Survival rates of IPS Empress 2 all-ceramic crowns and fixed partial dentures: Results of a 5-year prospective clinical study

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Objective: The aim of this prospective clinical study was to evaluate the survival rates of IPS Empress 2 (Ivoclar Vivadent) all-ceramic crowns and fixed partial dentures (FPDs) after an observation period of up to 5 years. **Method and Materials:** Forty-three patients (19 women and 24 men) were included in this study. The patients were treated with a total of 58 adhesive bonded IPS Empress 2 restorations. A total of 27 single crowns were placed on molars and premolars, and 31 three-unit FPDs were placed in the anterior and premolar regions. Clinical follow-up examinations took place at 6, 12, 24, 36, 48, and 60 months after insertion. Statistical analysis of the data was calculated using the Kaplan-Meier method. **Results:** Results of the 50-month analysis (interquartile range, 33 to 61 months) showed that the survival rate was 100% for crowns and 70% for FPDs. Six failures that occurred exclusively in the three-unit FPDs were observed. Framework fractures were recorded in three FPD units where the connector dimensions did not meet the manufacturer specifications. Only one FPD exhibited an irreparable partial veneer fracture, and 2 FPDs showed evidence of biologic failures. The accuracy of fit and esthetic parameters were clinically satisfactory for crowns and FPDs. **Conclusion:** The results of this 5-year clinical evaluation suggest that IPS Empress 2 ceramic is an appropriate material for the fabrication of single crowns. Because of the reduced survival rates, strict conditions should be considered before the use of IPS Empress 2 material for the fabrication of three-unit FPDs. *(Quintessence Int 2006;37:253–259)*

Key words: all-ceramic, crowns, fixed partial dentures, IPS Empress 2, survival rate

Nowadays, the conventional prosthetic treatment options such as porcelain-fused-to-metal (PFM) are increasingly being replaced by all-ceramic restorative systems. Long-term clinical studies have shown that the survival rates of PFM single crowns were between 59% and 84% after an observation period of 15 years.[1–4] Kerschbaum reported a survival rate of 29% for cast metal crowns after an observation period of more than 25 years.[5] Two meta-analyses reported a survival rate of conventional fixed partial dentures (FPDs) between 69%[6] and 74%[7] after an observation period of 15 years. In a systematic review, the survival rate of FPDs was found to be 81.8% after 10 years.[8] Despite the very good clinical success, the significant disadvantage of conventional PFM restorations is the potential for suboptimal esthetic outcomes. The presence of a dull grayish background may give the soft tissue around the restoration an unnatural bluish appearance. This presence of a gray gingival discoloration may be attributed to the thin gingival tissue in the area around the tooth that is incapable of blocking

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reflective light from the metallic framework surface.[9] In addition, deterioration and corrosion of the metal in the gingival sulcus may help to increase this unesthetic effect. Porcelain shoulder has been suggested to solve this problem.[10] With this method, the discoloration can be mitigated, as with natural teeth, via natural transmission and reflection of light through the ceramic.

Increasing patient demands for superior dental esthetics and high-quality restorations have led to the development of all-ceramic materials.[11] In contrast to PFM restorations, all-ceramic restorations exhibit a high level of translucency and luminousness resembling those of natural teeth. During the initial utilization of all-ceramic restorations the limiting factor was the brittleness of the materials.[12] Improvements in all-ceramic materials and enforcement modifications have substantially enhanced the resistance of all-ceramic restorations.[13–16] Contemporary high-strength all-ceramic systems using aluminum oxide and zirconia-based frameworks exhibit very good clinical data and superior esthetics.[17–20] In a long-term clinical study, the survival rate of all-ceramic single crowns fabricated of aluminum oxide framework material (Procera, Nobel-Biocare) was 93.5% with an observation period between 5 and 10.5 years.[21] Although this seems to be very promising, no data is available on the long-term clinical behavior of zirconia-based restorations. However, known problems with zirconia-based frameworks include a lack of translucency and esthetic quality. Thus, further improvements in all-ceramic materials are needed to develop a material that combines both high strength and excellent esthetic outcome.

The IPS Empress 2 (Ivoclar Vivadent) was first presented in November 1998. The material is composed of a lithium disilicate glass-ceramic that exhibits fracture strength of 350 MPa. According to the manufacturer, the material can be used for the fabrication of single crowns in the esthetic and lateral regions and three-unit FPDs extending to the premolar region.

The objective of this prospective clinical study was to evaluate the survival rate of IPS Empress 2 restorations after an observation period of up to 5 years.

METHOD AND MATERIALS

The all-ceramic system

The IPS Empress 2 all-ceramic material consists of two different glass ceramics. The framework material is a high-strength heat-pressed glass-ceramic containing lithium disilicate crystals. The compatible veneering ceramic material is composed of apatite sintered glass-ceramic.

The distinguishing characteristics of lithium disilicate ceramic are its flexural strength (350 ± 50 MPa), which is similar to that of In-Ceram System, and its high fracture strength.[22] Lithium disilicate crystal is a laminated silicate that exhibits a tight cross-linking of the SiO_3-tetragonal lattice. The strengthening mechanism of lithium disilicate is attributed to the higher percentage volume reduction of the particles compared to the surrounding glass matrix upon cooling. The higher percentage volume reduction of the crystals is accounted for by its higher coefficient of thermal expansion in comparison to the glass matrix and a high-to-low temperature phase transformation. The result of pressing the material at a temperature of 920°C is a primary crystalline phase of needle-shaped lithium disilicate crystals (0.5 to 5 mm), which comprise approximately 60 vol%. The volume differential between the lithium disilicate particles and the glass matrix causes residual stresses that place the surrounding glass matrix in compression, which must be counteracted by tensile stresses before cracks propagate. Irrespective of the large percentage of lithium disilicate crystals, IPS Empress 2 exhibits a high level of translucency due to the optical properties of the crystal structures. In addition to lithium disilicate crystals, the material contains minor quantities of lithium orthophosphate crystals (Li_3PO_4) with particle sizes between 0.1 and 0.3 mm.[23]

The IPS Empress 2 ceramic is etchable with hydrofluoric acid. Optimal bonding can be achieved when etching the ceramic for 20 seconds with IPS Empress ceramic etching gel, treating it with silane coupling agent Monobond S, and applying Heliobond (Ivoclar Vivadent).

Table 1 Distribution of abutment teeth for single-crown restorations (n = 27)

Abutment	First premolar	Second premolar	First molar	Second molar
Right maxilla	4	5	1	
Left maxilla	4	2		
Left mandible		3	3	
Right mandible		1	3	1

Table 2 Distribution of abutment teeth for FPD restorations (n = 31)

Abutment	Central incisor	Lateral incisor	Canine	Second premolar
Right maxilla	14	5	9	1
Left maxilla	9	6	6	2
Left mandible	1		2	2
Right mandible		1	2	2

A special apatite fluoride glass-ceramic was developed for veneering of the IPS Empress 2 frameworks. This veneering ceramic can be sintered at 800°C. During this process, a part of the apatite crystals of the glass matrix is precipitated out of the glass-ceramic. These crystals help to achieve a higher level of biocompatibility and optical characteristics such as translucency, brightness, and light-scattering of the veneering material.[23]

Patient distribution

Nineteen women and 24 men, aged 22 to 65 years, were included in this study. All patients met the following criteria: good oral hygiene, good or restored periodontal health (maximal degree of tooth mobility ≤ 1), no signs of bruxism, and women could not be pregnant or nursing.

The patients received a total of 58 adhesively bonded IPS Empress 2 restorations. Each patient was treated with a maximum of two restorations that were not positioned in antagonistic contact to each other. Twenty-seven single crowns were placed on molars and premolars, with the distribution of 14 crowns in the maxilla and 13 in the mandible (Table 1). A total of 31 three-unit FPDs were placed in the anterior and premolar regions. Twenty-six of these FPDs were placed in the maxilla, and 5 were placed in the mandible. The second premolar was considered as the maximal distal abutment tooth for the FPD restorations (Table 2).

Preparation and fabrication procedures

All abutment teeth for the crowns and FPDs were prepared using a high-speed handpiece and diamond burs (Praeparationssatz Prothetik der Universitäten Freiburg und Kiel, Komet Brasseler) under water cooling. A 1.2-mm-deep chamfer preparation was made with soft and rounded linear angles. To provide an appropriate material thickness, a circular reduction of 1.5 mm was made for all abutment teeth. An occlusal/incisal reduction of 2 mm was made for the posterior and anterior teeth to provide resistance to the occlusal surface or the incisal edge of the restoration. All angles were rounded to reduce the effect of tensile stresses on the ceramic. Nonvital teeth that required reinforcement with posts were restored with an all-ceramic post and core system (Cosmopost, Empress Cosmo core, Ivoclar Vivadent).

During the fabrication procedures of definitive restorations, provisional restorations were used to protect the remaining tooth structure and restore the function temporarily. The restorations were fabricated out of a self-curing acrylic material (Tab 2000, KerrHawe) and were cemented with an eugenol-free cement (Freegenol Temporary Pack, GC International). Final impressions were made using a polyether elastic impression material (Permadyne Soft/Putty 3M Espe) and custom-made plastic trays with the single-impression double-mixing technique.

The final restorations were fabricated with the IPS Empress 2 framework and veneering ceramic material in a dental laboratory according to the recommendations of the manufacturer. A minimal thickness of 0.8 mm for the framework material was considered. In addition, a minimum dimension of 3 × 4 mm and 4 × 4 mm was designed for the connectors in the anterior and lateral areas, respectively.

During the try-in, all restorations were required to exhibit a intimate fit and absence of stress or rotation. The static and dynamic occlusion was tested and corrected as required to establish anterior-canine protected occlusion. Stable centric contacts were checked in the static occlusion. When necessary, minor corrections to the glazed restorations were undertaken chairside with the help of diamond burs and water cooling, followed by high-gloss polishing with silicone polishers (Targis polisher and diamond polishing paste, Ivoclar Vivadent). Major corrections were performed in the dental laboratory.

Variolink II Professional Set (Ivoclar Vivadent) was used for the adhesive bonding of single crowns and FPDs. Prior to cementation, all teeth were conditioned with the Syntac System (Ivoclar Vivadent).

Tests

The clinical analysis and follow-up evaluations were performed as follows for the 5-year investigation: after initial treatment, at 6 months postplacement, once per year for 5 consecutive years. To provide consistency to the evaluation, the clinical parameters, such as fracture of the veneering and framework ceramic, marginal fractures, surface roughness/quality, and vitality/sensitivity of the abutment teeth, were recorded by only one examiner throughout the duration of the study. Irreparable fractures of the restorations were the primary criteria for technical failures, whereas abutment tooth fractures or endodontic problems were considered as biologic failures.

A 5-year survival rate analysis of the restorations was conducted according to the Kaplan and Meier method.[24] Irreparable fracture was the primary criteria for complete restoration failure.

RESULTS

For the 60–month follow-up, 11 patients of the FPD group and 13 patients who received single crowns could be observed. Reparable fractures of the veneering ceramic material were observed in two single crowns and one FPD pontic and were considered as relative failures. No complete failures were observed among the 27 single all-ceramic crowns. The survival rate for the IPS Empress 2 single crowns was 100% for the duration of the study. Results of the statistical analysis of the data showed that the IPS Empress 2 FPD restorations had a survival rate of 78% after 50 months (minimum 1 to maximum 66 months [interquartile range = 33 to 61 months]) at a 95% confidence interval (Fig 1).

The results for the 3-unit IPS Empress 2 FPDs included a total of 6 complete failures. The differences between technical and biologic failures were analyzed and recorded accordingly. The 4 complete failures that were considered technical failures (66.6%) occurred in the anterior region. Three of these complete failures exhibited fractures in the framework, and one exhibited partial fracture of the FPD veneering ceramic. The biologic failures (33.3%) included only one FPD framework that was irreparably damaged as a result of the trepanation of an abutment tooth that had received endodontic treatment; 1 abutment tooth fractured.

The high level of accuracy of fit (crown retention, marginal quality, and marginal accuracy) and esthetics accomplished with the IPS Empress 2 material was deemed very satisfying. During the observation period, no marginal discolorations or caries were noticeable.

DISCUSSION

All-ceramic single crowns indicate excellent esthetics, biocompatibility, and very good long-term success.[18,21,25,26] In the present study, the survival rate of single all-ceramic crowns was 100% with an observation period of more than 50 months. These good

results are comparable to those of previous long-term clinical investigations. In a retrospective clinical study, Fradeani and Redemagni reported a survival rate of 95.2% for 125 IPS Empress single crowns after an observation period of 11 years.[26] Segal illustrated a survival rate of 99.1% for 546 In-Ceram crowns after 6 years.[25] Bindel and Mörmann demonstrated a 100% survival rate after 39 ± 11 months for In-Ceram Spinell crowns in the posterior region.[27] Similar results were also shown with high-strength oxide-based all-ceramics crowns in the posterior region.[18,20,27,28]

In the present study, the survival rate of the IPS Empress 2 FPDs was 78%. The most frequent failure type—technical (66.6 %)—was because of either the fractures of the frameworks or irreparable fractures of the veneering ceramic material. Examination of the fractured fragments under electronmicroscopy revealed that these fractures appeared because of an underextension of dimensions of the connectors where the manufacturer's recommendation of a minimum connector area of 16 to 20 mm^2 was not followed. Inadequate dimension of the connector has been reported to weaken the connector and thus reduce the fracture resistance of the whole restoration.[29,30] Findings of clinical investigations have supported this issue and showed that the dimension of the connector and the tooth preparation influence the fracture resistance of all-ceramic FPDs.[31,32] In this study, it was noticed that FPDs in the premolar area had better results compared to anterior FPDs. This could be explained by the fact that more space is available in the posterior region for better dimensioning of the connector according to the design specifications.

In addition to the dimensions of the connector and tooth preparation, other factors can lead to technical failures of all-ceramic FPDs. Sharp-angled interproximal connector designs were reported to initiate cracks in stress-prone areas and should be therefore avoided.[33] Furthermore, the radius of the connector's surface curvature influences the fracture strength of all-ceramic FPDs. In an in vitro study, the fracture rate was shown to increase significantly when the connector's radius was decreased.[34] Limited studies are available on the success of FPDs fabricated of materials similar to IPS Empress 2, and the data for the implementation is scarce. Van Steyern et al investigated In-Ceram FPDs in the posterior region and found that the survival probability was 90% after an observation period of 5 years.[19] In another clinical study, the survival rate of In-Ceram FPDs was 93.3% after 35 months.[35] Yttria stabilized tetragonal zirconia (Y-TZP) FPD frameworks showed very good results over a 2-year observation period, indicating promising survival rates.[20,36]

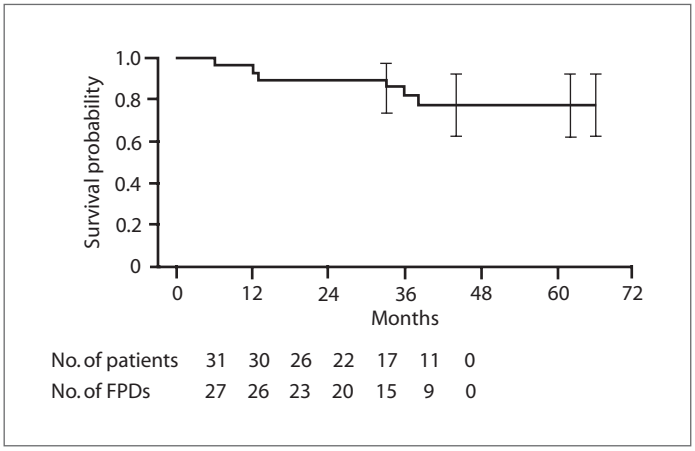

Fig 1 Survival rate analysis of the IPS Empress 2 FPD restorations according to the method of Kaplan and Meier.[24]

The biologic failures (loss of vitality or fracture of abutment tooth) may be attributed to extensive step preparation that leads to large loss of tooth substance, which in turn reduces the resistance to fracture and affects the vitality of the abutment. In a systematic review, 15% of all abutment teeth with preparation for PFM conventional restorations were reported to become nonvital after 10 years.[37,38] Further studies are needed to investigate the influence of the preparation type on the abutment's long-term resistance and vitality.

CONCLUSIONS

Within the limits of this study, it can be concluded that:

1. High esthetic results can be achieved with IPS Empress 2 all-ceramic restorations.
2. IPS Empress 2 all-ceramic crowns have proved to be a successful treatment in all areas and therefore can be recommended for use in general practice.
3. Because of the reduced survival rates, strict conditions should be considered before the application of IPS Empress 2 material for the fabrication of three-unit FPDs.

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REFERENCES

1. Kerschbaum TH, Paszyna GH, Klapp S, Meyer G. Verweilzeit und Risikoanalyse von Kronen und Brücken. Dtsch Zahnärztl Z 1991;46:20–24.
2. Erpenstein H, Kerschbaum TH, Fischbach H. Verweildauer und klinische Befunde bei Kronen und Brücken. Eine Langzeitstudie. Dtsch Zahnärztl Z 1992;47:315–319.
3. Howthorne WS, Smales RJ. Factors influencing long-term restoration survival in three private practices in Adelaide. Aust Dent J 1997;42:59–63.
4. Kerschbaum T. Langzeitüberlebensdauer von Zahnersatz: Eine Übersicht. Quintessenz 2004;55: 1113–1126.
5. Kerschbaum T. Hohe Haltbarkeit von Zahnersatz. Zahnärztl Mitt 2000;90:2706–2711.
6. Scurria MS, Bader JD, Shugars DA. Meta-analysis of fixed partial denture survival: Prostheses and abutments. J Prosthet Dent 1998;79:459–464.
7. Creugers NHJ, Käyser AF, van't Hof MA. A meta-analysis of durability data on conventional fixed bridges. Community Dent Oral Epidemiol 1994;22:448–452.
8. Pjetursson BE, Tan K, Lang NP, Bragger U, Egger M, Zwahlen M. A systematic review of the survival rate and complication rates of fixed partial dentures after an observation period of at least 5 years. Clin Oral Implants Res 2004;15:667–676.
9. Takeda T, Ishigami K, Shimada A, Ohki K. A study of discoloration of the gingiva by artificial crowns. Int J Prosthodont 1996;9:197–202.
10. Chiche G, Radiguet J, Pinault A, Genini P. Improved esthetics for the ceramometal crown. Int J Periodontics Restorative Dent 1986;1:76–87.
11. Breustedt A, Elss S, Kramer M. Ganzkeramikbrücken—Ein echter Fortschritt? Zahntechnik 1969;10:533.
12. Lüthy H, Dong JK, Wohlwend A, Schärer P. Effect of veneering and glazing on the strength of heat-pressed ceramics. Acta Med Dent Helv 1993;103: 1257–1260.
13. Seghi RR, Denry IL, Rosenstiel SF. Relative fracture toughness and hardness of a new dental ceramic. J Prosthet Dent 1995;74:145–150.
14. Wagner WC, Chu TM. Biaxial flexural strength and indentation fracture toughness of three new dental core ceramics. J Prosthet Dent 1996;76:140–144.
15. Mak M, Qualtrough AJ, Burke FJ. The effect of different ceramic materials on the fracture resistance of dentin-bonded crowns. Quintessence Int 1997;28: 197–203.
16. Chitmongkolusk S, Heydecke G, Stappert C, Strub JR. Fracture strength of all-ceramic lithium disilicate and porcelain-fused-to-metal bridges for molar replacement after dynamic loading. Eur J Prosthodont Restor Dent 2002;10:15–22.
17. Naert I, van der Donck A, Beckers L. Precision of fit and clinical evaluation of all-ceramic full restorations followed between 0.5 and 5 years. J Oral Rehabil 2005;32:51–57.
18. Fradeani M, D'Amilio M, Redemagni M, Corrado M. Five-year follow-up with Procera all-ceramic crowns. Quintessence Int 2005;36:105–113.
19. on Steyern PV, Jönsson O, Nilner K. Five-year evaluation of posterior all-ceramic three-unit (In-Ceram) FPDs. Int J Prosthodont 2001;14:379–384.
20. Van Steyern PV, Carlson P, Nilner K. All-ceramic fixed partial dentures designed according to the DC-Zirkon technique. A 2-year clinical study. J Oral Rehabil 2005;32:180–196.
21. Ödman P, Andersson B. Procera AllCeram crowns followed for 5 to 10.5 years: A prospective clinical trial. Int J Prosthodont 2001;14:504–509.
22. Pospiech P. Neue Möglichkeiten vollkeramischer Versorgungen mit Empress 2. Phillip Journal 1999;3:62–67.
23. Höland W. Werkstoffkundliche Aspekte der IPS Empress 2 Glaskeramik. Ivoclar Vivadent Report 1998;12:3–10.
24. Kaplan EL, Meier P. Nonparametric estimation from incomplete observation. J Am Stat Assoc 1958;53: 457–465.

25. Segal BS. Relative retrospective assessment of 546 all-ceramic anterior and posterior crowns in a general practice. J Prosthet Dent 2001;85:544–550.
26. Fradeani M, Redemagni M. An 11-year clinical evaluation of leucite-reinforced glass-ceramic crowns: A retrospective study. Quintessence Int 2002;33: 503–510.
27. Bindl A, Mörmann WH. An up to 5-year clinical evaluation of posterior In-Ceram CAD/CAM crowns. Int J Prosthodont 2002;15:451–456.
28. Odén A, Anderssen M, Krystek-Ondracek I, Magnusson D. Five-year clinical evaluation of Procera AllCeram crowns.J Prosthet Dent 1998;80:450–456.
29. Kelly JR, Tesk JA, Sorensen JA. Failure of all-ceramic fixed partial dentures in vitro and in vivo: Analyses and modelling. J Dent Res 1995;74:1253–1258.
30. Kamposiora P, Papavasiliou G, Bayne SC, Felton DA. Stress concentration in all-ceramic in posterior fixed partial dentures. Quintessence Int 1996;27: 701–706.
31. Sjögren G, Bergman M. Relationship between compressive strength and cervical shaping of the all-ceramic Cerestore crown. Swed Dent J 1987;11: 147–152.
32. Pospiech P, Rammelsberg P, Unsold F. A new design for all-ceramic resin-bonded fixed partial dentures. Quintessence Int 1996;27:753–758.
33. Pospiech P, Rammelsberg P, Goldhofer G, Gernet W. All-ceramic resin-bonded bridges: A 3-dimensional finite element analysis. Eur J Oral Sci 1996;104: 390–395.
34. Oh W-S, Anusavice KJ. Effect of connector design on the fracture resistance of all-ceramic fixed partial dentures. J Prosthet Dent 2002;87:536–542.
35. Pröbster L. Survival rate of In-Ceram restorations. Int J Prosthodont 1993;6:258–263.
36. Sturzenegger B, Fehér A, Lüthy H, Schumacher M, Loefeel O, Filser F, Kocher P, Gaukler L, Schärer P. Klinische Studie von Zirkonoxid-Brücken im Seitenzahngebiet. Acta Med Dent Helv 2000;5: 131–139
37. Kerschbaum TH, Voss R. Zum Risiko der Überkronung. Dtsch Zahnärztl Z 1979; 34: 740–743
38. Kerschbaum TH, Leempoel PJB. Kronen und Brücken – Konsequenzen aus Langzeitergebnissen. In: Voss R, Meiners H. Fortschritte der Prothetik und Werkstoffkunde Band 4, Hanser München,D 1989: 109–136