Porcelain Laminate Veneers: 6- to 12-Year Clinical Evaluation—A Retrospective Study

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The purpose of this study was to retrospectively evaluate the clinical performance of laminate veneers placed in the anterior segments of the dental arches over a 12-year period at two different private dental practices. Forty-six patients were restored with 182 porcelain laminate veneers. The veneers were studied for a mean observation time of 5.69 years. Color match, porcelain surface, marginal discoloration, and marginal integrity were clinically examined following modified CDA/Ryge criteria. On the basis of the criteria used, most of the veneers rated A. Risk of fracture was determined with a Kaplan-Meier survival analysis. Probability of survival of the 182 veneers was 94.4% at 12 years, with a low clinical failure rate (approximately 5.6%). Porcelain veneers must be bonded with a correct adhesive technique to reach this successful survival rate. (Int J Periodontics Restorative Dent 2005;25:9–17.)

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Because of their esthetic appeal, as well as their durability and biocompatibility, porcelain laminate veneers have became a standard procedure in the treatment of the anterior teeth. This technique was introduced as early as the 1940s; early work by Buonocore[1] and Bowen[2–4] laid the foundations for the use of acid etching and resin composite bonding procedures. However, it was the study conducted by Horn[5] that made it possible to develop resin composite technology; Simonsen and Calamia[6] described acid etching of ceramic being introduced with a view to long-term porcelain veneer retention.[7,8]

Porcelain laminate veneers can be used to correct tooth forms and position; close diastemata; replace old composite restorations; restore teeth, incisal abrasions, and tooth erosion; or mask or reduce tooth discolorations.[9,10] They are a valid alternative to complete-coverage restorations, as they avoid aggressive dental preparation, thus maintaining tooth structure.[11] Nevertheless, many authors suggest that parafunction constitutes a contra-

Figs 1a and 1b *Preoperative lateral views show an open bite and failed composite restorations in the maxillary incisors.*

Fig 1c *Six veneers are fabricated to be positioned on maxillary canines and incisors.*

indication to adhesive restorations.[7,12,13] Magne et al[14] report that the success rate for veneers is reduced to 60% in parafunctional patients; this rate is similar to that observed with conventional metal-ceramic crowns in the same situation. The success rate could be increased if the parafunction activities were under control.

Resin composite veneers are also commonly used as an alternative to porcelain veneers; however, they suffer from limited longevity because they are susceptible to discoloration, wear, marginal fractures, surface staining, and plaque accumulation, thereby affecting the esthetic result in the long term.[7,11,15] On the contrary, porcelain laminate veneers are commonly accepted as a useful restorative technique that offers assurance of a durable esthetic result.[7,9,16] The choice of porcelain allows stable esthetic qualities to combine with biocompatibility, abrasion resistance, appropriate translucency, and color and contour stability. Furthermore, there appears to be a low risk of gingival irritation because of minimal plaque accumulation, proven to be lower than around natural teeth.[14,17–19]

Magne and Douglas[20] demonstrate that the mean local flexibility of teeth doubles with facial enamel removal, and that tooth stiffness is completely reestablished after porcelain laminate veneer bonding, thus acknowledging that restorations could mimic the biomechanical properties and structural integrity of the original tooth and confirming the biomimetic behavior of porcelain (Figs 1a to 1e). A similar study concluded that tooth stiffness cannot be restored through composite veneers.[21]

Four groups of ceramic systems are currently used for veneers: feldspathic porcelain baked by the traditional powder-water-slurry method, castable glass-ceramic, heat-pressed ceramic, and the computer-aided design/manufacturing (CAD/CAM) technique.[8] In this retrospective clinical study, two different ceramic materials were used. One-hundred forty-three veneers were made using heat-pressed ceramic (IPS Empress I, Ivoclar Vivadent), and 39 veneers were made using feldspathic ceramic baked on refractory die material. The purpose was a review of the clinical performance of 182 laminate veneers placed from 1991 to 2002 at two different private dental practices. The veneers were monitored for up to 12 years, using Kaplan-Meier survival-type curves to assess the survival rate.

Method and materials

Between June 1991 and December 2002, 182 porcelain laminate veneers were placed. They were fabricated with both a pressed ceramic technique (Empress) and a refractory die technique (feldspathic porcelain, Vitadur Alpha, Vita).

The study population comprised 46 patients (17 men, mean age 36.8 years, range 20 to 66 years; and 29 women, mean age 38.3 years, range 19 to 65 years) who needed laminate

Figs 1d and 1e *Postoperative lateral views show good esthetic, functional, and biologic integration of the veneer restorations.*

Fig 1f (left) *To optimize the interproximal embrasures, tooth preparations are performed intrasulcularly. Cervical finish line is located in dentin even though more than 50% of the tooth preparation is confined in enamel.*

Fig 1g (right) *Final postoperative view shows good tooth arrangement and satisfactory integration.*

veneer therapy for a variety of reasons and were selected from consecutive patients at the authors' offices. Patients with uncontrolled parafunction, periodontitis, severe gingival inflammation, poor oral hygiene, or high caries rates were excluded from this study.

The veneers were placed in the 46 patients in either the maxilla (n = 127) or anterior mandible (n = 55). In the maxilla, the restorations included 51 central incisors, 38 lateral incisors, and 38 canines. In the mandible, the restorations included 20 central incisors, 19 lateral incisors, and 16 canines.

After 3 to 12 months, patients were recalled for oral hygiene, depending on their periodontal conditions. One restoration was placed on an endodontically treated tooth; the remaining 181 restorations were placed on vital teeth.

Tooth preparation

For each restoration, the shade was determined before starting any clinical procedure. For optimal tooth preparation reduction, the authors used a transparent template or silicone index, both derived from a waxup.[22]

Axial reduction was achieved through tapered round-ended burs, controlled by a silicone index. Buccally, the preparation thickness ranged from 0.3 to 0.6 mm in the cervical third to 0.8 to 1.0 mm in the incisal third. The incisal reduction was up to 2 mm.[23] It is mandatory to preserve enamel as much as possible; according to Friedman,[10] the best long-term retention for porcelain veneer restorations is achieved when 50% of the supporting substrate is enamel and all finish lines end within enamel.[11]

A light chamfered facial finish line is normally recommended for this type of technique, with the preparation extended only as far interproximally as necessary to hide the restoration margins. The presence of a Class III composite restoration can sometimes make it advisable for the clinician to open the interproximal contact points between the teeth. The incisal finish line consisted of either a butt or a conservative palatal light chamfer extended to the palatal incisal third but not involving the palatal concavity.

Localization of opposing tooth contact should prevent any centric contacts at the junction of the veneer and tooth structure.[11,22] All internal angles were smoothed to reduce stress concentration during luting procedures and function. The location of the cervical margin was

carefully selected for each restoration. The margins were preferably located supragingivally, thus resulting in simplified impression procedures and evaluation of marginal adaptation while helping to maintain periodontal health. When the shape and contour of the restoration needed to be changed, the margins were located either at the gingival crest or slightly into the crevice (Figs 1f and 1g).[24,25]

Impression taking

As for equigingival and intracrevicular margins, gingival displacement was obtained using a retraction cord (No. 00 Ultrapack, Ultradent) soaked in a hemostatic solution (Hemodent, Premier Dental; Ultradent Aluminum Chloride, Ultradent). No displacement was needed in the supragingivally prepared teeth.

Following cord removal, the final impression was made by means of a polyether material (Permadyne or Impregum, ESPE) or addition silicone materials (Extrude, Kerr; Imprint II, 3M); the single impression–double mixing technique was used with a light-activated custom tray (Palatray LC, Heraeus Kulzer) or a standard tray. An irreversible hydrocolloid (Jeltrate, Dentsply/Caulk) impression of the opposing dentition was made; interocclusal bite registrations were recorded, and a facebow was used to relate the master casts to a semiadjustable articulator (Denar Mark II, Denar).

Provisionalization

Although veneers were generally located in enamel thickness and a short time was required from the preparation procedure to bonding, the authors always used acrylic resin or composite provisional restorations.[11] Provisional restoration thickness was checked to confirm the degree of tooth reduction. An impression of the provisional restoration was made to serve as a prototype for the final restoration, relying on a silicone matrix technique. The provisional restorations were luted with provisional resin material (Temp Bond Clear, Kerr; Provilink, Ivoclar Vivadent) or a eugenol-free material (Freegenol, GC). Upon removal of the provisional restoration, the tooth was cleaned with a nonfluoridated cleaning paste (Syntac Cleaning Paste, Ivoclar Vivadent).

Luting

At the try-in stage, the individual veneers were assessed for proximal contacts, shade match, contour, and marginal adaptation. Final occlusion was examined after cementation. The color of the restoration was checked using glycerin. If ideal, translucent cement was used to ensure the best esthetic result. The use of colored translucent cement is sometimes advisable to partially change the color while avoiding making the veneer opaque. Color and viscosity of the cement of choice were established using try-in pastes.[11,26]

The ceramic restorations were etched for 2 minutes with 4.5% or 9.5% hydrofluoric acid (Porcelain Etch, Ultradent; Porcelain Etchant, Bisco). The acid concentration was 4.5% for Empress and 9.5% for porcelain baked by means of the refractory die technique. The acid was then washed with water and dried. A silane agent (Monobond S, Ivoclar Vivadent; Porcelain Primer, Bisco; Ceramic Primer, 3M) was applied and blown dry on the veneer restorations. Concurrently, the tooth surface was etched for 30 seconds with 37% orthophosphoric acid (Ultra-etch, Ultradent). After water rinsing of the tooth surface for 30 seconds, dentin adhesive was applied to both the prepared tooth (in case of dentin exposure) and the inner surface of the restoration (Syntac, Ivoclar Vivadent; All Bond 2, Bisco; Multipurpose, 3M). Finally, luting procedures were performed. Between 1991 and 1995, dual-polymerizing resin composite cement was used to lute most of the restorations (Dual Cement or Variolink, Ivoclar Vivadent). Beginning in 1995, only light-activated cement was used (Variolink; Opal Luting Cement, 3M), allowing the working time to be extended and avoiding any discoloration resulting from amine present in the dual cement catalyst.

Excess cement was removed with a brush and dental floss interproximally. The veneers were marginally covered with glycerin gel, and resin composite cement was light polymerized from each side for 40 seconds. Where intracrevicular preparation was performed, a

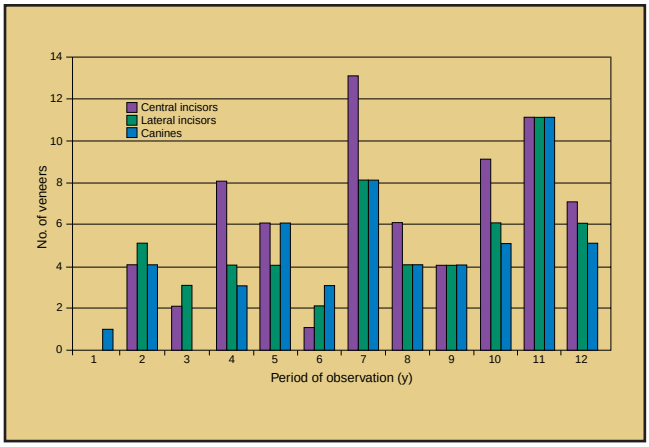

Fig 2 *Distribution of restored teeth and their relative periods of observation.*

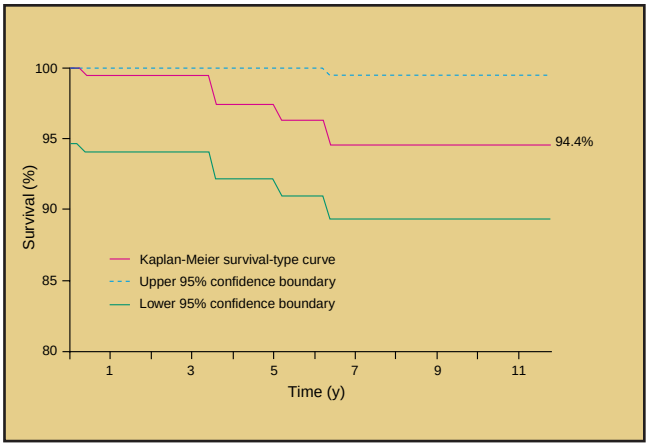

Fig 3 *Kaplan-Meier survival-type curve for 182 Empress veneers after 12 years (95% confidence interval 100% to 89.4%).*

gingival cord (No. 000 Ultrapack) was placed into the sulcus prior to luting to allow residual cement to be removed from the crevice.[27,28] A rubber dam was used in some situations when the margins were located supragingivally. The margins were then finished with a scaler to remove excess resin. Occlusion was evaluated; the occlusal properties of the teeth restored by porcelain laminate veneers were identical to those of intact natural teeth.[22]

Evaluation

Photography and data forms were used as documentation tools. Patients were reexamined by the authors at the oral hygiene recalls every 3 to 12 months by means of a mirror, sharp explorer, radiographs, and clinical slides; the absence of inflammation was shown upon examination according to the no-bleeding-on-probing parameter at each appointment. In failed restorations, the examiners tried to determine the cause of failure. Color match, porcelain surface, marginal discoloration, and marginal integrity were evaluated following modified California Dental Association (CDA)/Ryge criteria.[29,30] All patients were recalled between June and July 2003.

Kaplan-Meier statistics were used to analyze the survival rates of the veneers luted on anterior teeth.[31] The survival time was defined as the period starting at cementation of the restoration and ending when the veneer irreparably failed. Porcelain fracture and/or partial debonding that exposed the tooth structure and/or impaired esthetic quality or function were the main criteria for irreparable failure.[32] The restorations were replaced in either case.

Results

A total of 182 veneers placed in 46 patients were studied over 12 years. All the veneers were fabricated by two dental technicians separately, according to the manufacturers' instructions; 143 were made according to the Empress technique, and 39 were made of feldspathic porcelain in a refractory die technique. The mean observation time was 5.69 years (Fig 2). No patients were lost from the study. Therefore, all 182 veneers placed were assessed and subjected to statistical analysis.

During the evaluation period, five restorations (5.6%) failed. Two with a longitudinal fracture were replaced; the other three, with limited fracture extension, were immediately rebonded and are still in place. These five veneers were considered failures.

According to the Kaplan-Meier survival estimation method, the

Table 1 Modified CDA/Ryge criteria

Parameter/ratings	Restoration characteristics
Color match	
A	No mismatch in color, shade, and/or translucency between restoration and adjacent tooth
B	Mismatch between restoration and tooth structure within normal range of tooth color, shade, and/or translucency
C	Esthetically displeasing color, shade, and/or translucency
Porcelain surface	
A	Smooth surface (shiny after air drying)
B	Dull surface and/or chipping of porcelain; does not impair esthetics or function and/or expose tooth structure
C	Chipping of porcelain; impairs esthetics and/or exposes tooth structure; intraporcelain fissures detectable with explorer
Marginal discoloration	
A	No discoloration on margin
B	Superficial discoloration; does not penetrate in pulpal direction
C	Discoloration; penetrates in pulpal direction
Marginal integrity	
A	No visible evidence of crevice along margin; no catch or penetration of explorer
B	Visible evidence of crevice and/or catch of explorer; no penetration of explorer
C	Visible evidence of crevice; penetration of explorer
D	Restoration is mobile, fractured, or missing

survival probability of the 182 veneers was 94.4% at 12 years (Fig 3). The clinical ratings of the remaining restorations were satisfactory according to the modified CDA/Ryge criteria for color match, porcelain surface, and marginal integrity. Marginal discoloration recorded the lowest proportion of A ratings (86.44%) but can be considered acceptable. With the exception of the failed veneers, no restorations were rated C or D for any of the evaluation criteria (Table 1).

Discussion

Few studies of the clinical performance of porcelain veneers are available to date, whereas several papers dealing with in vitro studies of the system have been published.[14,20,23,33,34] However, in vitro studies do not have the same value as in vivo studies. In addition, Kelly[33] states that the specimens used for testing dental ceramics in the lab sometimes differ significantly in both size and structure from the restorations they represent.

Clinical studies are needed for evaluating the performance of restorative materials because certain intraoral conditions cannot be reproduced in the laboratory. These conditions include the application of multiple, intermittent, cyclic forces while chewing, grinding, and clenching; constant exposure to a moist, bacteria-rich environment; ingestion of hot or cold liquids and acids; and heavy toothbrushing. In vivo evaluation has been the ultimate basis for establishing criteria for acceptable veneers. Retrospective studies may provide a reliable picture of the clinical performance of both materials and techniques.

In the present study, the porcelain veneers were associated with a high survival rate (94.4% at 12 years) comparable with the results reported in other studies on porcelain veneers (91% to 100%[7,22,35,36]) (Fig 4). Other studies show less favorable results, probably related to inappropriate use of luting procedures.[15,37] For porcelain-fused-to-metal crowns, Leempoel et al[38] report an estimated survival rate of 99% after 5 years and 95% after 11 years. According to the results obtained in the present study, porcelain veneers are associated with nearly the same risk of loss by fracture as metal-ceramic crowns and all-porcelain crowns placed in the anterior region.[32,38,39]

Porcelain veneers must be bonded with a correct adhesive technique to reach this successful survival rate, which is comparable to the results obtained with traditional

Fig 4a *Preoperative anterior view of abraded dentition.*

Fig 4b *Tooth preparations are made for six maxillary veneers.*

Fig 4c *Veneers are luted with adhesive technique.*

Fig 4d (left) *After 10 years in service, restorations still appear of the same length, demonstrating good case maintenance.*

Fig 4e (right) *Long-term result is ensured by the combination of esthetic and functional rehabilitation. Appropriate anterior guidance, together with reestablished posterior occlusal stability, allowed successful maintenance of the prosthetic rehabilitation.*

crowns; the bonding procedure is currently popular among practitioners and the only advisable choice to lute ceramic veneers. All five fractured veneers were Empress, the most widely used material in this study. The material may not be responsible for the fractures that occurred. In fact, the veneers were bonded on tooth structure mostly represented by dentin, with a proportion of enamel below 50%, especially on the finish lines. Therefore, the technique, not the ceramic itself, was probably the only cause of fracture.[34]

As mentioned above, the three fractured veneers were rebonded after their inner surfaces had been acid etched. Although they are still present in the patients' mouths, these veneers were counted as failures. During the study period, three other veneers luted in the early 1990s decemented, probably because of an inappropriate bonding procedure, without any signs of fracture or core damage. These were recemented according to the adequate bonding procedure; they were not considered failures and still survive in the patients' mouths.

On the basis of the modified CDA/Ryge criteria (Table 2), a large percentage of veneers were rated A for color match (96.61%), porcelain surface (89.83%), and marginal integrity (92.09%). The high score

Table 2 **Frequency distribution (%) of clinical ratings in 177 veneers (modified CDA/Ryge criteria)**

Parameter	A	B	C	D
Color match	96.61	3.39	0.00	—
Porcelain surface	89.83	10.17	0.00	—
Marginal discoloration	86.44	13.56	0.00	—
Marginal integrity	92.09	7.91	0.00	0.00

achieved with this last parameter is particularly significant considering the great percentage of visible margins detectable in this study. Marginal discoloration (86.44%) was sometimes associated with a decrease in marginal integrity and was thought to be related to the cement used. Stains on supragingival nonpenetrating margins could usually be removed using a finishing bur.

The present study has some limitations: All clinical procedures were performed by two clinicians; the veneers were placed over a period of 12 years, not simultaneously; and the two materials used cannot be statistically compared with each other because the types of veneers used varied in number.

Nevertheless, this study also boasts some major advantages compared to previously published investigations: A large sample size and longer follow-up periods were included; all patients treated with porcelain veneers were serially accounted for at the end of the study; the patients were treated in private dental offices; and they paid the full office price for their porcelain veneers and were not offered any inducements. The data were accurately analyzed and presented so they could be compared with other studies.

Conclusions

Despite the limitations of this retrospective clinical study of the survival of porcelain veneers in two private practices, the following conclusions were drawn:

1. Porcelain veneers showed a low clinical failure rate, approximately 5.6% after 12 years.
2. The survival probability of the 182 porcelain veneers, according to the Kaplan-Meier survival estimation method, was 94.4% at 12 years for the anterior segment.
3. Three of a total of five fractured porcelain veneers were immediately recemented, and, even though still present in the patients' mouths, they were considered failures.
4. Color match, porcelain, and marginal integrity were mostly satisfactory. Marginal discoloration was rated as acceptable.

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