

The Longevity of Ceramic Veneers: Clinical Evaluation of Mechanical, Biologic and Aesthetic Performances of Ceramic Veneers, a 7-year Retrospective Study

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Abstract

The objective of this study was to evaluate the mechanical, biological and aesthetic performance of ceramic veneers after 5 to 7 years of service. The ceramic veneer restorations were clinically examined using a modified criteria of the United States Public Health Service (USPHS) and World Dental Federation (FDI). Clinical evaluation was performed by two clinicians during maintenance appointments between September 2016 and August 2017. Intra-examiner and inter-examiner reliability was evaluated by calculating the intraclass correlation coefficient and by inter-examiner calibration. The results were analysed by the Kaplan-Meier survival estimation method and log-rank test at a 95 % confidence level. One hundred and sixty-three veneers [a mean clinical service of 68.1 ± 0.66 months] were examined. Overall survival rate of the veneer restorations was 97.5 % with 2.5 % (four veneers) presenting clinically unacceptable problems, such as fracture and debonding. Caries were not detected in any teeth. Radiographic examination found the development of a periapical lesion in one patient after veneer placement. Veneer placement in premolars showed a higher failure rate than other dental regions. Most patients were comfortable with their restorations and satisfied with the aesthetic results. Ceramic veneers demonstrated a high survival rate with most failure cases resulting from fracture and debonding.

Keywords: Ceramic veneer, Clinical evaluation, Longevity, Porcelain laminates veneer, Success rate

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Introduction

Presently, people are more concerned with and consider facial and dental aesthetics as an expression of their individuality and a way to boost self-confidence.¹⁻⁴

Dissatisfaction with tooth color and shape has increased the demand for cosmetic dental treatment. Available options to restore unaesthetic teeth and create bright

smiles consist of both direct and indirect veneer treatment.

Direct resin composite veneers are applied straight onto prepared tooth surfaces at a dental clinic. Minimal tooth preparation renders this conservative technique an excellent as well as economical and aesthetic option.⁵ Disadvantages include marginal leakage, low color stability, low wear resistance and susceptibility to discolouration, which affect long-term aesthetic results.⁶⁻¹¹

The application of indirect ceramic veneers involves minimally invasive preparation with high aesthetic appeal, proven biocompatibility, good mechanical properties and predictability.^{2,11-14} Ceramic veneers have become the first choice of patients for alteration of color, shape, space closure and correction of malpositioned teeth. Ceramic veneers have also been proven to be highly effective for stabilising the color of tetracycline-stained teeth.¹⁵

Longevity is one of the most important factors to predict the survival and success of restorations. Many longitudinal clinical studies have evaluated the performance of ceramic veneer restorations and have confirmed good clinical performance, excellent aesthetics, and a high level of patient satisfaction. Major clinical complications commonly resulting in the failure of ceramic veneer restorations are fracture and debonding.^{2,7,8,13,16-19} However, limited studies have evaluated the longevity of ceramic veneers from the mechanical, biological, and aesthetic aspects.

This retrospective study reviewed clinical performance and patient perception regarding the mechanical, biological and aesthetic qualities of ceramic veneers after 5 to 7 years of service at the Department of Esthetic Restorative and Implant Dentistry, Chulalongkorn University.

Materials and Methods

One hundred and sixty-three ceramic veneers were performed on 26 patients for a variety of reasons between 2009 and 2012. All participants were examined

over a 11-month period from September 2016 to August 2017 during their regular maintenance appointments at the Department of Aesthetic Restorative and Implant Dentistry, Chulalongkorn University. Participants were informed of the purpose of this study, and their informed consent was obtained. The Ethical Committee, Faculty of Dentistry, Chulalongkorn University approved of the research protocol. If a patient developed complications of any kind from the procedure, appropriate follow-up treatment was performed at no additional cost. All failures of the ceramic veneer restorations were retreated or repaired.

The history of the restorations was investigated from the dental chart records. The clinical procedure used was similar. The participants were treated by graduate students at the Department of Aesthetic Restorative and Implant Dentistry, Chulalongkorn University. An expert supervisor controlled all treatment protocols and procedures. All preparations were performed according to the guidelines for tooth preparations approach in the Aesthetic Pre-evaluative Temporary (APT) protocol.²⁰

Clinical Evaluation

During the appointment, extraoral and intraoral photography and chart records were used as documentation tools. Each patient was invited to complete a self-evaluation questionnaire consisting of six simple questions, designed to measure perception regarding the aesthetic, functional and biological aspects of veneer treatment. Levels of satisfaction were classified as very satisfied, satisfied, neutral, dissatisfied and very dissatisfied (Fig. 1).

Two experienced and calibrated restorative dentists examined the patients. Each examiner performed evaluations using the same criteria in five patients. The evaluations were repeated three times. The calibration used Kappa coefficients and was carried out until the results of the two examiners were not significantly different, with a kappa score higher than 0.8.²¹ Clinical evaluation parameters were modified from the United States Public Health Service USPHS (Modified United

States Public Health Service Criteria)²² and World Dental Federation (FDI)^{23,24} criteria, adjusted for veneer restorations (Table 1). The examination used a dental explorer, mouth mirror, periodontal probe and visual inspection. Mechanical, biological, aesthetic, radiographic and patient satisfaction data were evaluated. Aesthetic performance was assessed clinically at chair side in terms of color matching. Mechanical performance was evaluated in terms of bonding/debonding, marginal discolouration/microleakage, marginal adaptation and

fracture of restoration. Biological performance was evaluated in terms of gingival index, gingival recession, postoperative sensitivity and secondary caries. Radiographic examination was evaluated by a radiologist. Two evaluators recorded the criteria following an index system. Each evaluator provided data separately and took a break every 10 minutes. Each evaluator was asked to stop evaluating every 30 minutes and look away at a distance of 20 feet for 20 seconds for prevention of visual fatigue.²⁵

Code _____ Sex _____ Age _____

Volunteer accepts all procedures of the study and accept to answer the questionnaire.

General information: Please write the ✓ in the box.

1. Do you smoking? Yes No

2. Do you drink coffee and/or tea? Yes No

Patient perception

Example: You score degrees of satisfy of restoration related to that topic. You should give a mark on the line as show below.

1. Are you satisfied with the color of restoration?
Please specify your problem _____

	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied
Veneer Cementation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nowadays	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. Are you satisfied with the shape both width and height of restoration?
Please specify your problem _____

	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied
Veneer Cementation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nowadays	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3. Are you satisfied with daily chewing after veneer placement?
Please specify your problem _____

	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied
Veneer Cementation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nowadays	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4. Do you have any problems with food impaction around your veneer restoration?
Please specify your problem _____

	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied
Veneer Cementation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nowadays	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. Do you have any problems with bleeding gums or swelling around the area of veneer restoration?
Please specify your problem _____

	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied
Veneer Cementation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nowadays	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

6. Do you have any problems while cleaning the restoration with a toothbrush and/or dental floss after veneer placement?
Please specify your problem _____

	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied
Veneer Cementation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nowadays	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 1 The patient's perception questionnaire

Table 1 Clinical evaluation modified from USPHS and FDI criteria

Criteria	Parameter	Rating and Restoration Characteristics
Aesthetic	Color Matching	0: The restoration matches the shade and translucency of adjacent tooth tissues / veneers restoration. Patient is very satisfied with the color. 1: The restoration does not match the shade or translucency of the adjacent tooth/ veneers restoration, but the mismatch is minor deviation within the normal range and clinically acceptable. Patient is satisfied with the color. 2: The restoration does not match the share or translucency of adjacent teeth/veneers restoration and the mismatch is esthetically displeasing and clinically unacceptable. Patient is dissatisfied with the color.
Mechanical	Bonding/ Debonding	0: No debonding and loss of restoration from tooth surface. 1: Debonding and loss of restoration from tooth surface.
	Marginal Discoloration	0: No visual evidence of marginal discoloration on the margin. 1: Visual evidence of marginal discoloration from slight staining, which can be polished away. 2: Visual evidence of marginal discoloration from obvious staining which cannot be polished away.
	Marginal Adaptation	0: Smooth margin. No catch or penetrate of explorer. 1: Slight discontinuity detectable from explorer but clinical acceptable. 2: Catch or penetrate of explorer.
	Fracture of Restoration	0: The restoration is intact and fully retained. 1: The restoration is intact with craze lines and /or minor chipping of restoration (1/4 of restoration). This fracture can be repaired or polished. 2: The restoration is deep crack line/moderate to severe chipping. Replacement is required (1/2 of restoration).
Biologic	Gingival Index	0: Absence of inflammation. 1: Mild inflammation: slight change in color and little change in texture. 2: Moderate inflammation: moderate glazing, redness, edema, and hypertrophy. Bleeding on probing (BOP). 3: Severe inflammation: marked redness and hypertrophy. Tendency to spontaneous bleeding. Ulceration.
	Gingival Recession	0: No visual evidence of gingival recession from restoration level. 1: Visual evidence of gingival recession \leq 1 mm. 2: Visual evidence of marginal tissue recession $>$ 1 mm.
	Postoperative Sensitivity	0: No symptom of postoperative sensitivity after veneer fixation. 1: Present symptom of postoperative sensitivity after veneer fixation.
	Secondary Caries	0: Absent caries. 1: Present caries.
Radiographic Examination	Radiographic Examination	0: No pathologic finding, harmonious transition between restoration and tooth. 1: Present cement excess, and/or marginal gap present and/or sign of secondary caries.

Statistical Analysis

Data was tabulated using Excel 2015 (Microsoft Office Excel 2015, Microsoft). An initial statistical analysis to determine frequencies and percentages for the variable

categories was performed using SPSS. All criterias were evaluated including color match, bonding/debonding, marginal discoloration, marginal adaptation, fracture, gingival bleeding index, recessions, secondary caries,

hypersensitivity, radiograph, and degree of patient satisfaction. In carrying out the statistical analysis, a descriptive approach was taken in analyzing the data. Survival rates of the ceramic veneer restorations were evaluated statistically using the Kaplan-Meier test to obtain the cumulative results in relation to observation time. Survival time was defined as the period starting from the successful fitting of the veneer restoration at baseline and ending when the veneer failed irreparably. The major criteria for irreparable failures included veneers fractures of more than ¼ of restoration and/or debonding and/or impaired aesthetics or function. A P value of less than 0.05 was considered to be statistically significant. For further statistical evaluation, the log-rank test was applied to statistical analysis between: the failure rates of veneers and dental arch.

Results

Demographic Data

A total of 163 ceramic veneers were placed in 26 patients. Mean clinical service was 68.1 ± 0.66 months. Almost 90 % of the patients (88.5 %) (n=23) with 85.3 % of the total veneers (n=139) were female and 11.5 % of the patients (n=3) with 14.7 % of the total veneers (n=24) were male. The age of the patients ranged from 23-61 years old, with the mean age at 44 ± 8.8 years. Each patient received between 1 and to 20 veneers (mean: 6.6 ± 5.7 veneers per patient). The distribution of 1-5 veneers was 48.1 % (n=13), 6-10 veneers, 22.2 % (n=6), 11-15 veneers, 14.8 % (n=4), and 16-20 veneers, 11.1 % (n=3) (Table 2). Ceramic veneers were prepared on both maxillary (69.3 %, n=113) and mandibular teeth (30.7 %, n=50) (Fig. 2).

Aesthetic Evaluation

The aesthetic parameter of color match was evaluated as excellent for all intact veneers after 5 to 7 years. No veneers exhibited unacceptable colour matching (Table 3) (Fig. 3). Most patients (n=17) were very satisfied with the esthetic results. (Table 5).

Mechanical evaluation

Mechanical evaluation included bonding/debonding, marginal discolouration, marginal adaptation and fracture. After 5 to 7 years, there was one veneer restoration that showed debonding at the left maxillary second premolar (Fig. 4). One veneer (0.6 %) showed visual evidence of marginal discolouration from slight staining. It was completely removed by polishing the palatal aspect of the right maxillary central incisor. Eight veneers presented a slight discontinuity detectable by the dental explorer with clinically acceptable marginal adaptation (Table 3). The midpalatal area was the most common area for slight detectable discontinuous margin (4.3 %) (Table 4).

A total of 96.3 % of the veneer restorations (n=157) were still intact and fully retained, with 1.2 % (n=2) intact with craze lines and/or minor chipping (1/4 of restoration) at the canine and maxillary second premolar. In contrast, 1.8 % (n=3) required replacement due to more than half of the fracture restoration at the maxillary lateral incisor, maxillary first premolar and lower first premolar tooth (Table 3) (Fig. 5). Fracture of restorations were found at the cervical area. The cause of the fracture for one lateral incisor was an iatrogenically caused during oral tube insertion by a medical surgeon, while others were of unknown cause.

Biological evaluation

Biological evaluation consisted of gingival index, gingival recession, postoperative sensitivity and caries evaluation. No teeth showed severe gingival inflammation, while 3.1 % (n=5) showed mild gingival inflammation and 15.3 % (n=25) showed moderate gingival inflammation (Table 3). The most common tooth showing moderate gingival inflammation was the left maxillary central incisor.

A total of 89.6 % of veneer restorations (n=146) showed no gingival recession and 9.8 % (n=16) showed gingival recession of less than 1 mm (Table 3). A total of 87.1 % of veneer restorations (n=142) showed no signs of hypersensitivity, whereas 12.3 % (n=20) showed a history of hypersensitivity after cementation, which

later disappeared (Table 3). Caries evaluation showed that all veneer restorations were free of caries (Table 3).

Radiographic Evaluation

After 5 to 7 years, one tooth, the right maxillary lateral incisor showed the pathological findings of a periapical lesion after veneer placement.

Patient Satisfaction

The functional satisfaction evaluation consisted of shape satisfaction, chewing satisfaction and lack of food impaction. Most patients (65.4 %) were very satisfied with the veneer shape. Moreover, 100 % experienced problem-free chewing. Also, 100 % had no problems with food impaction (Table 5). Biologic satisfaction consisted

of gingival bleeding and flossing problems. More than half of the patients (65.4 %) (n=17) had no bleeding or flossing problems (Table 5).

The survival rate of veneer

Overall, the survival of the 163 veneer restorations was 97.5 % (+0.34), as shown in Fig. 6, with 4 failures caused by 1 debonding and 3 fractures, which were replaced. New restorations were not included in subsequent evaluations. Statistical evaluation revealed that no statistical difference existed between the failure rates of veneers placed in the upper and lower teeth ($p=0.86$). However, veneer placement in the premolar area showed a clear tendency towards an increased risk of failure (Fig. 7).

Table 2 Patient demographics for veneer restoration

Description	Number	Percent
Number of Patient	26	100.0
Age (in years)		
20-30	5	18.5
31-40	4	14.8
41-50	11	40.7
51-60	5	18.5
>61	1	4.0
Smoking Status		
Yes	-	-
No	26	100
Coffee/Tea Consumption		
Yes	14	53.8
No	12	46.2
Number of Veneers		
Placed in 2009	22	13.5
Placed in 2010	65	39.9
Placed in 2011	27	16.6
Placed in 2012	49	30.1

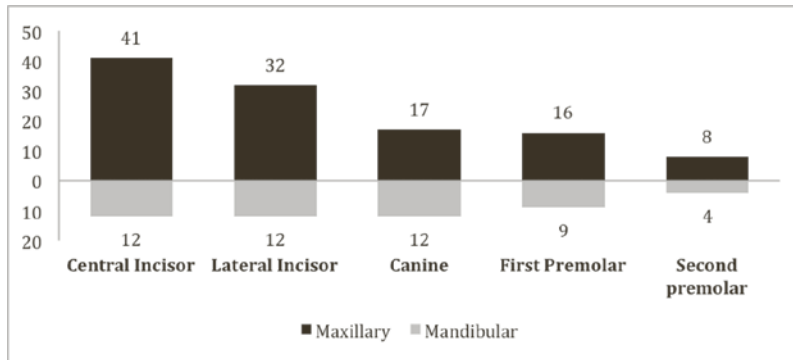


Figure 2 Distribution of teeth treated with ceramic veneers

Table 3 Frequency distribution of clinical evaluation of veneer restorations (number of restorations and percent)

Clinical Evaluation		Number (percentage) at study checkpoint			
		0	1	2	3
Aesthetic	Color Matching	162 (99.4 %)	-	-	
	Mechanical	162 (99.4 %)	1 (0.6 %)*		
Biological	Marginal Discoloration	161 (98.8 %)	1 (0.6 %)	-	
	Marginal Adaptation	154 (94.5 %)	8 (4.9 %)	-	
	Fracture	157 (96.3 %)	2 (1.2 %)	3 (1.8 %)**	
	Gingival Index	132 (81 %)	5 (3.1 %)	-	
	Gingival Recession	146 (89.6 %)	16 (9.8 %)		
Radiographic	Sensitivity	142 (87.1 %)	20 (12.3 %)		
	Caries	162 (99.4 %)	-		
	Radiographic Examination	161 (98.8 %)	1 (0.6 %)		

*There was 1 veneer restoration which showed debonding on the left maxillary second premolar, that had been placed 7 years ago.

**There were 3 veneer restorations which required replacement for more than half of the fracture restoration at the maxillary lateral incisor, maxillary second premolar and lower second premolar.



Figure 3 Veneer restorations at the Department of Esthetic Restorative and Implant Dentistry Program, Chulalongkorn University

A: 11,21 ceramic veneer restorations at 5 years recall.

B: 13-23 ceramic veneer restorations at 6 years recall.

C: 12-22 ceramic veneer restorations at 7 years recall.

D: 12,22 ceramic veneer restorations at 6 years recall.

Table 4 Distribution of marginal adaptation area

Evaluation	Distobuccal	Midbuccal	Mesiobuccal	Distopalatal	Midpalatal	Mesiopalatal
Excellent	162 (99.4 %)	160 (98.2 %)	159 (97.5 %)	162 (99.4 %)	155 (95.1 %)	162 (99.4 %)
Acceptable	-	2 (1.2 %)	3 (1.8 %)	-	7 (4.3 %)**	-
Unacceptable	-	-	-	-	-	-
Total	163	163	163	163	163	163

* One debonding case was not evaluated.

** The midpalatal area was the most common for a slightly discontinuous detectable margin.



Figure 4 Debonding of veneer restoration at 6 years recall on maxillary second premolar tooth

Table 5 Frequency Distribution of patient's perception

Level	Criteria					
	Aesthetic		Functional		Biologic	
	Color	Shape	Chewing	Food Impaction	Gingival Bleeding	Flossing
Very Satisfied	65.4 (n=17)	65.4 (n=17)	84.6 (n=22)	57.7 (n=15)	65.4 (n=17)	65.4 (n=17)
Satisfied	26.9 (n=7)	23.1 (n=6)	15.4 (n=4)	42.3 (n=11)	26.9 (n=7)	30.8 (n=8)
Neutral	7.7 (n=2)	11.5 (n=3)	-	-	7.7 (n=2)	3.8 (n=1)
Dissatisfied	-	-	-	-	-	-
Very Dissatisfied	-	-	-	-	-	-



Figure 5 Ceramic Veneer fracture

- A: Irreparable fracture of ceramic veneer at 5 years recall on right mandibular first premolar tooth
- B: Repairable fracture of ceramic veneer at 6 years recall on right mandibular canine
- C: Irreparable fracture of ceramic veneer at 5 years recall on left maxillary first premolar tooth
- D: Repairable fracture of ceramic veneer at 5 years recall on right maxillary first premolar tooth

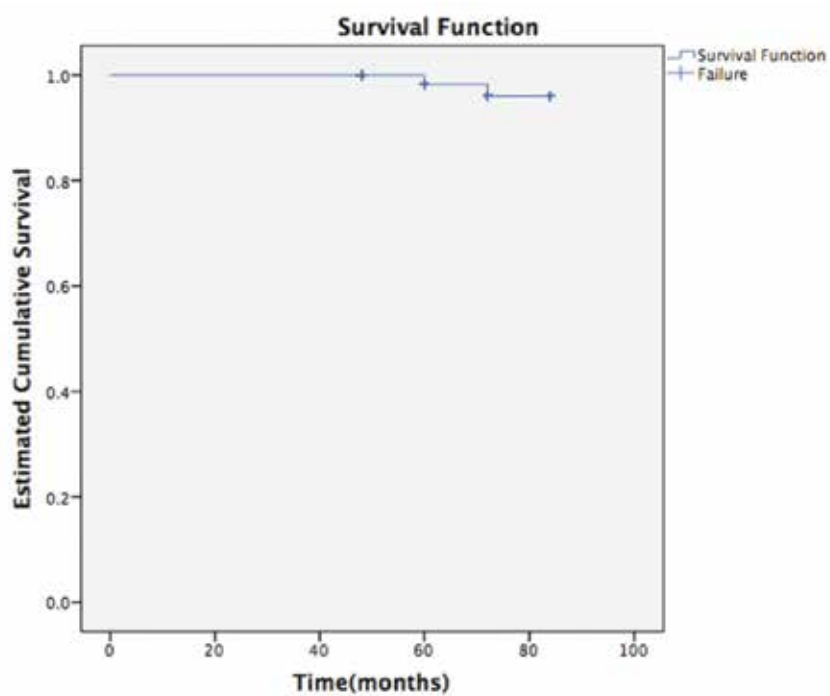


Figure 6 Kaplan-Meire analysis, showing estimated cumulative survival of veneer restorations

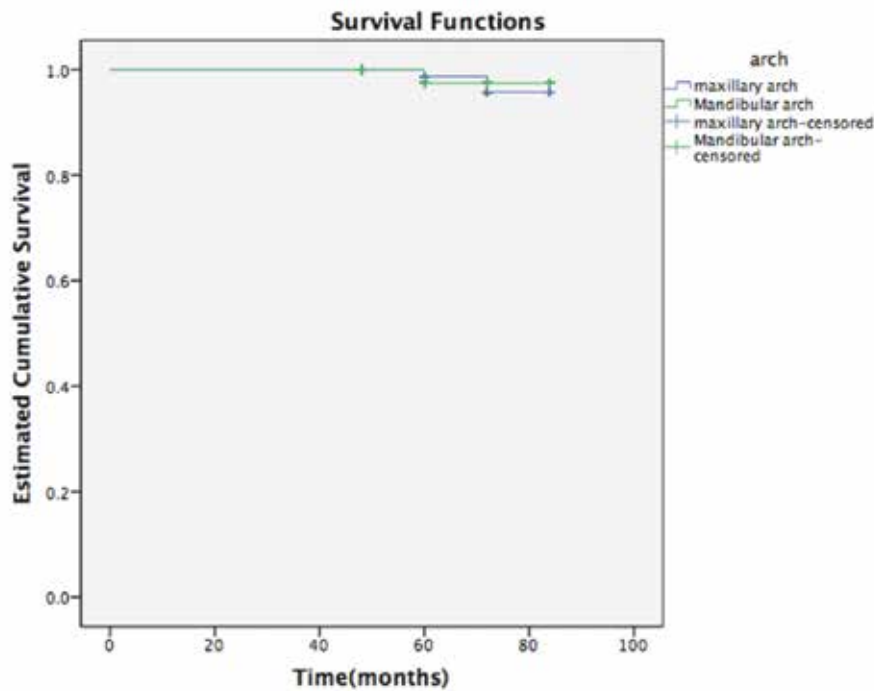


Figure 7 Kaplan-Meire analysis, showing estimated cumulative survival of veneer restorations with dental arch

Discussion

Recently, ceramic veneer restorations have gained respect as a durable and viable conservative restorative treatment method. Numerous studies have investigated the behaviour of ceramic veneers to evaluate the success and failure of restorative materials under intraoral conditions. Retrospective studies can provide reliable observation of the clinical performance of veneer restoration.

The clinical evaluation parameters in this study were modified from the United States Public Health Service USPHS (Modified United States Public Health Service Criteria) and World Dental Federation (FDI) criteria, adjusted for veneer restorations. Most studies have followed the criteria of (USPHS) Ryge Criteria for direct clinical evaluation of restoration. It is simplified, making it easy to evaluate the clinical veneer and analyse the results. In contrast, it does not cover all aspects of successful restoration. The authors consider that successful restoration should include an aesthetic,

mechanical and biological evaluation. World Dental Federation criteria for indirect restoration cover all aspects of evaluation. However, the criteria are difficult to apply clinically and evaluate veneer restoration from all aspects. Therefore, the authors have applied a modified criteria to clinically evaluate veneer restoration.

In this study, the cumulative success rate was 97.5 % after 5 to 7 years, which concurred with other studies showing high success rates (91 %-100 %) of ceramic veneer restorations: including 5-year clinical results of porcelain veneers by Peumans *et al.*⁸ (93 % on 87 veneers in 25 patients), clinical results of 323 porcelain laminate veneers by Granell-Ruiz *et al.*²⁶ (94 % at 3 to 11 years), clinical quality of 191 ceramic veneers by Dumfahrt and Schaffer²⁷ (97 % at 5 years and 91 % at 10.5 years), 6 to 12-year clinical results of Fradeani *et al.*¹² (94.4 % of 182 veneers) and clinical observations of 92 ceramic veneers by Gresnigt *et al.*²⁸ (94.6 % at 3.3 years in 20 patients). These results, however, greatly

differ from some studies.^{13,29}

Aesthetic evaluation

This study determined that all intact ceramic veneers displayed excellent aesthetics in terms of color matching, which is similar to reports in other clinical trials.^{13,27,30} Also, most patients felt very satisfied (65.4 %) with their veneer color. There were no statistically significant color changes between the cementation date and evaluation date. Compared to other habits, no relationship was noted between coffee, tea and/or soft drink consumption and color change.

The key to success for aesthetic results was good color matching. Opacity, translucency, characteristics and color distribution of the existing teeth should be communicated thoroughly to the technician by intraoral and extraoral photographs, shade and characteristic drawings and custom shade (the stump shade).^{2,18,20} Also, as light-cured resin cement had superior color stability compared to dual-cured resin cement.^{2,31} The main cause dual-cured resin cement color instability is oxidation of the amine coinitiator, which is prone to degradation, while the coinitiator in light-cured resin cement is usually aliphatic and more chemically stable resulting in less color variation.^{18,32} Turgut and Bagis³² evaluated different types and shades of resin cement and different thickness and shades of veneer restorations. They concluded that the type and shade of resin cement affected the final color of veneer restorations and the effect decreased when the ceramic thickness increased. Moreover, the ceramic used for the restoration is often easily finished and polished and its glazed surface is mostly impervious to extrinsic staining.¹⁸

Mechanical evaluation

One veneer, of the maxillary second premolar (1.2 %) presented debonding. This result was comparable to other studies. Beier *et al.*³³ showed debonding at 9.6 % (n=2), Simeone and Gracis³⁴ showed 5.5 % (n=15) and Alhekeir *et al.*²⁹ showed 10.3 % (n=3). Some authors reported high incidence of decementation due to the existence of composite restorations, which decreased

the bond strength of the porcelain veneer-tooth complex.^{2,27} Granell-Ruiz *et al.*³⁵ found that 9 % (n=29) of debond of 323 veneer restorations corresponded to patients with bruxism, and to teeth with large composite restoration, and less enamel. Moreover, if the veneer is not properly etched or if moisture contamination occurred during the bonding process, it is possible to experience debond or worse the complete delamination of the veneer. Therefore, it is important to pay close attention to the adhesion complex: tooth, luting composite and ceramic.

There was a low rate of marginal discoloration (0.6 %), found in the veneer restoration of a maxillary central incisor at the palatal site. These problems seldom occur because all margins are in areas that are easily cleaned, finished and polished at the time of cementation. Also, glazed porcelain is mostly impervious to extrinsic stain.³⁶ However, ill-fitting veneers, which exposed resin cement at their margins, or poorly seated restorations from using highly viscous cements result in cause a dark stain at the margins.¹⁸

The palatoincisor area was the most common location for a slight detectable discontinuous margin (4.3 %), which agrees with Peumans *et al.* who found that small marginal defects occurred more frequently at the palatoincisor than the cervical outline.¹⁶ The higher percentage of palatal defects can be explained by the wear of resin cement from occlusion and articulation.

Fractures were the most frequent cause of clinical failure for ceramic veneer restorations. Most clinical longitudinal studies reported a similar low failure rate resulting from fracture including Peumans *et al.*¹⁶ 1 % (n=1), Fradeani *et al.*¹² 5.6 % (n=5) and Guess and Stappert³⁷ 2.3 % (n=1). Many factors result in fracture of ceramic veneers including the type of ceramic. This study used pressable lithium disilicate glass ceramic (IPS e.max Press) with a high flexural strength (440 MPa), which increases fracture resistance.³⁸ Also, the preparation technique should preserve enamel to improve bond strength and fracture resistance. Preparation design in this study applied the aesthetic pre-evaluative temporary

(APT) technique based on mock-up teeth made on an additive diagnostic wax-up from a waxing cast. This allowed accurate preparation of enamel and can prevent unnecessary over preparation and preserve intact enamel to which etched ceramic veneer restorations can most reliably be bonded.²⁰ Moreover, etching with 10% hydrofluoric acid for 20 seconds significantly increased the microtensile bond strength of IPS e.max[®] ceramic veneer.^{2,39} After etching the porcelain surface, amorphous micro-structures with numerous porosities were revealed. These micro-porosities create a micro-mechanical interlocking of the resin composite by increasing the surface area for bonding.² Silanization with a bi-functional coupling agent, which is responsible for creating covalent bonds (Si-O-Si) between the inorganic ceramic phase and the organic phase of the resin cement, was applied on the etched porcelain surface to provides a chemical link between the luting cement and porcelain. Also, heating of the silane-coated porcelain could increase bond strength by double compared with no heating.⁴⁰ Moreover, several studied have confirmed that etching the inner side of porcelain veneer and silanizing can increase the bond strength of luting cement to enamel surface.^{2,41,42}

Also, patient selection is the key to success, especially regarding parafunctional habit. Parafunction may continue after careful restoration, even after specific guidelines are established with the patient. Consequently, after placing the ceramic restorations, patients who were bruxers, were provided with hard acrylic resin occlusal guards to protect the definitive restorations during bruxing. No statistically significant difference was determined between fracture and tooth position; however, veneer placement in the premolar area displayed significant increased risk for fracture.

The most common location of irreparable fracture of veneer restoration in this study was at the cervical area, which is susceptible to high stress with high occlusal loading both centric and eccentric as the dentin-enamel junction at the cervical area is very low

at 0.43-45 Although the ceramic veneer has an elastic modulus near enamel, high force can induce stress created fracture in the cervical area. M.R. Matson applied loading to veneer elements and the buccal enamel elements were subjected to maximum compressive stresses.⁴⁴ Therefore, the low fracture rate in this study indicated that porcelain veneers are durable restorations when the occlusion and articulation are not pathologic. It is also important to select patients without parafunctional habits.

Biologic evaluation

Gingival responses to the veneers were all in the satisfactory range. The optimal periodontal conditions indicated that preparation procedures were fully respectful of periodontal tissues. Kourkouta S. *et al.* concluded that veneer placement had no effect on the gingival index and the vitality and amount of plaque bacteria decreased after placement. The smooth surface texture of glazed ceramic decreased bacterial colonisation and growth, and facilitated plaque removal.⁴⁵

There was one patient that reported hypersensitivity after cementation (12.3 %), which later disappeared. This patient had tetracycline-stained teeth and preparation may have exposed dentin to mask the discolouration. However, there was no clear correlation between the existence of high sensitivity and the preparations being in dentin. Presumably, the pain threshold of the individual played a role in the described sensitivity. This result was similar to Granell-Ruiz who found that 3.1 % complained of hypersensitivity after treatment but such sensitivity seemed to gradually disappear over time.²⁶

Evaluations showed all veneer restorations free of caries, comparable to other studies.^{27,28} However, Granell-Ruiz *et al.* recorded 3.1 % of veneer restorations with secondary caries.²⁶ To avoid secondary caries, great importance is attributed to preparation margins bound by enamel. Peumans *et al.* noted that veneers with restoration margins located in composite fillings showed secondary caries incidence of 10 % after 10 years.¹³

Radiographic evaluation

One patient had asymptomatic apical periodontitis in one tooth (right maxillary lateral incisor) with no symptoms after veneer placement. Granell-Ruiz *et al.* observed that nine teeth that were vital at the beginning of the treatment became non-vital pulp after a few years.²⁶ Peuman *et al.* observed that pulpal irritation occurred in two veneered teeth with deep interproximal composite fillings after approximately three years.¹³

Further Study

Future clinical studies should critically address ceramic veneer fracture loading in the premolar teeth. Also, further studies should increase the sample size to evaluate the failure rate of veneer restorations between upper and lower arch.

Conclusions

Despite the limitations of this retrospective clinical study, the following conclusions were drawn: Survival probability of the 163 porcelain veneers according to the Kaplan-Meier survival estimation method was 97.5 % after 5 to 7 years. Most common failures resulted from fracture and debonding. Also, veneers placed in the premolar area had a higher failure rate. Moreover, aesthetic color matching was mostly rated as excellent for both clinical evaluation and patient satisfaction.

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