M. Molin, J.W. van Dijken, A 10-year prospective evaluation of CAD/CAM-manufactured (Cerec) ceramic inlays cemented with a chemically cured or dual-cured resin composite, Int. J. Prosthodont. 17 (2004) 241–246.
[22] N. Kramer, R. Frankenberger, Clinical performance of bonded leucite-reinforced glass ceramic inlays and onlays after eight years, Dent. Mater. 21 (2005) 262–271.
[23] M.B. Blatz, Long-term clinical success of all-ceramic posterior restorations, Quintessence Int. 33 (2002) 415–426.
[24] A. Della Bona, J.R. Kelly, The clinical success of all-ceramic restorations, J. Am. Dent. Assoc. 139 (2008) 8S–13S.
[25] M. Gehrt, S. Wolfart, N. Rafai, S. Reich, D. Edelhoff, Clinical results of lithium-disilicate crowns after up to 9 years of service, Clin. Oral Invest. 17 (2013) 275–284.
[26] M. Fradeani, M. Redemagni, An 11-year clinical evaluation of leucite-reinforced glass-ceramic crowns: a retrospective study, Quintessence Int. 33 (2002) 503–510.
[27] A. Klink, F. Huettig, Complication and survival of Mark II restorations: 4-year clinical follow-up, Int. J. Prosthodont. 26 (2013) 272–276.
[28] J.G. Wittneben, R.F. Wright, H.P. Weber, G.O. Gallucci, A systematic review of the clinical performance of CAD/CAM single-tooth restorations, Int. J. Prosthodont. 22 (2009) 466–471.
[29] A. Bindl, B. Richter, W.H. Mormann, Survival of ceramic computer-aided design/manufacturing crowns bonded to preparations with reduced macroretention geometry, Int. J. Prosthodont. 2005 (18) (2006) 219–224.
[30] A. Posselt, T. Kerschbaum, Longevity of 2328 chairside Cerec inlays and onlays, Int. J. Comput. Dent. 6 (2003) 231–248.
[31] N. Martin, N.M. Jedynakiewicz, Clinical performance of CEREC ceramic inlays: a systematic review, Dent. Mater. 15 (1999) 54–61.
[32] California Dental Association, Quality evaluation for dental care, Guidelines for Assessment of Clinical Quality and Professional Performance, California Dental Association, Los Angeles, 1977.
[33] D.M. Layton, T.R. Walton, The up to 21-year clinical outcome and survival of feldspathic porcelain veneers: accounting for clustering, Int. J. Prosthodont. 25 (2012) 604–612.
[34] U.S. Beier, I. Kapferer, H. Dumfahrt, Clinical long-term evaluation and failure characteristics of 1335 all-ceramic restorations, Int. J. Prosthodont. 25 (2012) 70–78.
[35] B. Reiss, W. Walther, Clinical long-term results and 10-year Kaplan–Meier analysis of Cerec restorations, Int. J. Comput. Dent. 3 (2000) 9–23.