Survival of Ceramic Veneers Made of Different Materials After a Minimum Follow-up Period of Five Years: A Systematic Review and Meta-Analysis

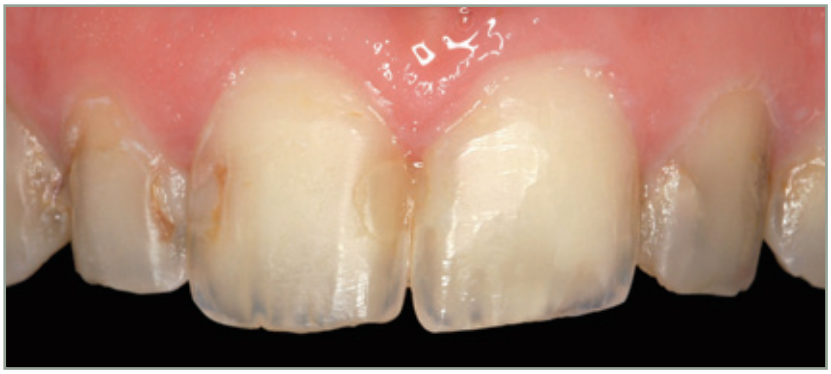
Haralampos P. Petridis, DDS, MSc, PhD
Assistant Professor, Department of Fixed Prosthesis and Implant Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

Alkisti Zekeridou, DDS
Dentist, Department of Fixed Prosthesis and Implant Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

Maria Malliari, DDS
Dentist, Department of Fixed Prosthesis and Implant Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

Dimitrios Tortopidis, DDS, PhD
Assistant Professor, Department of Fixed Prosthesis and Implant Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

Petros Koidis, DDS, MSc, PhD
Professor and Chair, Department of Fixed Prosthesis and Implant Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece



Correspondence to: Haralampos P. Petridis
Assistant Professor, Department of Fixed Prosthesis and Implant Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, 54124, Greece;
Tel/Fax: +30-231-099-9575; Mob: +30-694-425-0459; E-mail: Lpetridi@dent.auth.gr

Abstract

Purpose: The purpose of this systematic review was to compare the survival and complication rates of ceramic veneers produced with different techniques and materials after a minimum follow-up time of 5 years.

Materials and methods: A literature search was conducted, using electronic databases, relevant references, citations and journal researching, for clinical studies reporting on the survival of ceramic veneers fabricated with different techniques and materials with a mean follow-up time of at least 5 years. The search period spanned from January 1980 up to October 2010. Event rates were calculated for the following complications associated with ceramic veneers: fracture, debonding, marginal discoloration, marginal integrity, and caries. Summary estimates, and 5-year event rates were reported. Comparison between subgroups of different materials, as well as statistical significance, was calculated using a mixed effects model.

Results: Nine studies were selected for final analysis over an initial yield of 409 titles. No study directly compared the incidence of complications between ceramic veneers fabricated from different materials. Four of the included studies reported on the survival of ceramic veneers made out of feldspathic ceramics; four studies were on glass-ceramic veneers and one study included veneers fabricated from both materials. The mean observation time ranged between 5 and 10 years. Overall, the 5-year complication rates were low, with the exception of studies reporting on extended ceramic veneers. The most frequent complication reported was marginal discoloration (9% at 5 years), followed by marginal integrity (3.9–7.7% at 5 years). There was no statistically significant difference in the event rates between the subgroups of different materials (feldspathic vs. glass-ceramic).

Conclusion: The results of this systematic review showed that ceramic veneers fabricated from feldspathic or glass-ceramics have an adequate clinical survival for at least 5 years of clinical service, with very low complication rates.

(Eur J Esthet Dent 2012;7:138–152)

Introduction

Ceramic veneers became popular with the advent of ceramic etching and surface treatment during the 1980s, as conservative restorations for anterior teeth.[1] Ceramic veneers can be utilized to alter and improve the alignment, shape and form of teeth. They also permit the conservative esthetic rehabilitation of worn, fractured or anatomically malformed anterior teeth.

Three techniques and families of materials for fabricating ceramic veneers have been described in the literature.[2] The first involves the use of either a refractory die or a platinum foil using conventional feldspathic porcelain. The second involves the use of heat-pressable, leucite-reinforced glass-ceramic materials. The third technique, introduced in the last decade, is the use of computer-aided design and computer-aided manufacturing (CAD/CAM) systems to fabricate ceramic veneers utilizing high-strength ceramics.[3] The different fabrication techniques and materials influence important aspects and properties of ceramic veneers, such as marginal adaptation, mechanical strength, mode of cementation, esthetics, and ease of fabrication.[4]

The marginal adaptation achieved for ceramic veneers fabricated by using either the platinum foil technique or the refractory die technique was reported to be superior to that of castable glass-ceramics.[5-7] Two studies[8,9] found that CAD/CAM systems were quite effective in generating high quality ceramic veneers, and their marginal adaptation was essentially the same as those produced by conventional methods.

The various ceramic materials also differ as far as mechanical properties are concerned. Laboratory studies[10–12] have demonstrated the superior mechanical properties of zirconia or alumina-based ceramics, compared to leucite-reinforced ceramics and conventional feldspathic ceramics, the latter being presented as the weakest material. Glass-ceramic materials are proposed over feldspathic ceramics for the fabrication of veneers in clinical situations of possible mechanical challenges, such as extended veneer preparations, and the presence of dentin substructure or parafunctional habits.[13] Mechanical properties of materials though do not necessarily predict clinical outcomes of prostheses.[14-16]

Cementation techniques seem to be a critical factor for the survival of etchable feldspathic and leucite-reinforced glass-ceramic materials.[17-19] On the contrary, alumina or zirconia-based ceramic systems do not require any specific cementation procedure.[20]

Artificial ceramic veneers are designed to reproduce the depth of the color, translucency and texture of natural teeth. An ideal ceramic material would allow control of substrate color (hue, chroma and value) and translucency, but none of the existing systems are that flexible.[4,21] Feldspathic and glass-ceramic materials exhibit increased translucency compared to alumina or zirconia-based ceramics. The latter are useful for masking underlining discolorations but also require increased thickness of material and therefore a less conservative tooth preparation.[21]

Studies[22,23] that have reviewed the relevant literature up to the year 2000

have demonstrated a survival of ceramic veneers of over 90% after 3 to 5 years follow-up. The majority of clinical studies have investigated various veneer types, without taking into consideration the influence of the material and technique used to fabricate ceramic veneers. No review on the clinical behavior of ceramic veneers has been published within the past decade.

The purpose of this systematic review was to compare the survival and complication rates of ceramic veneers fabricated by different techniques and materials after a minimum follow-up time of 5 years.

Materials and methods

Search strategy

A literature search was conducted by two reviewers (AZ, MM) using three electronic databases (Medline, Scopus, Cochrane library) for clinical studies reporting on the survival of ceramic veneers fabricated by different techniques and materials. The search period spanned from January 1980 up to October 2010. The search terms that were used alone or in conjunction were "ceramic veneers," "porcelain veneers," "survival," and "complications." The option of "related articles," as well as the references and citations from different studies were used to identify relevant articles. Finally, the search was augmented, utilizing hand searching (time period: 01/1980–10/2010) of the following journals: "International Journal of Prosthodontics," "Journal of Prosthetic Dentistry," and "Journal of Esthetic Dentistry."

Selection of studies

The review process consisted of two phases. During the first phase, titles and abstracts were screened for relevance by the two reviewers together. Any disagreement was resolved by discussion amongst the reviewers or by consulting the third reviewer (HP). The screening during the first phase was performed according to the following inclusion criteria: prospective and retrospective clinical studies reporting on the survival and complications of ceramic veneers, and publications appearing in English. Case reports, laboratory studies, technical articles and reviews were excluded.

The full text of all studies of possible relevance was obtained. At this point, searching of the references of the selected studies and hand searching of the selected journals was also implemented.

The selected full texts were further screened by the two reviewers independently using the following inclusion criteria:

- Statement of the method and statement of the materials used for the fabrication of the ceramic veneers
- Mean follow-up time of at least 5 years, and
- Utilization of proper clinical technique. Any disagreement was resolved by discussion amongst the reviewers and the third reviewer (HP).

The final included studies that passed the second phase in the review process were classified, according to the strength of evidence, into four categories, according to Jökstad et al:[24]

Table 1 Results of electronic search.

Databases	Hits	Common titles in the same or in the other databases	Titles selected
Pubmed	207	99	108
Scopus	181	137	44
Cochrane	21	20	1
Total	409	256	153

- A1, controlled clinical trial with patient randomization (RCT)
- A2, controlled clinical trial with split-mouth randomization (split-mouth RCT)
- B, prospective controlled trial without randomization (CCT)
- C, clinical studies with different designs than categories A and B (retrospective, case series, etc).

Data extraction

Data of the final studies was tabulated for the following complications associated with ceramic veneers: fracture, debonding, marginal discoloration, marginal integrity, and caries. The incidence of each complication mentioned above was finally calculated in relation to time. In studies where only the minimum follow-up time was mentioned, that interval was used to measure the total exposure time of the restorations. In cases of multiple publications following the same cohort of patients, the study with the longest follow-up was taken into account.

Statistical analysis

Complication rates for ceramic veneers were calculated by dividing the total number of events (complications) in the numerator, by the total veneer exposure time in years in the denominator. The total number of events (numerator) was extracted directly from the publication. The exposure time (denominator) was calculated by multiplying the mean follow-up time by the number of ceramic veneers available for statistical analysis. The mean follow-up was directly extracted from the articles. Ceramic veneers available for the analysis were defined as all the prostheses from which information was available, relative to the issues considered. Event rates/100 prosthesis years were reported, along with summary estimates size and 95% intervals based on a random effects model. Poisson distribution was considered for the number of events per variable under examination. Five-year survival proportions (with the corresponding 95% confidence interval) were calculated via the relationship between event rate and

the survival function **S(t) = exp(-t*event rate)**, assuming a constant event rate. The 95% confidence interval was calculated with the aid of Poisson regression analysis with a logarithmic link function. Comparison between subgroups of different materials, as well as statistical significance was calculated using a mixed effects model. Statistical analysis was performed using appropriate software (Comprehensive Meta-analysis Version 2, Biostat, Englewood NJ, USA).

Results

Table 1 depicts the results from the initial electronic search of the three databases, and Figure 1 shows the process of identifying the studies finally included from an initial yield of 409 titles. Initial screening of titles led to 153 titles, from which 29 full texts were obtained. Twenty-six studies were retrieved from journal hand searching and references and, therefore, 55 full texts were screened for the inclusion/exclusion criteria of first phase. Thirty-nine studies[25-63] were reviewed during the second review phase. Twenty-eight studies[25-52] were excluded during the second review phase, the most frequent reason for exclusion being a mean follow-up time of less than five years (Table 2). Eleven studies[53-63] met the criteria of the second review phase. By exclusion of studies of same cohorts, nine studies[53-57,59-61,63] were finally selected for analysis.

Seven studies[53-57,59,60] were published in the past 10 years. The publication dates ranged from 1995 to 2009. No study directly compared the incidence of complications between ceramic veneers fabricated from different materials. Only one study[56] included both feldspathic and glass-ceramic veneers, but did not make a direct comparison between the materials.

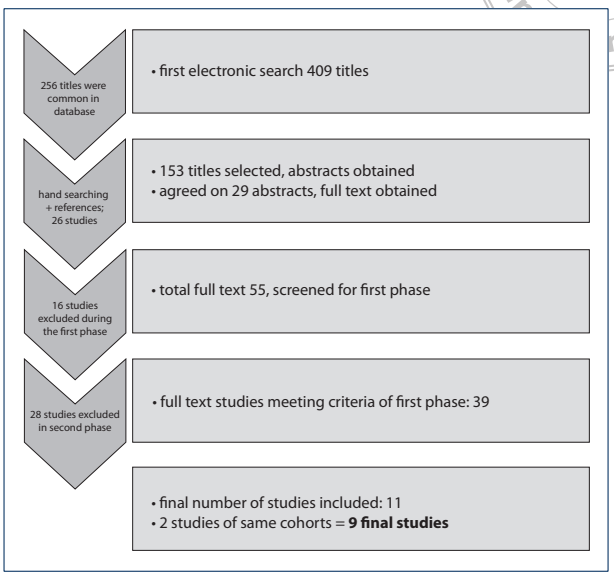


Fig 1 Flow diagram of study selection.

Most of the studies were classified as category C, and only two as A1 according to the strength of the evidence,[24] and most were implemented in a private clinical setting. The studies included a total of 215 patients with an age range of 15 to 73 years. One study[54] did not report the number of patients. The demographics and study design of the included studies are depicted in Table 3.

Four of the included studies[54,57,59,63] reported on the survival of ceramic veneers made out of feldspathic ceramics, four studies[53,55,60,61] on glass-ceramic

Table 2 Studies excluded during the second phase and reason for exclusion.

Studies	Reason for exclusion
Jensen & Soltys 1986[25], Jordan et al 1989[26], Strassler & Nathanson1989[27], Calamia 1989[28], Rucker et al 1990[29], Christensen & Christensen 1991[30], Barnes et al 1992[31], Karlsson et al 1992[32], Dunne & Millar 1993[33], Magne et al 2000[37], Nordbø et al 1994[34], Kihn & Barnes 1998[35], Meijering et al 1998[36], Dumfahrt 1999[38], Dumfahrt & Schäffer 2000[39], Smales & Etemadi 2004[40], Chen et al 2005[41], Cötert et al 2009[42], Granell-Ruiz et al 2010[43], Friedman 1998[44]	Mean follow up time <5 years or follow-up time not stated
Reid et al 1988[45], Pippin et al 1995[46], Murphy et al 2005[47], Burke & Luccarotti 2009[48], Luccarotti & Burke 2009[49]	Mean follow up time <5 years and no statement of material or method
Shaini et al 1997[50], Shang & Mu 2002[51]	No tooth preparation Flawed clinical/laboratory technique
Wiedhahn et al 2005[52]	Mean follow up time <5 years Use 108 veneers as repairs without separating results

veneers and one study[56] included veneers fabricated from both materials. All included studies reporting on glass-ceramic veneers utilized the same commercially available material, three with leucite-reinforced (IPS Empress I, Ivoclar Vivadent, Schaan, Liechtenstein) and one with lithium disilicate-reinforced (IPS Empress II, Ivoclar Vivadent, Schaan, Liechtenstein) glass ceramics. No studies of ceramic veneers fabricated out of high-strength ceramics and CAD/CAM systems fulfilled the criteria for inclusion in the analysis. A total of 577 glass-ceramic and 517 feldspathic veneers were observed over a minimum period of 0.25 years up to a maximum period of 16 years. The mean observation time ranged between 5 and 10 years. The clinical information of the ceramic veneers is presented in Table 4.

All of the studies reported on the survival and complication rates of ceramic veneers. The results of one study[54] did not differentiate the complication rates separately, so those results were not included in the statistical analysis. The data from the other studies was pooled and complication rates were estimated. The most frequent complication reported was marginal discoloration (9% at 5 years), followed by marginal integrity (3.9–7.7% at 5 years). These high rates reflected the effect of mainly two studies,[55,63] which presented with higher complication rates, compared to the rest of the included studies. These studies mainly included extended ceramic ven-

eers. Overall, the 5 years complication rates were low for the rest of the studies (Table 5). There was no statistically significant difference in the event rates between the subgroups of different materials (feldspathic vs. glass-ceramic).

Discussion

Ceramic veneers are considered the treatment of choice for the conservative esthetic restoration of discolored, worn, fractured or anatomically malformed anterior teeth. Although various materials with different inherent properties have been proposed[2] for the fabrication of ceramic veneers, no study has compared the complication rates between different materials.

Systematic reviews are often useful in the evaluation of various materials and interventions. They differ from other types of reviews, in that they adhere to a strict scientific protocol to make them more comprehensive, to eliminate the likelihood of bias, and to provide more reliable results upon which to draw conclusions and make clinical decisions. Rather than reflecting the views of the authors or being based on only a (possibly biased) selection of the published literature, they represent a comprehensive summary of the available evidence, with strict inclusion and exclusion criteria.[64] The gold standard for systematic reviews is to include randomized controlled clinical trials, which directly compare various interventions.[65] The majority of the studies included in this review were prospective uncontrolled clinical trials. No study existed that directly compared different veneer materials. There-

Table 3 Study design and demographics of included studies.

Study	Year	Category of evidence	Planned no. of patients	Actual no. of patients	Drop out	Drop out %	Age range (y)	Mean age (y)	Setting
Aykor and Ozel[53]	2009	A1(P RCT)	30	30	0/30	0	28–54	41	NR
Layton and Walton[54]	2007	C (P)	100 (83f, 17m)	NR	NR	NR	15–73	41 +/- 14,7	Private
Guess and Stappert[55]	2008	C (P)	25 (12f, 13m)	9	16/25	64	19–64f 20–45 m	43f 45 m	University
Fradeani et al[56]	2005	C (R)	46 (29f, 17m)	46	0/46	0	19–65f 20–66m	38.3f 36.8m	Private
Peumans et al[57]	2004	C (P)	25	22	3//25	12	19–69	44	Private
Aristidis & Dimitra[59]	2002	C (P)	61 (38f, 23m)	61	0/61	0	18–70	NR	Private
Sieweke et al[60]	2000	C (R)	17	17	0/17	0	24–69	45.24	University
Fradeani[61]	1998	C (P)	21 (9f, 12m)	21	0	0	NR	NR	Private
Walls[62,63]	1995	C (P)	12	9	3//12	25	NR	NR	University

NR: Not reported, P: Prospective, R: Retrospective, f: Female, m: Male

Table 4 Information of ceramic veneers in included studies.

Study	Material/ technique	Planned no. of veneers	Actual no. of veneers	Drop out	Drop out %	Follow-up range (y)	Mean follow-up (y)
Aykor & Ozel 2009[53]	IPS-Empress II/ Heat pressed	300	300	0/300	0	NA	5
Layton & Walton 2007[54]	Feldspathic porcelain/ refractory die technique	304 veneers in study, 180 for at least 6 years	168	12/180	6.7	6–16	6
Guess & Stappert 2008[55]	IPS-Empress/ Heat pressed	66	23	43/66	65.1	6–7	6
Fradeani et al 2005[56]	Feldspathic refractory die ,IPS-Empress/ Heat pressed	182 = 39 veneers: Feldspathic; 143 veneers: IPS-Empress	182	0/182	0	NR–12	5.69
Peumans et al 2004[57]	Feldspathic porcelain/ refractory die technique	87	81	9//87	10	NA	10
Aristidis & Dimitra 2002[59]	Feldspathic porcelain	186	186	0/186	0	NA	5
Sieweke et al 2000[60]	IPS-Empress/ Heat pressed	36	36	0/36	0	0.25–7.9	6.7
Fradeani 1998[61]	IPS-Empress/ Heat pressed	83 only 36 with follow up period 5 years	36	0/36	0	5–6	5
Walls 1995[62,63]	Feldspathic porcelain/ refractory die technique	54	43	11//54	20.3	4.2–5.4	5

NR: Not reported, NA: Not applicable

fore the results of this study present an indirect comparison between complication rates of different veneer materials.

The exclusion of papers in languages other than English may have resulted in the loss of some information. On the other hand, it is difficult to gain access to non-English-language journals from over the world, and it is difficult to define the features of the peer-review processes of these journals. Moreover, when non-English papers are selected, the contents must be translated based on their abstracts, with the risk of interpretation issues.

The results of this systematic review showed that the only ceramic veneer materials documented for a period of clinical function that exceeds 5 years were feldspathic ceramics and a heat-pressed glass-ceramic material. It was interesting to note that only one specific glass-ceramic material brand was included in the final group of studies. Although other commercial brands may possess similar chemistry and properties,[66] the lack of clinical documentation is an issue of concern.[16] Only one clinical study[52] of veneers fabricated out of a high-strength ceramic via CAD/CAM technique was identified but the mean follow-up time was less than 5 years. The follow-up time chosen was set at a minimum of 5 years, which could be considered adequate for at least short-term results.

The statistical analysis of the studies included showed that the various complication rates for ceramic veneers were generally low after 5 years of clinical service. Similarly low complication rates have been reported in a previous review.[23] The rate of complications showed that extended ceramic veneers appeared to have higher complication levels, compared to more conservative veneer preparations. This was more evident concerning marginal microleakage, where a frequency of approximately 9% at 5 years was estimated when pooling the results of all included studies. Marginal microleakage can be minimized by locating the preparation margins of the veneer in enamel,[23,53,67] a fact that is probably absent in extended veneer preparations. No statistically significant difference was detected between the complication rates of feldspathic and glass-ceramic veneers. This is an important finding, especially regarding veneer fractures because glass-ceramics possess improved mechanical properties compared to feldspathic ceramics.[12] Veneer fracture rates were not significantly higher for both materials, even in studies[55,63] which included extended veneer preparations. One possible explanation for the lack of difference between materials could be attributed to the same pre-cementation treatment, which included ceramic surface etching and silanating along with the bonding procedure to the underlying tooth structure. This cementation protocol reduces crack propagation initiated at the internal surface of ceramic veneers and acts as a similar strengthening mechanism for both materials.[68] Another reason could be the fact that the majority of ceramic veneers were fabricated on the anterior part of the dentition where occlusal forces are reduced. A recent clinical study[15] of all-ceramic crowns also failed to show differences in survival between feldspathic and a high-strength ceramic material.

Table 5 Ceramic veneers complication data.

Study	Material	Number of veneers	Mean follow-up (y)	Total exposure time	Number of fracture events	Estimated rate (per 100 prostheses years)	Number of debonding events
Aykor and Ozel 2009[53]	IPS-Empress II	300	5	1500	NR	NR	0
Guess and Stappert 2008[55]	IPS-Empress	23	6	138	3	2.2	1
Fradeani et al 2005[56]	IPS-Empress	182	5.69	1036	5	2.7	NA
Sieweke et al 2000[60]	IPS-Empress	36	6.7	241	4	1.7	2
Fradeani 1998[61]	IPS-Empress	36	5	180	1	0.6	NA
TOTAL		577					
	Summary estimate (95% CI)				0.7 (0.2–1.2)		0.2 (0–0.7)
	Cumulative 5y rates % (95% CI)				3.4 (1–5.8)		1 (0–3.4)
Fradeani et al 2005[56]	Feldspathic porcelain	39	5.69	222	0	0.2	NA
Peumans et al 2004[57]	Feldspathic porcelain	81	10	810	11	1.4	0
Aristidis & Dimitra 2002[59]	Feldspathic porcelain	186	5	930	3	0.3	0
Walls 1995[62,63]	Feldspathic porcelain	43	5	215	6	2.8	0
TOTAL		349					
	Summary estimate (95% CI)				0.7 (0.1–1.3)		0.06 (0–0.2)
	Cumulative 5y rates % (95% CI)				3.4 (0.5–6.3)		0.3 (0–1)
Material comparison glass vs. feldspathic ceramic based on mixed effects model					*P* = 0.95		*P* = 0.53

NR: Not reported, NA: Not applicable, CI: Confidence interval

Estimated rate (per 100 prostheses years)	Number of marginal discolora-tion events	Estimated rate (per 100 prostheses years)	Number of marginal integrity events	Estimated rate (per 100 prosthe-ses years)	Number of caries events	Estimated rate (per 100 prostheses years)
0.03	5	0.3	5	0.3	0	0.03
0.7	12	8.7	5	3.6	0	0.3
NA	NA	NA	NR	NR	NR	NR
0.8	NR	NR	NR	NR	0	0.2
NA	NA	NA	NA	NA	NA	NA
	2.0 (0.16–3.8)		1.6 (0–4.7)		0.04 (0–0.1)	
	9.5 (0.8–17.3)		7.7 (0–20.9)		0.2 (0–0.5)	
NA	NA	NA	NR	NR	NR	NR
0.06	15	1.8	16	2.0	8	1.0
0.05	2	0.2	1	0.1	0	0.05
0.2	12	5.6	1	0.5	0	0.2
	1.9 (0–3.8)		0.8 (0–1.8)		0.3 (0–0.8)	
	9 (0–17.3)		3.9 (0–8.6)		1.5 (0–3.9)	
	$P = 0.59$		$P = 0.63$		$P = 0.26$	

In the future, there is a need for long-term clinical studies that directly compare ceramic veneer materials, especially high-strength ceramics.

Clinical relevance

The results of this systematic review showed that ceramic veneers fabricated from feldspathic or glass-ceramics have an adequate clinical survival for at least five years, with very low complication rates. Extended ceramic veneers presented with higher complication rates.

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