An 11-year clinical evaluation of leucite-reinforced glass-ceramic crowns: A retrospective study

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Objective: The purpose of this study was to retrospectively evaluate leucite-reinforced glass-ceramic crowns placed over a 6-year period at two different private dental practices. **Method and materials:** One hundred twenty-five Empress crowns were placed in 54 patients. The 93 anterior and 32 posterior crowns were evaluated clinically with a mirror and probe, radiographically, and from clinical photographs, in accordance with a modified California Dental Association and Ryge quality evaluation system. The risk of fracture was determined with the Kaplan-Meier survival analysis. **Results:** Crowns were studied over periods ranging from 4 to 11 years. The probability of survival of the 125 crowns was 95.2% at 11 years (98.9% in the anterior segment and 84.4% in the posterior segment). Six crowns had to be replaced. Most of the 119 successful crowns were rated excellent; Alfa ratings were assigned to 94.2% for color match, 91.6% for porcelain surface, 86.6% for marginal discoloration, and 94.2% for marginal integrity. **Conclusion:** Leucite-reinforced glass-ceramic crowns showed a low clinical failure rate and excellent esthetics after up to 11 years. *(Quintessence Int 2002;33:503–510)*

Key words: all-ceramic crown, Empress, glass-ceramic crown, longevity, randomized clinical study, survival rate

CLINICAL RELEVANCE: Of 125 glass-ceramic crowns, 119 were still in service after 4 to 11 years. Most of the fractured crowns had been placed on molars and premolars; thus, the risk of fracture should be considered whenever glass-ceramic crowns are placed on teeth that are likely to be subjected to substantial stresses.

The demand for high-quality esthetic dentistry has resulted in the development of all-ceramic materials, used for individual crowns, veneers, inlays, onlays, fixed partial dentures, and implant restorations.[1] In 1885, Land pioneered the all-ceramic jacket crown, making use of a glass feldspathic material. Practitioners soon realized that this material was not sturdy enough, which eventually resulted in the introduction of the metal-ceramic crown.[2]

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A natural tooth has a transparent body that can absorb, transmit, and reflect light. Brightness results from the portion of reflected light, and it depends on both the angle of incidence (as influenced by the smoothness of the tooth and the presence of saliva) and the refractive index; unlike opaque bodies, translucent bodies are capable of showing reflected light more smoothly and plainly, thus emphasizing depth. Therefore, although natural teeth, which are transparent, share the same dimensions as artificial teeth, natural teeth look more harmonious and less bulky. Both mineralized teeth, which are partly transparent, and the soft tissues surrounding natural teeth can absorb, transmit, and reflect the light they receive.

Porcelains fired on metal alloy frameworks are not as refractive; they cause internal reflection, which is capable of modifying the volume effect and making objects look bigger than they actually are. Furthermore, metal frameworks are masked cervically by thick ceramic material; where thick application of ceramic is not feasible, hyperreflection of the metal and thin ceramic layer will result in the well-known poor esthetics.[3,4]

Numerous attempts have been made to develop all-ceramic systems that eliminate metal infrastructures and provide optimal distribution of reflected light.[1,3,4] Dental ceramic materials have been shown

to possess some extremely desirable properties, including biocompatibility, a pleasant appearance, chemical resistance, wear characteristics and a coefficient of thermal expansion similar to those of enamel, low thermal conductivity, radiopacity, and diminished plaque accumulation.[1,5,6] Unfortunately, ceramic is brittle and has a low tensile strength. In addition, it is subject to fractures, which has always been a crucial factor when all-ceramic crowns are selected for clinical applications.[1]

The principal all-ceramic systems developed to date can be divided into two categories: glass ceramics and alumina-based ceramics. Materials such as the glass ceramic Dicor (Dentsply), the leucite-reinforced glass ceramic Optec HSP (American Thermocraft), and the leucite-reinforced pressed glass ceramic IPS Empress (Ivoclar) can guarantee some excellent qualities of light transmission and translucency, very similar to those of a natural tooth.[4]

A high flexural strength value (320 to 600 MPa) is the most positive feature of the alumina systems, which include In-Ceram (Vita Zahnfabrik), the most recent Procera system (Nobel Biocare), and the In-Ceram Spinell system (Spinell-core and Vita Dur Alpha, Vita Zahnfabrik); however, they do not possess the same light transmission qualities as glass-ceramic materials.

There have been few in vivo studies to document the longevity of all-ceramic Empress crowns,[7-9] whereas numerous in vitro studies have dealt with the resistance of all-ceramic crowns to flexural stress. In vitro investigations, however, are commonly incapable of addressing all clinically relevant criteria. Thus, clinical studies are needed to evaluate the performance of restorative materials.

Certain intraoral conditions cannot be reproduced in the laboratory. These conditions include the application of multiple, intermittent, cyclic forces during chewing, grinding, and clenching; constant exposure to a moist, bacteria-rich environment, ingestion of hot or cold liquids and acids, heavy toothbrushing, or inadequate toothbrushing. In addition, Kelly[10] stated that the specimens used for testing dental ceramics in the laboratory sometimes differ significantly in both size and structure from the restorations they represent. In vivo evaluation has been the ultimate basis for establishing criteria for acceptable crowns.[1]

The present retrospective study was aimed at reviewing the long-term clinical performance of IPS Empress crowns placed over a 6-year period (from 1990 to 1996) at two different private dental practices. The crowns were monitored for up to 11 years. Kaplan-Meier survival-type curves were used to assess the survival rate, and clinical examinations were performed to assess clinical criteria.

METHOD AND MATERIALS

Study group

Between May 1990 and December 1996, 170 all-ceramic IPS Empress crowns were placed in 59 patients. Four patients who were lost to follow-up and one patient who died were removed from the study. The study population, comprising 24 men and 30 women who needed crown therapy for a variety of reasons, was selected from consecutive patients at the authors' offices. The female and male patients were aged, on average, 41 (20 to 66) and 40 (18 to 68) years, respectively.

For each of the 54 patients, treatment involved both the anterior and posterior segments of the maxilla and the mandible. The distribution of the restored teeth is shown in Figs 1a to 1c.

Patients with severe parafunction, periodontitis, serious gingival inflammation, poor oral hygiene, or high caries rates were excluded from this study. Although the authors are still using Empress crowns, not all the crowns placed so far were included in the present study, to enable collection of more significant long-term data.

After 3 to 12 months, the patients were recalled for oral hygiene measures, depending on their periodontal condition.

Seventy restorations were placed on endodontically treated teeth; the remaining 55 restorations were placed on vital teeth. The endodontically treated teeth received mainly resin composite restorations and esthetic posts, such as zirconium or metal-porcelain post and cores.[11] Some abutments previously restored by amalgam or gold post and core were maintained in the posterior area when they were judged to be adequate.

Tooth preparation

For each crown, the shade was determined prior to tooth preparation. A 90-degree rounded axiogingival line angle, 1.2 to 1.5 mm in depth, was created circumferentially with rotary diamond burs to ensure maximum resistance form.[7,12,13] A deep, chamfered finishing line was used in the patients with significantly scalloped gingival architecture.[7,14] All the internal angles were smoothed to reduce stress concentrations during cementation and function. A minimum thickness of 1.5 mm was maintained in the occlusal surfaces of the posterior teeth, and a minimum lingual thickness of 1.2 mm was maintained in the maxillary anterior region.

In the maxillary anterior region, the lingual concavity was accurately determined, to provide proper anatomic anterior disocclusion. The taper of the preparation ranged between 5 and 10 degrees, depending on the length of the abutment.[7,15,16]

The location of the gingival margin was carefully selected for each restoration. In the posterior restorations, the margins were generally located supragingivally, resulting in simplified impression-taking procedures and evaluation of marginal adaptation and helping to maintain periodontal health. In the anterior regions, the margins were located either at the gingival crest or slightly in the sulcus.[7,18]

For the equigingivally and intrasulcularly positioned margins, a gingival displacement cord (No. 00, Ultrapack, Ultradent) soaked in a hemostatic solution (Hemodent, Premier Dental, or Ultradent Aluminum Chloride, Ultradent) was used to displace the gingiva. No displacement was needed in the supragingivally prepared teeth.

Following removal of the cord, the final impression was made in a polyether material (Permadyne, Impregum, ESPE Premier). The single-impression–double-mixing technique was used with a light-activated custom-tray (Palatray LC, Kulzer) or a standard tray. An irreversible hydrocolloid impression (Jeltrate, Caulk/Dentsply) of the opposing dentition was made. The maxillomandibular relationships were recorded, and a facebow was used to relate the master casts to a semiadjustable articulator (Mark II, Denar).

The thickness of the provisional restoration was checked to determine the degree of tooth reduction. For each anterior restoration, a silicone matrix technique was used to make an impression of the provisional restoration to serve as a prototype for the final restoration. All the crowns were fabricated by two dental technicians, working separately, in accordance with the manufacturer's instructions. The layering technique was used to fabricate 80 crowns, and the surface coloration method was used to make the other 45 crowns.

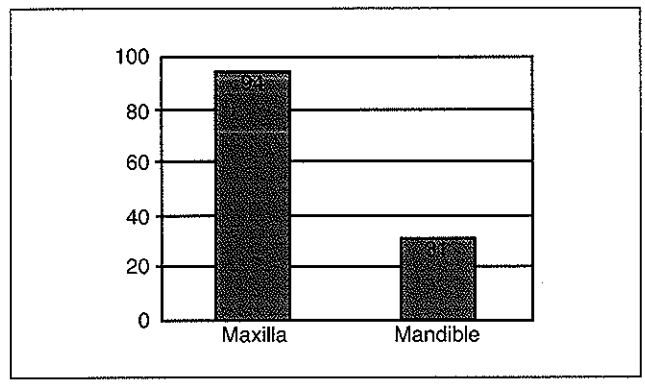

Fig 1a Distribution of restored teeth by arch.

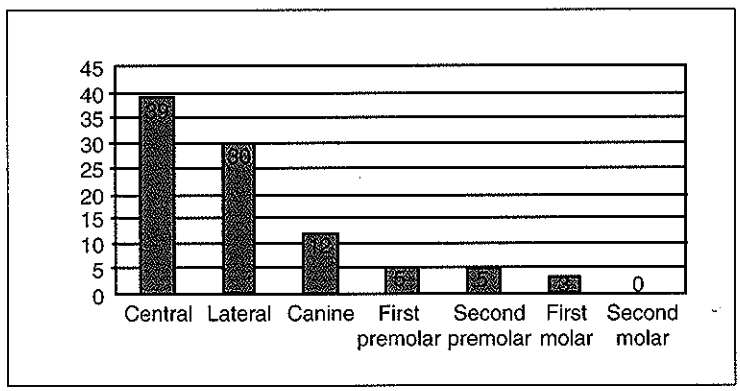

Fig 1b Distribution of restored maxillary teeth by tooth type.

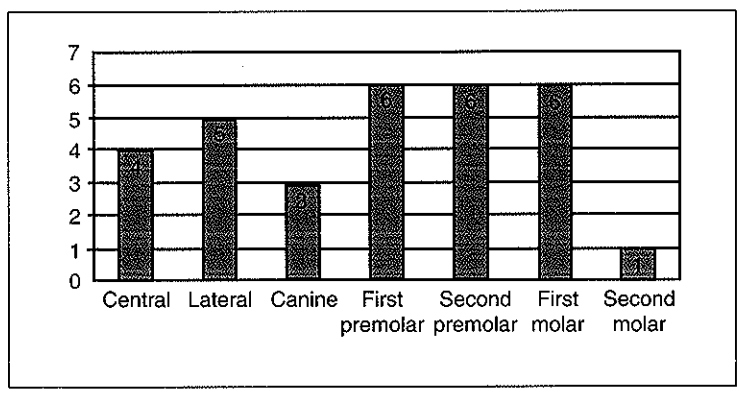

Fig 1c Distribution of restored mandibular teeth by tooth type.

TABLE 1 Clinical ratings for 119 Empress glass-ceramic crowns*

Criteria	Alfa	Bravo	Charlie	Delta
Color match	112	7	0	0
Porcelain surface	109	10	0	0
Marginal discoloration	102	16	1	0
Marginal integrity	112	7	0	0

* Modified from California Dental Association[19] and Ryge[20] criteria. Data refers to last control (check) of patients.

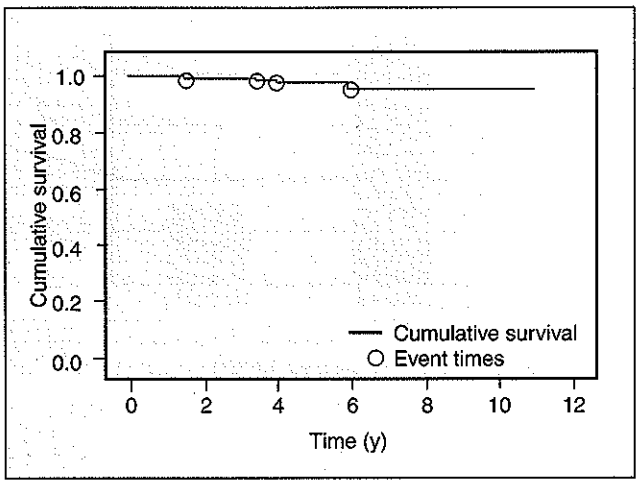

Fig 2 Kaplan-Meier survival plot for all crowns as a function of time.

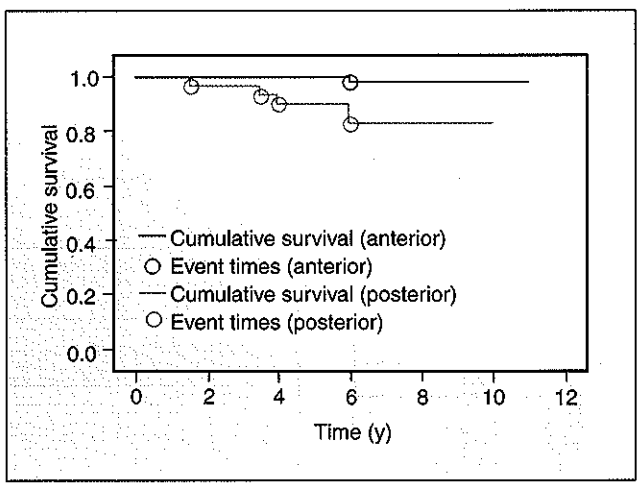

Fig 3 Kaplan-Meier survival plot for anterior and posterior crowns as a function of time.

The provisional restorations were luted with a eugenol-free material (Freegenol, GC). On removal of the provisional restoration, the tooth was cleaned with a nonfluoridated cleaning paste (Syntac cleaning paste, Ivoclar).

Each crown was assessed for proximal contacts, occlusion relationships, shade match, contour, and marginal adaptation. Minor occlusal adjustments were made prior to cementation, and final occlusion was examined after cementation.

Luting

The restoration was etched with 4.5% hydrofluoric acid (Porcelain Etch, Ultradent; Porcelain Etchant, Bisco Dental) for 2 minutes, washed with water, and dried. A silane agent (Monobond S, Ivoclar; Porcelain Primer, Bisco Dental) was then applied and blown dry. Concurrently, a dentin adhesive (Syntac, Ivoclar; All-Bond 2, Bisco Dental) was applied to the prepared tooth. Dual-polymerizing resin composite cement was used to lute most of the restorations (Dual Cement and Variolink, Ivoclar).

Excess cement was removed with a brush, and dental floss was used interproximally. The margins of the crown were covered with glycerin gel, and resin composite cement was light polymerized from each side for 40 seconds. A gingival cord (No. 000, Ultrapack) was placed into the sulcus before the crown was luted, to allow residual cement to be removed from the crevice.

The occlusion was evaluated again.[7,11,12]

Clinical evaluation

Photography and data forms were used as documentation tools in this study. Patients were reexamined at intervals of 6 months for the first year and annually thereafter. Examinations included the use of a mirror, a sharp explorer, radiographs, and clinical slides. Inflammation was considered to be absent if there was no bleeding on probing during the examination. For failed restorations, the examiners tried to determine the cause of failure.

All the patients were recalled between January 2001 and March 2001. Color match, porcelain surface, marginal discoloration, and marginal integrity were evaluated in accordance with modified California Dental Association[19] and Ryge[20] criteria at baseline (placement) and at subsequent recall appointments (Table 1). Restorations having neither Charlie nor Delta ratings for any criteria were defined as successful.[8]

Kaplan-Meier statistics were used to analyze the survival rates obtained for the crowns luted on anterior or posterior teeth[9,21] (Figs 2 and 3). The survival time was defined as the period of time starting at the

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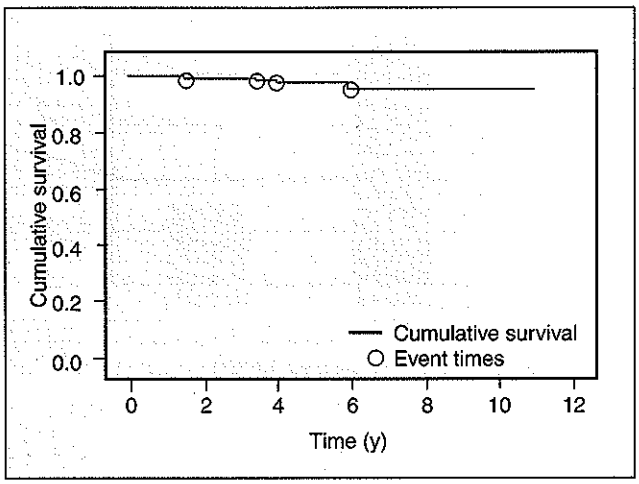
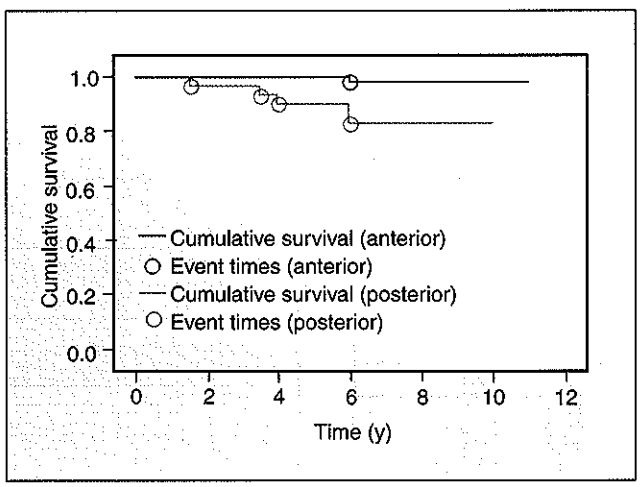


Fig 2 Kaplan-Meier survival plot for all crowns as a function of time.



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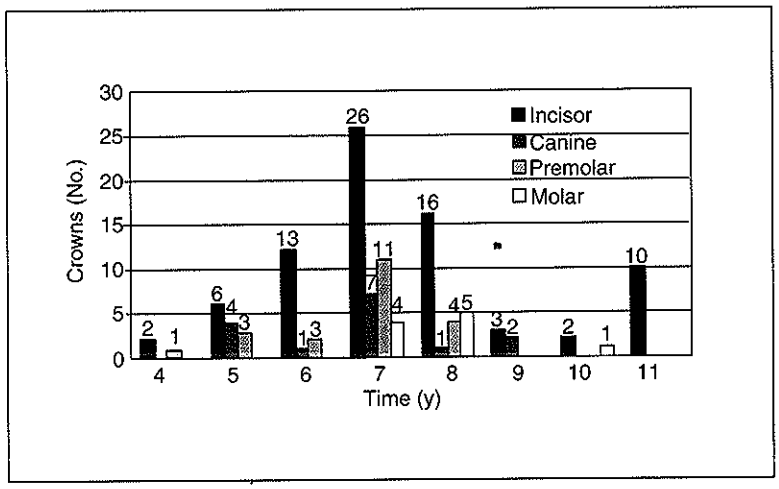


Fig 4 Distribution of restored teeth and their relative periods of observation.

cementation of the restoration and ending when the crown was shown to have irreparably failed. Porcelain fracture or partial debonding that exposed the tooth structure and impaired esthetic quality or function were the main criteria for irreparable failure. The restorations were replaced in either case.

RESULTS

A total of 125 crowns placed in 54 patients (30 females and 24 males) were studied over periods ranging from 4 to 11 years. The crowns were placed over a period of 6.5 years, namely from May 1990 to December 1996. The final evaluations of the crowns took place between January 2001 and March 2001 (Fig 4).

One patient died before the end of the study. Four more patients were lost for other reasons, and thus were removed from the study. Therefore, 125 of 170 of the originally placed crowns were assessed with a view to statistical analysis.

Ninety-four crowns (75.2%) were placed in the maxillas and 31 (24.8%) in the mandibles. Ninety-three crowns (74.4%) were placed in the anterior segments of the dental arches. The remaining 32 were placed (25.6%) in the posterior segments.

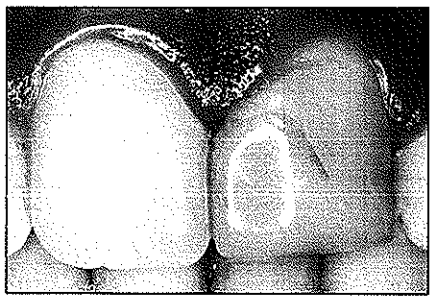
During the evaluation period, six restorations failed: four crowns fractured (three in the posterior segment and one in the anterior segment); one restoration in the posterior segment fractured the post and core; and one restoration in the posterior segment fractured the root. The following complete crowns were replaced:

1. Mandibular left second molar (endodontically treated): The crown fractured 16 months after initial luting.
2. Mandibular right second premolar (endodontically treated): The post and core fractured 42 months after initial luting of the crown.
3. Mandibular left second premolar (endodontically treated): The root fractured 4 years after initial luting of the crown.
4. Maxillary left first molar (endodontically treated): The crown fractured 6 years after initial luting.
5. Maxillary left first molar: The crown fractured 6 years after initial luting.
6. Maxillary left central incisor (endodontically treated): The crown fractured 6 years after initial luting.

Thus, the total failure rate over the entire observation period was 4.8%. One restoration failed in the anterior segment, a failure rate of 1.1%, and five failed in the posterior segment, a failure rate of 15.6%.

According to the Kaplan-Meier survival estimation method, the overall survival probability of the 125 Empress crowns was 95.2% at 11 years. For the 93 crowns placed in the anterior segment of the arch, the survival probability was 98.9%. For the 32 crowns placed in the posterior segment, the survival probability was 84.4% (see Figs 2 and 3).

The frequencies of scores for the evaluated criteria are shown in Table 1. Six crowns were not analyzed because of fractures. Most of the 119 evaluated crowns were rated excellent. The highest rating, Alfa, was awarded to 94.2% of crowns for color match, 91.6% for porcelain surface, 86.6% for marginal discoloration, and 94.2% for marginal integrity.



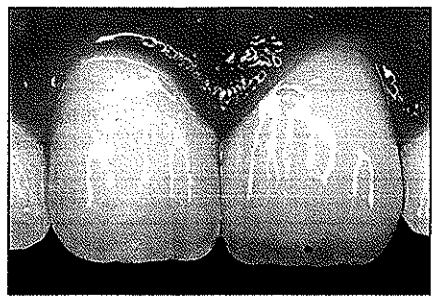
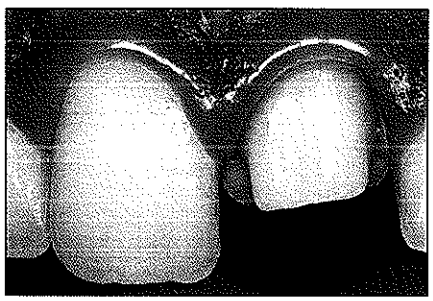
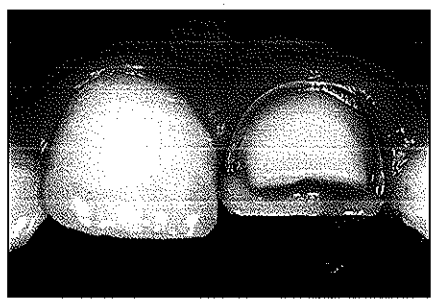


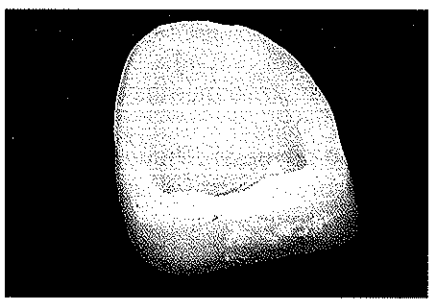
Fig 5a Maxillary left central incisor with a failing resin composite restoration.

Fig 5b Newly placed Empress crown, demonstrating proper esthetic and biologic integration.





Figs 5c and 5d Failure of the crown with a cross-sectional fracture after 6 years.



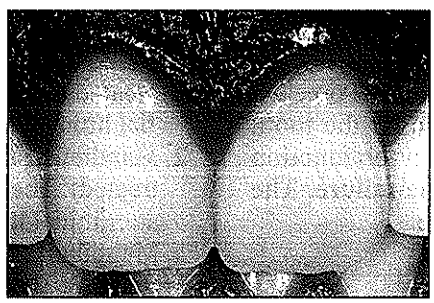


Fig 5e Cleaned, etched, and silanized Empress fragment, ready for bonding to the remaining tooth-ceramic structures.

Fig 5f Bonded fragment still in service, 1 year after repair.

DISCUSSION

Only a few studies of the clinical performance of IPS Empress crowns are available to date, but results of several in vitro studies of the system have been published.[22-25] However, in vitro studies are not as useful as clinical studies: In vivo studies are needed to evaluate the actual clinical applications of new dental systems and materials. Retrospective studies may provide a reliable picture of the clinical performance of both materials and techniques.[9]

In this study, the IPS Empress crowns were connected with a high survival rate, 95.2% at 11 years. This rate was comparable with the results reported for porcelain-fused-to-metal crowns, studied by Leempoel et al,[26] who reported an estimated survival rate of 95% after 11 years. In contrast, Kerschbaum et al[27] reported decreased survival rates for single porcelain-fused-to-metal crowns, namely 92% and 79% after 5 and 10 years, respectively.

According to the present results, IPS Empress crowns are connected with nearly the same risk of fracture as metal-ceramic crowns. However, if the crowns placed on anterior teeth are separated from the crowns placed on posterior teeth, posterior crowns are connected with a higher risk of fracture (survival rate: 84.4%) than are anterior crowns (survival rate: 98.9%). The number of crowns placed in the anterior segment (93) differed from that placed in the posterior segment (32), because, after initial failure, the authors decided not to place any more crowns in the posterior region.

In the posterior segment, the higher occlusal forces play a major role in determining restoration failures. That is the rationale for limiting the posterior use of Empress crowns to premolars.[12] However, the results suggest that crown fractures do not occur as frequently as do failures arising from ceramic breakage.[26] The only fractured crown in the anterior region showed a cross-sectional breakage on the incisal-palatal area (Figs 5a to 5d). The fractured fragment was cleaned, and the inner surface of the ceramic was etched and silane treated (Fig 5e). The fragment was then bonded again as a veneer restoration. The patient was informed of the risks of this procedure and agreed to this treatment. When the restoration was checked after 10 months, it was still functioning normally in the patient's mouth (Fig 5f).

It is mandatory that Empress crowns be bonded with a correct adhesive technique to reach this successful survival rate, comparable to the results obtained with traditional porcelain-fused-to-metal crowns. The high success rate obtained in this study could have been dramatically lessened if the crowns had been cemented conventionally instead of being bonded.[28] Any comparison between modified metal-ceramic crowns systems and all-ceramic restorations that are not bonded but are conventionally luted is not relevant. The use of bonding procedures is currently very popular among practitioners and today represent the only acceptable choice for luting glass-ceramic restorations.[29]

The crowns received the highest rating (Alfa) for most of the modified California Dental Association[19] and Ryge[20] criteria. The crowns made with the painting technique showed a perfect color match, having changed very little in color and shine, as did the crowns made with the layering technique. Therefore, no significant differences were found between crowns made with the different techniques.

It was sometimes difficult to accurately investigate marginal discoloration and integrity, because most of the crown margins had been placed intrasulcularly. However, marginal integrity was rated Alfa in 94.2% of the crowns. Marginal discoloration was rated Bravo in 13.4% of the crowns, probably as the result of the placement of the margin into the cementum.

This study had some limitations:

1. Only complete crowns were included.
2. All the clinical procedures were performed by two clinicians.
3. The crowns were placed over a period of 6 years and not simultaneously.

Nevertheless, this study also boasted some major advantages compared to previously published investigations of IPS Empress crowns:

1. The sample was large.
2. The crowns were studied for longer follow-up periods.
3. All the patients treated with IPS Empress crowns were serially accounted for at the end of the study.
4. The patients were treated in private dental offices.
5. The patients paid the full office price for their IPS Empress crowns and were not offered any inducements.
6. The data were accurately analyzed and presented, so that the results could be compared with those of other studies.

CONCLUSION

Despite the limitations of this retrospective clinical study of the survival of IPS Empress crowns in two private practices, the following conclusions were drawn:

1. IPS-Empress crowns showed a low clinical failure rate of approximately 4.8% after 11 years.
2. The survival probability of 125 anterior and posterior Empress crowns, according to the Kaplan-Meier survival estimation method, was 95.2% at 11 years. The survival probability of 93 crowns placed in the anterior segment was 98.9% at 11 years. The survival probability of 32 crowns placed in the posterior segment was 84.4% at 11 years.
3. Most of the fractured crowns had been placed on molars and premolars. Thus, the risk of fracture should be considered whenever crowns are placed on teeth that are likely to be subjected to substantial stress.
4. The color match, the porcelain surface, marginal discoloration, and marginal integrity were mostly rated satisfactory.

ACKNOWLEDGMENTS

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