

Longevity and Clinical Performance of IPS-Empress Ceramic Restorations — A Literature Review

• Jean-François Brochu, DMD •
• Omar El-Mowafy, BDS, PhD, FADM •

A b s t r a c t

A literature review of longevity and clinical performance of IPS-Empress restorations is presented. A MEDLINE search was conducted in fall 2000. Selection criteria were set so as to identify suitable clinical trials that were published in full and that had lasted more than 2 years. A total of 6 clinical trials on the performance of IPS-Empress inlays and onlays and a total of 3 clinical trials on the performance of IPS-Empress crowns were identified. Survival rates for IPS-Empress inlays and onlays ranged from 96% at 4.5 years to 91% at 7 years; most failures were due to bulk fracture. IPS-Empress crowns had a survival rate ranging from 92% to 99% at 3 to 3.5 years; crown failure was also mainly due to fracture. Dentists should inform their patients about these survival rates when offering such treatment. The use of IPS-Empress crowns in the posterior of the mouth is not recommended until the results of more long-term clinical trials are available.

MeSH Key Words: crowns; dental porcelain; dental restoration failure; inlays

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Restorative dentistry faces new challenges in adopting emerging technologies related to dental materials and in meeting patients' demands for esthetic nonmetallic restoration of posterior teeth. Currently available choices of nonmetallic materials for such restorations include direct and indirect resin composite, porcelain/ceramic. With the increasing clinical success of such alternative restorative materials, the use of metallic restorations in the posterior teeth is declining. Original porcelain or ceramic restorations have several inherent problems, including poor marginal fit, difficulty in polishing, bulk fracture and excessive wear of opposing teeth. However, the introduction of improved ceramic formulations, new bonding procedures and new resin cements have helped to overcome some of these problems, which has led to an increase in their use.¹

Since the introduction of Dicom, a castable ceramic material, (Corning Glass Works, Corning, NY) in 1984² a number of all-ceramic restorative systems have been developed. At present, most all-ceramic systems fall into 2 categories: alumina-based core materials and castable or pressable glass matrix ceramics.³ The IPS-Empress system

(Ivoclar Vivadent, Schaan, Liechtenstein) belongs in the latter category.

The IPS-Empress system was developed at the University of Zurich, Zurich, Switzerland, in 1983. Ivoclar Vivadent took over the development project in 1986 and presented it to the profession in 1990.³ The material used in the IPS-Empress system is a leucite-reinforced castable glass ceramic designed primarily for single-unit restorations. According to the manufacturer, it is appropriate for fabrication of inlays, onlays, crowns and veneers.

A major problem with all-ceramic restorations is the presence of surface microporosities that develop during sintering.^{4,6} These microporosities can predispose to crack initiation and propagation, which can in turn lead to failure of the restoration. The main advantage of the IPS-Empress system is that through the injection-moulding process, which involves the use of heat and pressure, the leucite crystals incorporated in the material create barriers that counteract the buildup of the tensile stresses that predispose to formation of microcracks.^{3,6,7} Thus the added leucite crystals improve flexural strength and fracture resistance through so-called dispersion strengthening. The crystals act as



Figure 1: Maxillary first premolar tooth prepared to receive IPS-Empress inlay. The second premolar was prepared to receive onlay restoration. Dental work by O.E.-M.



Figure 3: Premolar teeth shown in **Fig. 1** at 2 years after cementation of the restorations. Dental work by O.E.-M.

“roadblocks” in preventing crack propagation, so that the restoration does not undergo catastrophic failure during function.³ In addition, the combination of heat and pressure used in the casting process reduces the amount of ceramic shrinkage and results in higher flexural strength.

The basic constituent of IPS-Empress is feldspathic porcelain, which consists of 63% silicon dioxide and 19% aluminum oxide, to which the leucite crystals are added. The material is available in the form of glass-ceramic ingots pre-sintered by the manufacturer. During fabrication of an IPS-Empress restoration a mould is made of a wax-up of the restoration according to the lost-wax technique; the method is very similar to that followed for metallic castings. A glass-ceramic ingot is placed in the Empress furnace and pressed with an aluminum oxide plunger into a preheated muffle. A temperature of 1200°C is required to achieve the plasticity phase of the ceramic material necessary to ensure proper pressing and adaptation to form.^{3,8-10} When the casting procedure is complete, divesting follows, and there are 2 techniques for finishing the restoration and reproducing the desired colour characteristics. One option is the shading



Figure 2: Fabricated inlay and onlay restorations ready for cementation. Technical work by Siltech Dental Laboratories.

technique, whereby the restoration is first made in the neutral shade of an ingot.^{3,8,9,11} A heavily pigmented characterization colour is then added and glazed to a thickness of 50 to 60 µm. The second option is the layering technique, whereby a casting that conforms to the dentinal portion of the restoration is made of a dentin-shade ingot. The enamel layer is then added in increments each 0.3 mm thick.^{5,8,11} The layering technique is typically used in the fabrication of crowns to ensure optimum esthetics, whereas the shading technique is typically used in the fabrication of inlays and onlays.

Figure 1 shows a maxillary first premolar tooth prepared to receive an IPS-Empress inlay, with the second premolar prepared to receive onlay restoration. **Figure 2** shows the fabricated inlay and onlay restorations ready for cementation. Etching of enamel and dentin for 20 seconds was followed by application of a bonding agent (Prime & Bond NT, Dentsply, York, PA). A dual-cure resin cement was used for cementation (Calibra, Dentsply, York, PA). After occlusal adjustment with fine-grit diamond burs, the restorations were polished with Soflex discs (3M, St. Paul, MN). **Figure 3** shows the teeth in **Fig. 1** at 2 years after cementation of the restorations.

In this literature review we evaluate the clinical performance and longevity of restorations made with the IPS-Empress porcelain system.

Materials and Methods

A MEDLINE search was conducted in fall 2000 to identify clinical trials of the performance and longevity of all-ceramic restorations made with the IPS-Empress system that had been published in the previous 10 years. Only studies that dealt with inlays, onlays or crowns and were published in English were included. Studies that lasted less than 2 years were excluded, as were studies that were published in abstract form only. The studies identified were divided into 2 categories: those that dealt with inlay and onlay restorations and those that dealt with crowns.

Results

Inlay and Onlay Restoration Studies

A total of 6 studies dealing with the performance of IPS-Empress inlay and onlay restorations met the inclusion criteria and were included in the review. The studies were conducted in Germany, Italy, Norway, Sweden (2 studies) and Switzerland. **Table 1** lists details of these 6 studies (see **Table 1**, Details of the 6 studies on IPS-Empress inlays and onlays reviewed, <http://www.cda-adc.ca/jcda/vol-68/issue-4/233.html>).

Frankenberger and others¹² conducted a controlled prospective clinical trial of IPS-Empress inlays and onlays. Among the teeth included in the study 30% had proximal margins below the cemento-enamel junction. Six dentists placed a total of 96 restorations in 34 patients, and 2 examiners using a calibrated technique used modified United States Public Health Service (USPHS) criteria to assess the quality of the restorations at baseline and periodically thereafter up to 72 months. At 4 years 92% of the restorations were available for assessment, whereas at 6 years only 69% were available. Seven of the original 96 restorations had to be replaced, 5 because of bulk fracture and 2 because of endodontic treatment. Of the surviving restorations, 94% exhibited marginal deficiencies, independent of the luting cement. However, even at baseline, marginal quality was rated as “good” for only 43% of the restorations. The absence of enamel at the gingival margins had no effect on marginal integrity or secondary caries. At 6 years, the survival rate was calculated as 93%. The authors concluded that restorations of larger cavities in molar teeth performed satisfactorily and that cuspal reconstruction was not a limiting factor for clinical success.

Fradeani and others¹⁶ reported on the performance of 125 IPS-Empress inlay and onlay restorations. Although only 18 of these restorations were onlays, 60% of the restorations were placed in molar teeth. The restorations were placed in a private practice, and the patients were followed for up to 56 months (mean follow-up period 40.3 months). All restorations were evaluated during periodic recall visits by the dentists who had placed them. Apart from 4 restorations that underwent bulk fracture, the remaining restorations were rated as either “good” or “satisfactory” according to the modified USPHS criteria that were used for their evaluation. Estimated survival at 4.5 years was 96%.

Lehner and others¹⁴ conducted a clinical trial involving 138 inlays and 17 onlays. The restorations were placed by 18 clinicians who used a calibrated technique in a university clinic. The restorations were evaluated by 2 examiners according to modified USPHS assessment criteria. At a mean observation time of 5.3 years, 7 restorations were judged as clinical failures. At 6 years the authors estimated a survival rate for the restorations of 95%. There was no statistical difference in performance between onlays and

inlays or between premolars and molars. In a later report of the same patient group at 7-year recall, 9 fractures had occurred, and 3 teeth had recurrent caries.¹⁸ The Kaplan–Meier survival rate had dropped to 91% at 7 years.

Molin and Karlsson¹⁵ conducted a prospective, randomized clinical trial of 3 ceramic inlay systems, including the IPS-Empress system. Twenty patients were included in this study, and each received 4 inlay restorations, one of cast gold, one with the IPS-Empress system, one with the Cerec system (Vita Zahnfabrik, H. Rauter GmbH & Co. KG, Sackingen, Germany) (made with computer-aided design and manufacturing technology) and one with the Mirage system (Chamelon/Mirage Dental Products Inc., Kansas City) (conventional porcelain buildup sintering technique). Of the IPS-Empress restorations, 9 were placed in molars and 11 in premolars. Eleven of these restorations involved 3 surfaces and the remainder 2 surfaces. The restorations were inserted according to standard techniques, with etching of both enamel and dentin and use of a bonded resin cement. Two calibrated examiners used California Dental Association criteria to assess the restorations during recall appointments conducted at 1, 3 and 5 years. At 5 years, 4 of the 20 inlays had fractured. Unresolved postoperative hypersensitivity was not experienced with any of the IPS-Empress restorations. However, marginal ditching occurred frequently, and at 5 years 45% of the restorations showed evidence of this problem.

Van Dijken and others¹³ reported the results of a short-term (2 years) clinical trial involving 79 IPS-Empress inlay restorations placed by 3 dentists in a university clinic. Two different resin-based luting cements were used for cementation of the inlays. Six inlays were not available at the 2-year recall assessment. Of the remaining restorations, 2 exhibited evidence of small chip fractures at the marginal ridge areas but did not need replacement. All of the other restorations were judged to be performing satisfactorily.

Tidehag and Gunne¹⁷ reported on the performance of 62 IPS-Empress inlay and onlay restorations, 40 in premolars and 22 in molars, followed for 2 years. The restorations were inserted by 2 investigators in 18 patients and were examined during recall appointments at 7 and 26 months. Only one failure (due to fracture) was identified. Marginal ditching was detected in 13% of the restorations, and 23% had a slight colour mismatch. Excellent rating for anatomic form was reported for 82% of the restorations.

Crown Studies

Three studies dealing with IPS-Empress crowns and meeting the selection criteria were reviewed. These studies were conducted in Italy, Sweden and the United States. **Table 2** lists details of these 3 studies (see **Table 2**, Details of the 3 studies of IPS-Empress crowns reviewed, <http://www.cda-adc.ca/jcda/vol-68/issue-4/233.html>).

In a retrospective case series Sjögren and others¹ reported on the performance of 110 IPS-Empress crowns and onlays placed in anterior and posterior teeth after 3.5 years of service. Of the 110 restorations, 35 were onlays. Fractures occurred in 6% of all restorations: 7% of molar restorations, 12% of premolar restorations and 3% of anterior restorations. The authors used the California Dental Association criteria for assessment of the restorations. At 3.5 years 92% of the crowns and onlays were rated "satisfactory." Recurrent caries occurred in only 2% of the restorations.

Fradeani and Aquilano⁹ reported on the performance of 144 anterior and posterior IPS-Empress crowns that were followed for up to 68 months (mean follow-up period 37 months). One hundred and one of these crowns were inserted in anterior teeth, 28 in premolars, 11 in first molars and 4 in second molars. Two resin-based luting cements were used for cementation. Five of the 144 crowns failed, 3 because of fracture and 2 because of failure of the underlying core buildup. Two of the 4 crowns inserted in second molar teeth were among the 3 that experienced fracture. All failures involved the same resin cement. For the remaining crowns, modified USPHS criteria for assessment indicated satisfactory performance in terms of contour, marginal integrity, marginal discolouration, colour match and recurrent caries. At 3 years Kaplan–Meier survival analysis revealed a survival rate of 95%.

Sorensen and others¹⁹ reported the results of a 3-year prospective clinical trial of IPS-Empress crowns conducted in a university clinic. A total of 75 crowns were placed in 33 subjects: 47 in anterior teeth, 15 in premolars and 13 in first molars. The authors elected not to include any second molar teeth in the study. The gingival margins of selected teeth were located 1 mm subgingivally, and 2 resin cements were used. At 3 years only one molar crown had fractured. Of the 75 crowns, 53 were cemented on vital teeth, and postoperative sensitivity was experienced with 3 of them, 2 cemented with one cement and one with the other cement; however, this sensitivity subsided in 3–8 weeks.

Discussion

Given the results of the first 3 studies of inlays and onlays that lasted 5 years or more^{12, 14, 16} some overall conclusions can be drawn about the performance and longevity of IPS-Empress inlays and onlays. Those 3 studies involved a total of 376 restorations and survival rates ranging from 96% at 4.5 years to 91% at 7 years. Recurrent caries were not a major factor in failure; instead, bulk fracture was the most frequent cause. The size of the restoration (inlay or onlay) did not seem to influence failure. Although marginal ditching was common, it was not severe enough to warrant replacement of the restorations. When dentists are prescribing such relatively new treatment modalities they must inform their patients about the 5% to 10%

possibility of failure, mainly due to fracture, that can occur in the first 5 years. The clinical trial reported by Molin and Karlsson¹⁵ lasted 5 years, but the number of IPS-Empress restorations included (20) was too small to allow any meaningful conclusions. In addition, 4 of the 20 restorations fractured, a proportion much higher than that experienced in the first 3 studies, which had much bigger sample sizes.

When the results of the 3 studies of IPS-Empress crowns (which accounted for a total of 329 crowns)^{1,9,16} are considered collectively, some overall conclusions can be drawn. The survival rate ranged from 92% to 99% at 3 to 3.5 years. Most failures were due to fracture. Because more crowns were placed on anterior teeth and fewer on posterior teeth, any conclusions will be more applicable to anterior than to posterior crowns. When prescribing this type of treatment dentists must inform patients of the 1.3% to 8% possibility of fracture after 3 to 3.5 years. Also, the use of such crowns in posterior teeth should be avoided until more long-term information is available.

The question of postoperative sensitivity was addressed in most of the studies reviewed here. In most cases postoperative sensitivity was transient and resolved within a maximum of 8 weeks. Only a few patients needed either retreatment or root canal therapy because of persistent unresolved sensitivity. However, since these studies were conducted, there have been major developments in dentin surface treatment in preparation for bonding and in the chemistry of bonding agents. It is anticipated that with new dentin bonding systems and new application techniques the low incidence of postoperative sensitivity may decline further. When an all-etch procedure is used in conjunction with clinically proven bonding agents and resin cements, the chances for long-term success will be further enhanced. For inlay and onlay restorations, preparation designs that allow for sufficient bulk of material at the isthmus portion will improve longevity.

The results of the 9 studies reviewed here must be interpreted with care as most of the restorations were placed in a university clinic setting under ideal conditions with virtually no time limit on the procedures. The patients were selected carefully, and only those with good oral hygiene, low risk of caries and without bruxism were included. In a busy private practice, where time can sometimes be limited, it is possible that such restorations will not perform to the level reported in these studies. Dentists should select cases for IPS-Empress restorations with great care. Situations in which excessive occlusal loading is anticipated should be avoided. The use of reliable dentin bonding systems along with proven resin cements for the cementing procedure will reduce problems during placement and enhance longevity.

Conclusions

According to reports of 9 clinical trials evaluating the performance of IPS-Empress restorations, survival of inlays and onlays ranged from 96% at 4.5 years to 91% at 7 years,

with most failures caused by bulk fracture. The survival of crowns ranged from 92% to 99% at 3 to 3.5 years, with failure again being caused primarily by fracture. Use of IPS-Empress crowns is not recommended in the posterior region of the mouth until the results of a sufficient number of long-term clinical trials of premolars and molars are available. ♦

Dr. Brochu is a graduate student, discipline of prosthodontics, department of clinical dental sciences, faculty of dentistry, University of Toronto, Toronto, Ontario.

Dr. El-Mowafy is associate professor, discipline of restorative dentistry, department of clinical dental sciences, faculty of dentistry, University of Toronto.

Correspondence to: Dr. Omar El-Mowafy, Discipline of Restorative Dentistry, Department of Clinical Dental Sciences, Faculty of Dentistry, University of Toronto, Toronto, ON M5G 1G6. E-mail: oel.mowafy@utoronto.ca.

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References

1. Sjögren G, Lantto R, Granberg A, Sundstrom BO, Tillberg A. Clinical examination of leucite-reinforced glass-ceramic crowns (Empress) in general practice: a retrospective study. *Int J Prosthodont* 1999; 12(2):122-8.
2. Giordano R 2nd. A comparison of all-ceramic restorative systems, Part 1. *Gen Dent* 1999; 47(6):566-70.
3. Dong JK, Luthy H, Wohlwend A, Scharer P. Heat-pressed ceramics: technology and strength. *Int J Prosthodont* 1992; 5(1):9-16.
4. Probst L, Geis-Gerstorfer J, Kirchner E, Kanjantra P. In vitro evaluation of a glass-ceramic restorative material. *J Oral Rehabil* 1997; 24(9): 636-45.
5. McLean J. The science and art of dental ceramics. Chicago: Quintessence Publishing Co Inc; 1979.
6. Ohyama T, Yoshinari M, Oda Y. Effects of cyclic loading on the strength of all-ceramic materials. *Int J Prosthodont* 1999; 12(1):28-37.
7. Sorensen JA, Engelman MJ, Torres TJ, Avera SP. Shear bond strength of composite resin to porcelain. *Int J Prosthodont* 1991; 4(1):17-23.
8. Wohlwend A, Schärer P. The Empress technique: A new technique for the fabrication of full ceramic crowns, inlays, and veneers. *Quintessenz Zahntech* 1990; 16:966-78.
9. Fradeani M, Aquilano A. Clinical experience with Empress crowns. *Int J Prosthodont* 1997; 10(3):241-7.
10. Sulaiman F, Chai J, Jameson LM, Wozniak WT. A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. *Int J Prosthodont* 1997; 10(5):478-84.
11. Luthy H, Dong JK, Wohlwend A, Scharer P. Effects of veneering and glazing on the strength of heat-pressed ceramics. *Schweiz Monatsschr Zahnmed* 1993; 103(10):1257-60.
12. Frankenberger R, Petschelt A, Krämer N. Leucite-reinforced glass ceramic inlays and onlays after six years: clinical behavior. *Oper Dent* 2000; 25(6):459-65.
13. van Dijken JW, Ormin A, Olofsson AL. Clinical performance of pressed ceramic inlays luted with resin-modified glass ionomer and autopolymerizing resin composite cements. *J Prosthet Dent* 1999; 82(5):529-35.
14. Lehner C, Studer S, Brodbeck U, Schärer P. Six-year clinical results of leucite-reinforced glass ceramic inlays and onlays. *Acta Med Dent Helv* 1998; 3:137-46.
15. Molin MK, Karlsson SL. A randomized 5-year evaluation of 3 ceramic inlay systems. *Int J Prosthodont* 2000; 13(3):194-200.
16. Fradeani M, Aquilano A, Bassein L. Longitudinal study of pressed glass-ceramic inlays for four and a half years. *J Prosthet Dent* 1997; 78(4):346-53.
17. Tidehag P, Gunne J. A 2-year clinical follow-up study of IPS Empress ceramic inlays. *Int J Prosthodont* 1995; 8(5):456-60.
18. Studer S, Lehner C, Scharer P. Seven year results of leucite-reinforced glass ceramic inlays and onlays. *J Dent Res* 1998; 77:803.
19. Sorensen JA, Choi C, Fanuscu MI, Mito WT. IPS Empress crown system: Three-year clinical trial results. *J Calif Dent Assoc* 1998; 26(2):130-6.

Table 1 Details of the 6 studies on IPS-Empress inlays and onlays reviewed

Reference	Type of study	Assessment criteria	No. of clinicians and examiners	No. of patients	Type of repair; no. of teeth				Cement	Follow-up (months)	No. (and %) failures	Causes of failure
					Inlay	Onlay	Premolar	Molar				
Frankenberger and others ¹²	Controlled clinical trial	Modified USPHS	6, 2	34	72	24	39	57	Dual Variolink Low Variolink Ultra Tetric	48-72	7 (7)	Fracture (5) Pulpitis (2)
Van Dijken and others ¹³	Controlled clinical trial	Modified USPHS	3, 2	29	79	0	53	26	Fuji Plus Panavia ²¹	24	0 (0)	
Lehner and others ¹⁴	Prospective clinical trial	Modified USPHS	18, 2	43	138	17	53	102	Panavia TC Porcelite Dicor LA VP891	60-84	2 onlays 5 inlays	Complete fracture (5) Partial fracture (2)
Molin and Karlsson ¹⁵	Randomized controlled clinical trial	CDA	1, 2	20	20	0	9	11	Dual	70	4 (20)	Fracture (4)
Fradeani and others ¹⁶	Case series	Modified USPHS	3, 3	29	107	18	50	75	Dual Variolink	7-56	4 (3)	Fracture (3) Tooth fracture (1)
Tidehag and Gunne ¹⁷	Controlled clinical trial	Modified CDA	2, NS	18	62	NS	40	22	Cem-Kit	26	1 (2)	Fracture (1)

USPHS = United States Public Health Service, CDA = California Dental Association, NS = not stated

Dual, Variolink Low, Variolink Ultra, Tetric, VP891, Cem-Kit (Ivoclar Vivadent, Schaan, Liechtenstein), Fuji Plus (GC Dental, Tokyo, Japan), Panavia21 and Panavia TC (Kuraray, Osaka, Japan), Porcelite (Sybron Kerr, Orange, CA), Dicor LA (Dentsply International, York, PA)

Table 2 Details of the 3 studies of IPS-Empress crowns reviewed

Reference	Type of study	Assessment criteria	No. of clinicians	No. of patients	No. of crowns	Position of tooth	Cement	Follow-up (months)	No. (and %) failures	Survival rate	Causes of failure
Sjögren and others ¹	Retrospective case series	CDA	5	29	75 crowns 35 onlays	43 anterior 25 premolar 42 molar	RC Cement	42	7 (6)	92% at 3.5 years	Fracture (1 incisor, 3 premolars, 3 molars)
Sorensen and others ¹⁹	Prospective clinical trial	Modified USPHS	NS	33	75	47 anterior 15 premolar 13 molar	Dual Variolink	14-42	1 (1)	99% at 3 years	Fracture (1 molar)
Fradeani and Aquilano ⁹	Case series	Authors' criteria	1	55	144	101 anterior 28 premolar 15 molar	Dual Variolink Zinc Phosphate	6-68	5 (3)	95% at 3 years	Core failure (2) Fracture (1 incisor, 2 molars)

USPHS = United States Public Health Service, CDA = California Dental Association, NS = not stated, RC = resin composite.
Dual, Variolink (Ivoclar Vivadent, Schaun, Liechtenstein)
Zinc Phosphate (DeTrey/Dentsply, Weybridge, UK)