A Short-Term Clinical Evaluation of IPS Empress 2 Crowns

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Purpose: The aim of this study was to evaluate the clinical performance of all-ceramic crowns made with the IPS Empress 2 system after an observation period of 12 to 60 months. ***Materials and Methods:*** Seventy-nine IPS Empress 2 crowns were placed in 21 patients. The all-ceramic crowns were evaluated clinically, radiographically, and using clinical photographs. The evaluations took place at baseline (2 days after cementation) and at 6-month intervals for 12 to 60 months. Survival rate of the crowns was determined using Kaplan-Meier statistical analysis. ***Results:*** Based on the US Public Health Service criteria, 95.24% of the crowns were rated satisfactory after a mean follow-up period of 58 months. Fracture was registered in only 1 crown. One endodontically treated tooth failed as a result of fracture at the cervical margin area. ***Conclusion:*** In this in vivo study, IPS Empress 2 crowns exhibited a satisfactory clinical performance during an observation period ranging from 12 to 60 months.
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All-ceramic crowns are increasingly demanded by patients and clinicians for the esthetic replication of the natural dentition.[1] All-ceramic crowns are characterized by enhanced esthetic properties, optimal integration with gingival tissues, and biocompatibility.[2] However, the mechanical and physical properties and manufacturing techniques of so-called conventional dental ceramics have revealed certain clinical shortcomings, ie, excessive brittleness, crack propagation, low tensile strength, fracture of the restorations, wear on antagonists, and sintering shrinkage.[3–5] These shortcomings, among other factors, have limited the indications for dental ceramics.

However, improvements in ceramic materials and adhesive luting systems have increased the clinical application of all-ceramic restorations. The IPS Empress 2 system (Ivoclar Vivadent) derives its strength from a heat-pressed lithium-disilicate glass-ceramic framework veneered with a fluoroapatite ceramic.[6] Compared to other all-ceramic systems, the relatively high translucency of the IPS Empress 2 system makes it a suitable material for restoring translucent natural teeth.[7] IPS Empress 2 is described by the manufacturer as having improved physical characteristics over previous generations of leucite glass-ceramic materials. Because of its high strength, this material may be used in the fabrication of single crowns or fixed partial dentures in the anterior and premolar region.[8] The flexural strength and fracture toughness of this system have demonstrated significant improvements over earlier materials.[2]

For more than 15 years, it has been reported that all-ceramic restorations should be inserted using adhesive techniques.[9–11] For silicate ceramics, hydrofluoric acid etching followed by the application of a silane agent is a common and clinically well-proven procedure.[12,13] The conditioned ceramic surface can interact micromechanically and chemically with the luting composite.[8] The adhesive cementation technique improves the fracture resistance of a ceramic material by penetrating the flaws and irregularities of the restoration's internal surface and inhibiting crack propagation.[14]

Certain intraoral conditions cannot be reproduced in the laboratory. These conditions include multiple in-

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Table 1 No. of IPS Empress 2 Crowns According to Evaluation Time

	No. of crowns								
	Maxilla				Mandible				
Evaluation time (mo)	Incisors	Canines	Premolars	Molars	Incisors	Canines	Premolars	Molars	Total
12	6	4	4	–	–	–	–	–	14
15	–	–	1	–	–	–	–	–	1
25	–	–	–	–	–	–	–	1	1
35	3	1	1	–	–	–	–	–	5
36	11	1	1	1	–	1	2	–	17
39	2	–	–	–	–	–	–	–	2
46	2	1	–	–	–	–	–	–	3
47	–	–	–	1	–	–	–	1	2
49	–	–	–	–	–	–	–	1	1
57	8	3	5	–	–	–	1	3	20
60	5	2	–	–	4	2	–	–	13

termittent cyclic forces during chewing, grinding, and clenching; constant exposure to a moist, bacteria-rich environment; ingestion of hot or cold liquids and acids; and heavy or inadequate toothbrushing. In addition, it has been 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.[15] Therefore, in vivo evaluation has been the basis for establishing criteria for acceptable crowns.[16] The aim of this study was to evaluate IPS Empress 2 crowns in function over a variable observation period.

Materials and Methods

Twenty-one patients (16 women and 5 men, ages 18 to 60, mean age 38.28 years) treated with 79 crowns were analyzed at the Department of Prosthetic Dentistry at Ege University in İzmir, Turkey. The patients gave informed consent prior to treatment.

Patients with severe parafunction, periodontitis, serious gingival inflammation, and poor oral hygiene or caries rates were excluded from the study. Teeth included in this study had adequate periodontal support for a single-unit restoration, exhibited minimal mobility, and showed adequate tooth preparation length to ensure proper retention and resistance form.

Sixty-three IPS Empress 2 crowns were placed in the maxilla, and 16 were placed in the mandible. The restored teeth included 41 incisors, 15 canines, 15 premolars, and 8 molars. The distribution of the crowns related to evaluation time is shown in Table 1. Except for 2 crowns placed on endodontically treated teeth, all crowns were placed on vital teeth. Of those 2 endodontically treated teeth, 1 was reconstructed with a glass fiber–reinforced composite post (FRC Postec, Ivoclar Vivadent) and direct resin composite core (Tetric Ceram, Ivoclar Vivadent) as a result of severe coronal destruction.[17,18] The other endodontically treated tooth was intact and did not require a post-and-core restoration.[17] For 55 crowns, the opposing dentition consisted of natural teeth, whereas 24 crowns were opposed by ceramic materials.

For each crown, the shade was determined prior to tooth preparation. For the preparations, a circumferential shoulder with rounded internal line angles at a depth of 1.0 to 1.3 mm was created with rotary diamond burs to ensure maximum resistance form. The occlusal reduction was 2 mm for posterior crowns and 1.5 mm for anterior crowns, and the palatal area of the anterior teeth was reduced by 0.8 mm. Finally, all sharp edges and angles were rounded. After tooth preparation, margins were finished with a fine diamond bur (856EF012, Komet). The smoothness of the finish line and ability to transfer the details to the stone die is essential for the precision and fit of the crown. In the maxillary anterior region, the palatal concavity was accurately determined to provide proper anatomic anterior disocclusion.

In the posterior region, the margins were located supragingivally or equigingivally to facilitate impression making and evaluation of the marginal adaptation. In the anterior region, the margins were located at the level of the gingival crest or slightly into the sulcus, depending on the esthetic demands.[19] Where needed, and especially in the anterior region (equigingivally or intrasulcularly positioned margins), gingival displacement was obtained using a retraction cord (no. 01 Ultrapack, Ultradent). Following removal of the retraction cord, full-arch vinyl polysiloxane impressions (Affinis, Coltene Whaledent) of the prepared teeth were made and immediately poured with a type V dental stone (Glastone Dental Stone, Dentsply). Full-arch irreversible hydrocolloid impressions (CA37, Cavex) were made of the opposing dentition and immediately poured with a type IV dental stone (Silky-Rock, Whip Mix). Interocclusal registrations and face-

Table 2 Criteria for Direct Evaluation of the Restorations

Category	Score	Criteria
Anatomic form	Alpha	Restoration is continuous with tooth anatomy
	Bravo	Slightly under- or overcontoured restoration; marginal ridges slightly undercontoured; contact slightly open (may be self-correcting); occlusal height reduced locally
	Charlie	Restoration is undercontoured; dentin or base exposed; contact is faulty (not self-correcting); occlusal height reduced; occlusion affected
Marginal adaptation	Alpha	Restoration is continuous with existing anatomic form; explorer does not catch
	Bravo	Explorer catches; no crevice is visible into which explorer will penetrate
	Charlie	Crevice at magrin; enamel exposed
Color match and surface texture	Alpha	Excellent color match; smooth surface
	Bravo	Good color match; slightly rough or pitted surface
	Charlie	Slight mismatch in color, shade, or translucency; rough surface; cannot be refinished
Caries	Alpha	No evidence of caries contiguous with the margin of the restoration
	Bravo	Caries is evident contiguous with the margin of the restoration
Postoperative sensitivity	Alpha	No sensitivity
	Bravo	Slight sensitivity

bow transfers (Quick Mount Facebow, Whip Mix) were obtained and the master casts were mounted on a semiadjustable articulator (Dentatus ARH-type, Dentatus). Provisional crowns (Dentalon Plus, Kulzer) were prepared to maintain gingival health and tooth position and then cemented with a eugenol-free temporary cement (Cavex Temporary Cement, Cavex). All crowns were fabricated by the same certified dental technician using the layering technique.[20] The habitual intercuspal position of the patients was maintained, and the occlusion was evaluated for protrusive and lateral movements.

The gingival margins surrounding the abutment teeth were healthy, with no signs of color change or bleeding at the cementation appointment. The operative field was isolated with cotton rolls and high-velocity evacuation during cementation. After the trial insertion, the internal surfaces of the IPS Empress 2 crowns were etched with 5% hydrofluoric acid (IPS Ceramic etching gel, Ivoclar Vivadent) for 60 seconds, then rinsed, dried, and silanated with Monobond S (Ivoclar Vivadent) for 60 seconds. Prepared tooth surfaces were conditioned with 37% phosphoric acid gel (Email Preparator GS, Ivoclar Vivadent) for 30 seconds. Syntac Primer (Ivoclar Vivadent) and Syntac Adhesive (Ivoclar Vivadent) were applied to the rinsed and air-dried dentin surfaces. Subsequently, a bonding agent (Heliobond, Ivoclar Vivadent) was brushed onto the dentin surfaces and internal surfaces of the all-ceramic crowns. The bonding agent was air thinned, and cementation was performed immediately. The crowns were luted with a low-viscosity dual-cure resin composite cement (Variolink 2, Ivoclar Vivadent). Initial light polymerization was performed for 10 seconds. Excess cement was removed with a dental probe and dental floss. The luting agent was polymerized from each margin using visible light with an irradiance of 480 mW/cm^2 (Optilux, Kerr) for 40 seconds. The occlusion and articulation of the crowns were controlled carefully using an 80-μm-thick articulating paper (Hanel, Coltene Whaledent) during the try-in procedure and after the crowns were luted.[21] All procedural steps, from preparation to luting, were performed by the same prosthodontist.

The United States Public Dental Health criteria were used to evaluate the quality of the all-ceramic crowns (Table 2).[22,23] Each crown was evaluated 2 days after cementation (baseline), and the patients were reexamined at intervals of 6 months. Clinical examinations included the use of a mirror and sharp explorer, radiographs, and photographs. The restorations were evaluated for a period of 12 to 60 months (mean, 58 months) after insertion. The clinical evaluations were performed by 2 clinicians. Agreement between the 2 clinicians was 95%, and disagreements were resolved through discussion.

Kaplan-Meier[24] statistics were used to analyze the survival rates obtained for the crowns luted on anterior or posterior teeth. Porcelain fracture and partial debonding that exposed the tooth structure and impaired esthetic quality or function were the main criteria for irreparable failure.[25]

Results

During the evaluation period, 1 restoration failed in the anterior region. The endodontically treated tooth without a post-and-core restoration fractured at the cervical margin 12 months after cementation. A fiber-reinforced composite post (FRC Postec) was placed and restored directly with a resin composite core (Tetric Ceram). A new all-ceramic crown was then placed. Because the restoration required replacement, the crown was rated as a failure. Thus, the total failure rate and failure rate in the anterior region were 4.76%. No crown failed in the posterior region.

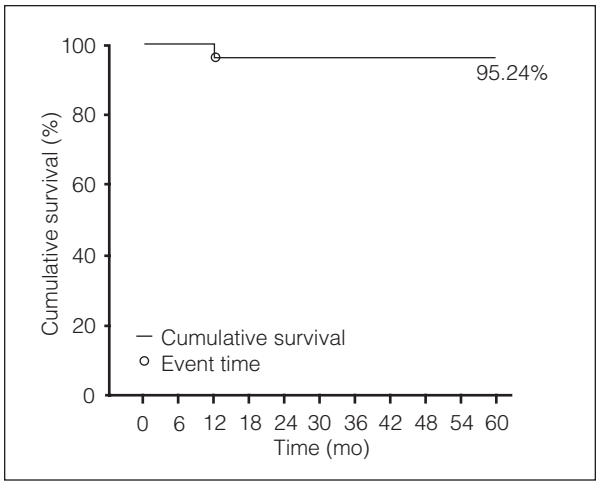

Table 3 Clinical Ratings (%) for 78 IPS Empress 2 Crowns

Criteria	Alpha	Bravo	Charlie
Anatomic form	76 (97.43)	2 (2.57)	-
Marginal adaptation	55 (70.51)	23 (29.49)	-
Color match and surface texture	68 (87.17)	10 (12.83)	-
Caries	78 (100)	-	-
Postoperative sensitivity	78 (100)	-	-

Fig 1 Survival probablities for the entire sample.

According to the Kaplan-Meier survival estimation method, the overall survival rate of the 79 IPS Empress 2 crowns was 95.24% (Fig 1). The estimated survival rates were 95.24% and 100% for crowns in the anterior region and posterior region, respectively.

Over the whole observation period, the remaining 78 investigated crowns exhibited no caries at the cervical margin. One tooth showed postoperative sensitivity. The other scores of the evaluated variables and their distributions are presented in Table 3. One crown was not analyzed because of fracture. Most of the 78 crowns were rated as excellent. The highest rating, Alpha, was awarded to 97.43% of crowns for anatomic form, 70.51% for marginal adaptation, 87.17% for color match and surface texture, 100% for caries, and 100% for postoperative sensitivity.

Seventy-six of the 77 vital teeth showed no postoperative sensitivity. One maxillary premolar had root canal treatment because pulpitis occurred 30 months after cementation. In this case, the root canal therapy was performed through the crown, and the hole was filled with resin composite. This crown is still functioning in the patient's mouth and thus was not considered as a failure. In 2 crowns placed on mandibular second molars, the layering ceramic chipped 3 months and 6 months after cementation. These crowns were smoothed, finished, and not considered as failures because the frameworks were not fractured, the prepared teeth surfaces were not exposed, and the crowns are still in function.

Discussion

This in vivo study evaluated the clinical performance of IPS Empress 2 crowns cemented with a water-based, 3-step, etch-and-rinse dentin bonding system (Syntac Classic) and a dual-cure luting composite cement (Variolink 2) for 5 years.

The IPS Empress 2 crowns demonstrated a survival rate of 95.24% over the observation period. This is compatible with the results of a recent in vivo study by Marquardt and Strub,[26] in which a total of 27 IPS Empress 2 crowns were rated satisfactory for the variable observation period. In an in vivo study by Taskonak and Sertgöz,[23] 20 adhesively luted IPS Empress 2 crowns exhibited a 100% success rate after 2 years. The same result was found in a study by Zimmer et al[27] after a mean observation period of 38 months. Gemalmaz and Ergin[28] reported that 37 adhesively luted IPS Empress crowns exhibited a 94.6% survival rate after 24.56 months.

The endodontically treated tooth without a post-and-core restoration fractured 12 months after crown cementation. Preparing the shoulder at the cervical area of a tooth may reduce the fracture resistance of endodontically treated teeth with a narrow cervical width, such as a maxillary lateral incisor.

All-ceramic crowns are generally used in the maxillary anterior region because of their esthetic and natural appearance. In this region, the finish line of the tooth preparation at the cervical area should be approximately 0.5 mm below the free gingival crest for a good esthetic result. Therefore, durable dentin bonding of luting composites, mediated by dentin bonding agents, is important in such clinical conditions.

Microleakage is an important factor for the clinical longevity of fixed restorations.[29] In an in vitro study, it was concluded that hybrid layer formation plays an important role in the bonding process by improving the sealing ability of the adhesive material and preventing microleakage.[30] In this study, only 1 tooth exhibited postoperative sensitivity 30 months after cementation.

The Syntac Classic dentin bonding system is a water-based, 3-step system. After the dentin surface was conditioned with 37% phosphoric acid, the surface was completely air dried. In most cases, the place-

ment of rubber dam for the cementation procedure is not possible with crowns that have subgingival finish lines. In this clinical situation, a wet-bonding technique may be advantageous because of the humidity of the gingival sulcus. In a wet-bonding system, after the application and rinsing of the dentin conditioning, the surface is left moist.[31] In a 3-year clinical study on the various dentin bonding systems, it was reported that there was no significant difference between 1- and 2-bottle dentin bonding systems, or among water-based, ethanol-based, and solvent-free adhesives during the evaluation period.[32]

Another interface related to the cementation procedure is the resin cement–ceramic interface. IPS Empress 2 is a silica-based ceramic with a high crystalline content (60% by volume).[6] A strong resin bond relies on micromechanical and chemical bonding to the ceramic surface, which requires roughening and cleaning for adequate surface activation.[33] In vitro studies indicate that acid etching with hydrofluoric acid to roughen the ceramic surface, along with application of a silane coupling agent, provided the most durable bonding between silica-based ceramic and luting composite cement.[34,35] The clinical success of a resin-cemented ceramic restoration depends on the quality and durability of the bond between the ceramic and the tooth.

Conclusion

Within the limitations of this study's design, a 4.76% failure rate was recorded for the 79 IPS Empress 2 crowns, and a satisfactory clinical performance was observed.

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