

# Fracture Rates of IPS Empress All-Ceramic Crowns—A Systematic Review

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**Purpose:** The aim of this study was to evaluate the clinical fracture rate of crowns fabricated with the pressable, leucite-reinforced ceramic IPS Empress, and relate the results to the type of tooth restored. **Materials and Methods:** The database SCOPUS was searched for clinical studies involving full-coverage crowns made of IPS Empress. To assess the fracture rate of the crowns in relation to the type of restored tooth and study, Poisson regression analysis was used. **Results:** Seven clinical studies were identified involving 1,487 adhesively luted crowns (mean observation time:  $4.5 \pm 1.7$  years) and 81 crowns cemented with zinc-phosphate cement (mean observation time:  $1.6 \pm 0.8$  years). Fifty-seven of the adhesively luted crowns fractured (3.8%). The majority of fractures (62%) occurred between the third and sixth year after placement. There was no significant influence regarding the test center on fracture rate, but the restored tooth type played a significant role. The hazard rate (per year) for crowns was estimated to be 5 in every 1,000 crowns for incisors, 7 in every 1,000 crowns for premolars, 12 in every 1,000 crowns for canines, and 16 in every 1,000 crowns for molars. One molar crown in the zinc-phosphate group fractured after 1.2 years. **Conclusion:** Adhesively luted IPS Empress crowns showed a low fracture rate for incisors and premolars and a somewhat higher rate for molars and canines. The sample size of the conventionally luted crowns was too small and the observation period too short to draw meaningful conclusions. *Int J Prosthodont* 2010;23:129–133.

There is a growing tendency towards replacing metal-based restorations with all-ceramic ones in prosthetic dentistry. Single crowns made of different materials (lithium disilicate, leucite, aluminum oxide) have been successfully placed for 10 to 20 years. They have been shown to achieve good clinical survival rates and have thus become the standard of care.<sup>1,2</sup>

A review article on the frequency of clinical complications in fixed prosthodontics reported a mean fracture incidence for all-ceramic crowns of 7% within 4 years (range: 0% to 16%) and 13% for 5 or more years (range: 5% to 14%).<sup>3</sup> Crown fracture was the most prevalent complication in all-ceramic crowns, followed

by retention loss and pulpitis. According to this review, the fracture rate was significantly higher for molar crowns than for premolar crowns (21% versus 7%), and for premolar crowns compared to anterior crowns (7% versus 3%). However, the review did not differentiate between the all-ceramic materials used. For instance, crowns composed of the glass-ceramic material Dicor (Dentsply, no longer available) showed a much higher fracture rate than crowns made of In-Ceram (VITA).<sup>4</sup>

The gold standard in fixed prosthodontics are metal-ceramic restorations, also known as porcelain-fused-to-metal (PFM) restorations. All new materials that are to be used as an alternative have to be as reliable as metal-ceramic, particularly with regard to fracture rate and marginal fit. The fracture rate of PFM restorations is low. A systematic review that selected 12 prospective clinical studies with 1,317 fixed partial dentures (FPDs) made of PFM revealed that the risk of core fracture was 1% over a period of 10 years.<sup>5</sup> When also including the incidence of chipping of the ceramic veneer, the estimated 10-year risk of material fracture was 3.2% (95% confidence interval: 1.5 to 6.5).

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**Table 1** Overview of Included Studies in the Systematic Review

Study/ tooth type	n	No. of fractures	Mean (median) follow-up (y)
1. Fradeani and Redemagni <sup>8</sup>			
I	80	1	7.5 (7.0)
C	16	0	6.6 (7.0)
P	22	0	6.6 (7.0)
M	8	3	6.4 (7.0)
2. Gemalmaz and Ergin <sup>9</sup>			
I	21	0	2.1 (2.2)
C	0	0	NA
P	10	0	1.9 (1.9)
M	6	1	2.0 (2.0)
3. Studer et al <sup>10</sup>			
I	53	4	5.5 (6.0)
C	14	4	4.5 (5.0)
P	36	2	5.6 (6.0)
M	39	4	5.6 (6.0)
4. Edelhoff et al <sup>7</sup>			
I	85	3	2.0 (2.0)
C	17	0	2.3 (2.4)
P	77	1	2.1 (2.2)
M	81	2	1.9 (1.8)
5. Malament et al <sup>4</sup>			
I	310	6	4.9 (5.0)
C	75	3	5.0 (5.0)
P	249	9	4.9 (5.0)
M	168	10	5.3 (5.0)
6. Sorensen et al <sup>11</sup>			
I	48	0	3.0 (3.0)
C	0	0	NA
P	15	0	3.0 (3.0)
M	13	1	2.9 (3.0)
7. Sjögren et al <sup>12</sup>			
I	0	0	NA
C	0	0	NA
P	0	0	NA
M	44	3	3.9 (4.0)

I = incisor; C = canine; P = premolar; M = molar; NA = not applicable.

The pressable, leucite-reinforced ceramic IPS Empress (Ivoclar Vivadent) is an all-ceramic material with one of the longest clinical track records. It has been on the market for more than 15 years; in 2004, its name was changed to IPS Empress Esthetic. The results of a literature review on the clinical performance of IPS Empress crowns were published in 2002; these results were based on a MEDLINE search performed in 2000.<sup>6</sup> Only three clinical studies with a mean observation period of 3 to 4 years were included in the review. In summary, the review concluded that the survival rate of IPS Empress crowns ranged from 92% to 99% after 3 to 3.5 years, with crown fracture being the most prevalent reason for failure. The authors concluded that the use of IPS Empress crowns in the posterior region was not recommended until the results of more long-term clinical trials were available.

Seven years have passed since the acquisition of data for the latest review on IPS Empress crowns. Therefore, it seemed appropriate to search the newest literature available for longitudinal trials on IPS Empress

crowns and to evaluate whether the aforementioned recommendation of not using the material for posterior crowns is still valid. Hence, the purpose of this study was to assess the fracture frequency of crowns made of IPS Empress in relation to tooth type.

## Materials and Methods

### Search for Studies

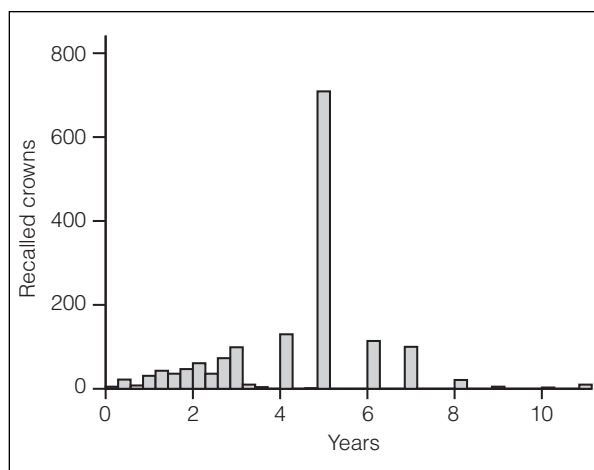
SCOPUS scientific abstract and citation database (Elsevier) was searched for clinical studies involving full-coverage IPS Empress crowns. The search words used were "Empress," "clinical," and "crown." The search was conducted in March 2009. For one study, the principal investigator provided the raw data as an SPSS data file; the original study did not report on all crowns inserted and did not distinguish between premolar and molar restorations.<sup>7</sup> Additional information on the observation period and fracture rates was provided by another investigator.

### Evaluation of Studies

The main outcome variable was fracture of the crown. Failures that were not related to crown fractures but to other reasons, such as endodontic treatment, fractured posts, or recurrent caries, were not taken into consideration.

### Statistical Analysis

Since individual data were not available for most studies, the authors had to analyze the grouped data summarized in Table 1. The table contains the number of adhesively luted crowns, as well as the number of fractures observed for incisors, canines, premolars, and molars in each of the selected clinical studies. Also included are the mean and median follow-up times. The goal was to model the number of fractures in function of the factor "tooth type." Since the number of fractures is a count variable, Poisson regression (with the usual logarithm link function) was used. The study by Sjögren et al<sup>12</sup> included only molars, and because no canines were followed up in the studies by Gemalmaz and Ergin<sup>9</sup> and Sorensen et al,<sup>11</sup> the authors were left with 23 counts to model. To account for the different sample sizes and follow-up times, an offset was included in the model as  $\log(\text{exposure})$ , where exposure was defined as the product of the number of crowns followed up  $\times$  the average follow-up time. To account for the fact that counts within a study might be correlated with one another, "study" was also included in the model as its own factor. Hence, the model was defined as follows:



**Table 2** Number of IPS Empress Crowns and Crown Fractures in Relation to Tooth Type

Tooth type	Adhesively luted		Zinc phosphate	
	n	No. of fractures (%)	n	No. of fractures (%)
Incisor	597	14 (2.3%)	28	0
Canine	122	7 (5.7%)	6	0
Premolar	409	12 (2.9%)	16	0
Molar	359	24 (6.7%)	31	1 (3.2%)
Total	1,487	57 (3.8%)	81	1 (1.2%)

**Fig 1 (left)** Number of recalled IPS Empress crowns in relation to the observation period.

$\text{Log}(\text{number of fractures/exposure}) = \text{intercept} + \text{canine} + \text{premolar} + \text{molar} + \text{study 2} + \text{study 3} + \text{study 4} + \text{study 5} + \text{study 6} + \text{study 7}$

Wald tests were used to test whether the tooth type or the study had a significant influence on fracture. The antilog of the intercept is an estimate of the hazard in the reference group (incisors in study 1), which can be roughly interpreted as the probability to observe a fracture within 1 year for a crown in this group. Antilogs of the other coefficients are estimates of hazard ratios. Statistical analysis was performed using SPSS 15.0 for Windows (SPSS).

## Results

Ten clinical studies were found to have investigated IPS Empress crowns. One study<sup>13</sup> was excluded since the crowns ( $n = 8$ ) had been inserted in children aged 6 to 8 years who had developmental defects on their first molars. Another study examined the remake of Empress restorations (crowns, veneers, inlays) as a result of color mismatch, misfit, and fractures before and after cementation in relation to the restored tooth type.<sup>14</sup> Since the data were not based on a clinical trial but on protocols of a dental laboratory, the study was excluded. Another study was excluded because it was published only in Chinese.<sup>15</sup> According to the abstract, only anterior crowns were inserted and followed up for 2 years. Of the remaining seven studies, six were prospective trials and one study was a retrospective study involving restorations placed by general practitioners in a private practice.<sup>12</sup> In all studies, IPS Empress crowns were adhesively luted using an adhesive system in combination with an acrylic resin cement. In two of these studies, crowns were also luted with zinc-phosphate cement (81 crowns in one study<sup>7</sup> and 14

crowns in another<sup>10</sup>). While the first study reported the recall results concerning the crowns luted with zinc-phosphate cement, the second study did not.

A total of 1,487 adhesively luted crowns and 81 conventionally luted crowns were evaluated. The mean observation period for the adhesively luted crowns was  $4.5 \pm 1.7$  years, and that for the conventionally luted crowns was  $1.6 \pm 0.8$  years. The observation period ranged from 2 months to 11 years, with the majority of crowns being recalled between 3 and 7 years (Fig 1). The number of dropouts was reported in only two studies.

The majority of crowns were placed in incisors (40.1%), followed by premolars (27.5%), molars (24.1%), and canines (8.2%) (Table 2). Fifty-seven fractures occurred with adhesively luted crowns. The majority of fractures (62%) occurred between the third and sixth year after placement. One molar crown of the zinc-phosphate group fractured after 1.2 years.

In the Poisson regression model, the type of crown was significant ( $P = .02$ ) while the study was not ( $P = .20$ ). The significance of the former was still more pronounced in a model without the latter ( $P = .004$ ), meaning that the rates of fractures differed significantly across the different tooth types. In this simpler model, the intercept (referring to incisors) was equal to  $-5.2870$ , while the coefficients for canines, premolars, and molars were equal to 0.8653, 0.2805, and 1.1287, respectively. Thus, the hazard rate for incisors was estimated to be  $\exp(-5.2870) = 0.005$ , meaning that on average, 5 out of every 1,000 incisor crowns will fracture each year. For canines, premolars, and molars, this hazard rate will be inflated by a factor of  $\exp(0.8653) = 2.38$ ,  $\exp(0.2805) = 1.32$ , and  $\exp(1.1287) = 3.09$ , respectively. This means that, on average, one can expect 5 incisor crown fractures, 12 canine crown fractures, 7 premolar crown fractures, and 16 molar crown fractures per 1,000 crowns per year.

## Discussion

The quality of the selected clinical studies is low. None of the studies fulfilled the requirements of a randomized controlled clinical trial.<sup>16,17</sup> There was no randomization of subjects, no control material (such as metal-ceramic), and no estimate of the number of subjects necessary to come to meaningful conclusions. The number of subjects involved varied across the studies, as did the number of different tooth types restored with crowns. In some studies the subjects received more than one crown but detailed information was not given. In most studies, the detailed number of drop-outs in relation to tooth type was not reported.

The Poisson model used for the number of fractures is equivalent to an exponential model for the failure times, which is itself characterized by a constant hazard rate over time. Thus, the authors had to assume that the probability to observe a fracture remains constant over time for each study and for each type of tooth. This is of course a strong assumption that may appear unrealistic but allows the use of grouped data without knowing the exact dropout rates. All that was necessary was the number of fractures and the total (or average) follow-up time in each group, which could be found in the literature.

There were differences between studies with regard to the overall fracture rate, but these differences were because of the different number of restorations placed in different tooth types. To calculate the fracture rate, the studies were pooled.

The overall fracture rate of the IPS Empress crowns was 3.8%, with molars showing the highest fracture rate (6.7%). The observation period for most crowns was 5 to 6 years. The difference in the fracture rate of incisor and molar crowns was statistically significant. Canine crowns also showed an increased fracture rate (5.7%). The higher fracture rate in molars can be explained by the higher masticatory forces that are exerted in the posterior region. A clinical study involving all-ceramic, three-unit FPDs that assessed occlusal forces revealed that the fracture of the FPDs was related to high occlusal forces and a ceramic layer of insufficient thickness.<sup>18</sup> The higher fracture rate of canine crowns can be explained by the fact that most patients have canine guidance during articulation, which puts extraordinary stress on the material. In a clinical study where canine guidance was established with IPS Empress orofacial veneers, 4 of 36 veneers fractured over a period of 6 years, which corresponds to a fracture rate of 11%.<sup>19</sup>

When compared to studies involving other materials, the results are similar. In a systematic literature review on VITA In-Ceram crowns, the 5-year survival rate was in the range of 92% to 100%.<sup>20</sup> However, the review did

not differentiate between the different reasons for failure. According to one review, most failures are related to the fracture of the core or chipping of the veneer material.<sup>3</sup> It may be assumed that the failures reported in this review are related mostly to fractures. Only a few studies in this review reported on the differences in the survival rate in relation to restored tooth type. With Procera crowns (core and veneer), the fracture rate was between 1% and 4% after a period of 3 to 5 years<sup>21-23</sup>; the fractures occurred mostly in molars.

There are other systems currently on the market that use the same material concept (leucite-reinforced ceramics) in conjunction with press technology. Such systems include Authentic (Ceramay), Cerpress SL (Dentagold), Cerapress (Girrbach Dental), Cergogold (Degussa), Finesse All Ceramic (Dentsply), Imagine Press (Wieland), Optec OPC (Pentron Ceramic), and VitaPress (VITA). However, no clinical studies have been found in the literature that evaluate these materials for the full-coverage crown.

The flexural strength of IPS Empress is approximately 160 MPa.<sup>24</sup> The manufacturer recommends that an adhesive luting protocol be used for all types of IPS Empress restorations. Laboratory data indicate that an adhesive luting procedure supports the brittle ceramic material and enhances the fracture strength of leucite-reinforced restorations.<sup>25</sup> In all studies, the crowns were adhesively luted using different resin-based luting cements. In two studies, some crowns were also conventionally cemented with zinc-phosphate cement<sup>7,10</sup>; however, only one study reported on the outcome.<sup>7</sup> In this study, there was only one fracture of a molar crown. According to the principal investigator (Edelhoff D, personal communication, 2008), a significant number of dislodged crowns were observed during later recall periods. The fracture rate, however, did not increase significantly thereafter. However, since the number of restorations was very low and the observation period very short, it cannot be concluded that conventionally cemented IPS Empress crowns perform equally as well as adhesively luted crowns. A longer observation period and a larger sample size is required to draw this conclusion.

Since the launch of IPS Empress, several high-strength materials have been developed. In 1998, the lithium-disilicate ceramic IPS Empress 2 was introduced to the market. This material demonstrated a tensile strength of 340 MPa<sup>26</sup> and needed to be veneered. In 2006, it was replaced by the translucent lithium disilicate material IPS e.max Press, which allows full-contour restorations to be fabricated. Prospective clinical trials revealed that crowns fabricated with these materials and luted with glass-ionomer cement showed a low fracture rate between 0% and 3% after 5 years.<sup>27-31</sup>

## Conclusions

Adhesively luted IPS Empress crowns showed a low fracture rate on incisors and premolars and a somewhat higher fracture rate on molars and canines. The sample size of the conventionally luted crowns was too small and the observation period too short to draw meaningful conclusions. Since the fracture rate of IPS Empress crowns was significantly higher for molar than for incisor crowns, special caution should be exercised when using the material for these teeth. A ceramic layer of sufficient thickness needs to be ensured and the material should not be used in patients with confirmed or suspected bruxism.

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## Disclosure

Dr Heintze is the head of the department of preclinical research at Ivoclar Vivadent, the manufacturer of IPS Empress.

## References

- Blatz MB. Long-term clinical success of all-ceramic posterior restorations. *Quintessence Int* 2002;33:415–426.
- Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. *Oper Dent* 2004;29:481–508.
- Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications in fixed prosthodontics. *J Prosthet Dent* 2003;90:31–41.
- Malament KA, Socransky SS, Thompson V, Rekow D. Survival of glass-ceramic materials and involved clinical risk: Variables affecting long-term survival. *Pract Proced Aesthet Dent* 2003; suppl:5–11.
- Tan K, Pjetursson BE, Lang NP, Chan ESI. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clin Oral Implants Res* 2004;15:654–666.
- El-Mowafy O, Brochu JF. Longevity and clinical performance of IPS-Empress ceramic restorations—A literature review. *J Can Dent Assoc* 2002;68:233–237.
- Edelhoff D, Horstkemper T, Richter E-J, Spiekermann H, Yildirim M. Adhäsiv und konventionell befestigte Empress-1-Kronen—Klinische Befunde nach vierjähriger Tragedauer. *Dtsch Zahnärztl Z* 2000;55:326–330.
- Fradeani M, Redemagni M. An 11-year clinical evaluation of leucite-reinforced glass-ceramic crowns: A retrospective study. *Quintessence Int* 2002;33:503–510.
- Gemalmaz D, Ergin S. Clinical evaluation of all-ceramic crowns. *J Prosthet Dent* 2002;87:189–196.
- Studer S, Lehner C, Brodbeck U, Schäfer P. Six-year results of leucite-reinforced glass ceramic crowns. *Acta Med Dent Helv* 1998;3:218–225.
- Sorensen JA, Choi C, Fanuscu M, Mito WT. IPS Empress crown system: Three-year clinical trial results. *J Calif Dent Assoc* 1998;26:130–136.
- Sjögren G, Lantto R, Granberg A, Sundström BO, Tillberg A. Clinical examination of leucite-reinforced glass-ceramic crowns (Empress) in general practice: A retrospective study. *Int J Prosthodont* 1999;12:122–128.
- Koch MJ, García-Godoy F. The clinical performance of laboratory-fabricated crowns placed on first permanent molars with developmental defects. *J Am Dent Assoc* 2000;131:1285–1290.
- Hekland H, Riise T, Berg E. Remakes of Colorlogic and IPS Empress ceramic restorations in general practice. *Int J Prosthodont* 2003;16:621–625.
- Liu Y, Li Y, Nie Y. Two years clinical observation of a kind of castable ceramic—IPS Empress [in Chinese]. *Zhonghua Kou Qiang Yi Xue Za Zhi* 1999;34:123–125.
- Moher D, Schulz KF, Altman D. The CONSORT statement: Revised recommendations for improving the quality of reports of parallel-group randomized trials. *JAMA* 2001;285:1987–1991.
- Hickel R, Roulet JF, Bayne S, et al. Recommendations for conducting controlled clinical studies of dental restorative materials. Science Committee Project 2/98—FDI World Dental Federation. Study design (Part I) and criteria for evaluation (Part II) of direct and indirect restorations including onlays and partial crowns. *J Adhes Dent* 2007;9(suppl 1):121–147 [erratum 2007;9:546].
- Esquivel-Upshaw JF, Young H, Jones J, Yang M, Anusavice KJ. Four-year clinical performance of a lithia disilicate-based core ceramic for posterior fixed partial dentures. *Int J Prosthodont* 2008;21:155–160.
- Sieweke M, Salomon-Sieweke U, Zöfel P, Stachniss V. Longevity of orofacial ceramic veneers on canines—A retrospective study. *J Adhes Dent* 2000;2:229–234.
- Wassermann A, Kaiser M, Strub JR. Clinical long-term results of VITA In-Ceram Classic crowns and fixed partial dentures: A systematic literature review. *Int J Prosthodont* 2006;19:355–363.
- Fradeani M, D'Amelio M, Redemagni M, Corrado M. Five-year follow-up with Procera all-ceramic crowns. *Quintessence Int* 2005;36:105–113.
- 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.
- Odén A, Andersson M, Krystek-Ondracek I, Magnusson D. Five-year clinical evaluation of Procera AllCeram crowns. *J Prosthet Dent* 1998;80:450–456.
- Seghi RR, Sorensen JA. Relative flexural strength of six new ceramic materials. *Int J Prosthodont* 1995;8:239–246.
- Krämer N, Lohbauer U, Frankenberger R. Adhesive luting of indirect restorations. *Am J Dent* 2000;13(spec no.):60D–76D.
- Albakry M, Guazzato M, Swain MV. Biaxial flexural strength and microstructure changes of two recycled pressable glass ceramics. *J Prosthodont* 2004;13:141–149.
- Böning K, Ullmann U, Wolf A, Lazarek K, Walter M. Dreijährige klinische Bewährung konventionell zementierter Einzelkronen aus Lithiumdisilikat-Keramik. *Deutsche Zahnärztl Z* 2006;61:604–611.
- Toksavul S, Toman M. A short-term clinical evaluation of IPS Empress 2 crowns. *Int J Prosthodont* 2007;20:168–172.
- Marquardt P, Strub JR. Survival rates of IPS Empress 2 all-ceramic crowns and fixed partial dentures: Results of a 5-year prospective clinical study. *Quintessence Int* 2006;37:253–259.
- Taskanak B, Sertgöz A. Two-year clinical evaluation of lithia-disilicate-based all-ceramic crowns and fixed partial dentures. *Dent Mater* 2006;22:1008–1013.
- Mansour YF, Al-Omiri MK, Khader YS, Al-Wahadni A. Clinical performance of IPS-Empress 2 ceramic crowns inserted by general dental practitioners. *J Contemp Dent Pract* 2008;9:9–16.

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