

## Survival of In-Ceram crowns in a private practice: A prospective clinical trial

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**Statement of problem.** Prior reports on some all-ceramic crown systems have indicated high failure rates through fracture.

**Purpose.** This study prospectively evaluated the survival of infiltrated alumina crowns (In-Ceram) in a private practice.

**Material and methods.** All the In-Ceram crowns placed in a prosthodontic practice since its introduction in 1990 were serially included. Patients were recalled at 6 monthly intervals. Those who did not attend in the previous 6 months were contacted by telephone and a series of answers to standardized questions recorded. The few patients who were lost to follow-up or who died were removed from the study from the time of last contact.

**Results.** A total of 408 crowns in 107 patients were followed for periods from 1 to 86 months. As the 3-year data combined a meaningful period of service with a large sample size, these data were focused on. The 3-year survival rate was 96% for a sample size of 223. Three-year data indicated that core fracture and porcelain fracture occurred at rates of approximately 0.6% and 0.3% per year, respectively. Otherwise sound restorations were removed at a rate of approximately 0.3% per year for esthetic, endodontic, or prosthetic reasons. Anterior crowns tended to have a slightly higher 3-year survival rate (98%) than premolars or molars (94%).

**Conclusion.** Clinical failure rate of In-Ceram crowns was low. Crowns were lost because of core fracture, porcelain fracture, and removal without failure. Failure tended to be more common for molar and premolar crowns than for anterior crowns. (J Prosthet Dent 2000;83:216-22.)

### CLINICAL IMPLICATIONS

*Infiltrated alumina In-Ceram crowns had a high survival rate in a private practice. Because the failure rate was low, clinical studies require large sample sizes for meaningful comparisons. Anterior crowns tended to fracture slightly less than posterior crowns. The results of this study suggest that In-Ceram crowns are only at slight risk to core fracture.*

All-ceramic crowns have steadily become more popular with patients and dentists because they are commonly thought to be more esthetic and more biocompatible than metal-ceramic crowns.<sup>1</sup> Over the last 25 years, many new types of all-ceramic crown have been introduced. Early all-ceramic systems had high failure rates by fracture, especially when used for posterior crowns.<sup>2-9</sup> Thus, their survival rate was substantially lower than for metal-ceramic crowns.<sup>3,10,11</sup> As failure rates by fracture were often high, development of new all-ceramic systems has been driven by the need for greater strength.<sup>12,13</sup> Because most clinical fractures of all-ceramic crowns are thought to originate from the internal intaglio surfaces and because the appearance of

the core is less critical,<sup>14-16</sup> more attention has been focused on improving core materials than on improving veneering porcelains. Recently, several high-strength all-ceramic systems have been introduced that are recommended by their manufacturers for use on posterior teeth. One of these is In-Ceram, an infiltrated alumina core material that is veneered with a feldspathic porcelain. Unlike most high-strength industrial ceramics, it can be processed in a regular dental laboratory. Although In-Ceram has been extensively investigated in vitro,<sup>17-24</sup> limited clinical performance data has been published.<sup>25-29</sup>

Three previous studies reported In-Ceram crown survival rates of 98.4% to 100%, with maximum follow-up periods of 24 to 56 months.<sup>25,27,29</sup> However, those studies had small sample sizes ( $n = 61$  to  $63$ ), which were insufficient to monitor fracture, and most of the crowns included were followed for relatively short periods. Another anecdotal study reported only 2 losses among 352 In-Ceram crowns placed over a 5-year period, but the methods and follow-up rate were not

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reported.<sup>28</sup> In contrast, a study of 35 In-Ceram crowns studied for 2.5 to 21 months reported that 3 crowns fractured after 4, 8, and 12 months.<sup>26</sup> Survival rates at fixed intervals were not reported, but the failure rate was probably an order of magnitude greater than found in the other reports. Most anecdotal reports on In-Ceram success indicate low failure rates, but few studies have included careful data analysis, long follow-up periods, or large sample sizes. Life tables or survival curves have not yet been published, and data have mostly been confined to university clinics, not private practices.

The purpose of this study was to evaluate the survival of infiltrated alumina crowns (In-Ceram) in a private practice with a larger sample size and longer follow-up times.

## MATERIAL AND METHODS

All In-Ceram crowns serially placed in a private prosthodontic practice since the crowns' introduction to the United States (1990 to 1997) were included. This study was prospectively designed. An office staff member was chosen to maintain patient lists and data sheets.

In-Ceram crowns were used for patients who requested metal-free crown restorations or who requested the most esthetic crown available. Only teeth considered to have adequate remaining tooth structure for the achievement of conventional resistance and retention form,<sup>30</sup> uninfamed periodontal tissues, and good long-term endodontic prognoses were treated. Informed consent, including other crown options, was obtained from each patient.

Data sheets were maintained for every patient with In-Ceram crowns. Details recorded included the patient's code number and gender; tooth number(s); dates of cementation, each office visit, and telephone survey, loss of serviceability or removal or replacement; and the reason for loss of serviceability. Predictive variables recorded included: type of cement, placement and type of build-up material, presence of prior endodontic treatment, placement and type of post, and preoperative presence of signs of undue wear or bruxing. Reasons for failure and any other complications or findings were also noted on the data sheets. Serviceable crowns were defined as those crowns that were present without core fracture, porcelain fracture, caries, signs of periodontal inflammation (specifically bleeding on probing or brushing), or endodontic signs and symptoms. Thus, crowns with the above defects were considered to be unserviceable failures, even if the defect could be corrected without crown replacement.

All patients were treated by a single prosthodontist. Clinical procedures were performed according to Sadoun.<sup>31</sup> Finish line designs included shoulders with rounded internal line angles and moderate or deep

chamfers. Marginal reduction depths of 0.6 to 1.2 mm were used. Axial reductions of approximately 1.2 mm were achieved. Incisal or occlusal reductions of 1.5 to 2.0 mm were used. Depth grooves were used to aid in the achievement of optimal reduction depth. External line angles were rounded. Efforts were made to obtain even reduction. If buildups were needed, they were placed shortly before tooth preparation. Amalgam (Dispersalloy, Dentsply, York, Pa.) was used for posterior teeth, and composite (F2000, 3M, St Paul, Minn.) was used for anterior teeth. Small defects in the crown preparations were restored with a resin-modified glass ionomer (Fuji II LC, GC Corp, Tokyo, Japan).

For the first 3 years, all the laboratory procedures were performed by the treating dentist according to manufacturer guidelines.<sup>32-34</sup> For the later years, most of the copings were fabricated by a single certified dental technician. Core thicknesses of at least 0.5 mm were used. Where interocclusal space allowed, 0.7-mm core thicknesses were used for molar teeth. Core thickness was checked with spring calipers before veneering with porcelain.

Before cementation, the internal aspects of the crowns were subjected to airborne particle abrasion with 50  $\mu$ m alumina. Several different cements were used and included composite (Panavia, Kuraray, Osaka, Japan), resin-modified glass ionomer (Infinity, Den-Mat, Santa Maria, Calif.), conventional glass ionomer (Ketac Cem, ESPE, Seefeld Oberbay, Germany), polycarboxylate (Durelon, ESPE), and zinc phosphate (Flecks, Keystone/Mizzy, Cherry Hill, N.J.). The composite cement was routinely used, but other cements were used in specific clinical circumstances. The resin-modified glass ionomer was used when maximal translucency was needed, whereas zinc phosphate was used when opacity was desired. The glass ionomer was used when fluoride release was desired. The polycarboxylate cement was used when retrievability was a priority.

After completion of treatment, patients were recalled at 6 monthly intervals or returned to the office of the referring general dentist for maintenance. Approximately 33% of the patients were sent back to the referring general dentist for maintenance. Those who did not attend the prosthodontic office in the previous 6 months to termination of the trial were contacted by telephone and answers to a series of 11 standardized questions recorded (Table I). These standardized questions were designed to determine whether the In-Ceram crowns were present and serviceable. In addition, the general dentists currently treating the telephone-surveyed patients were also telephone surveyed to determine whether any new undocumented In-Ceram failures had occurred and to verify their patients' accounts.

At the conclusion of data collection in 1997, all data sheets were compared with the patients' clinical charts

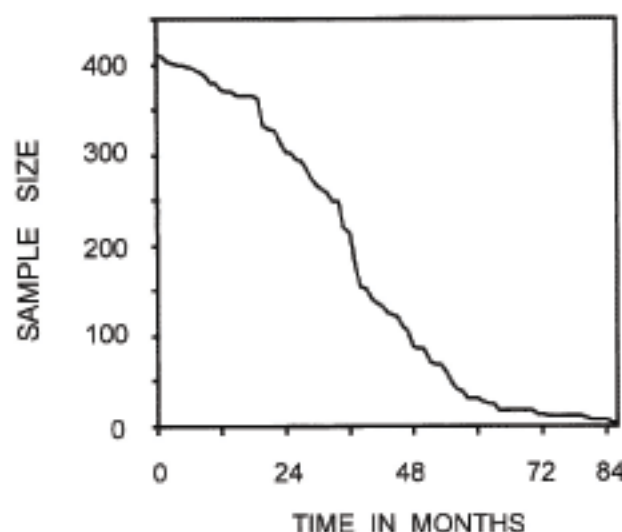


Fig. 1. Sample sizes of In-Ceram crowns. After 36 months, sample sizes dropped dramatically. Data for crowns followed for 36 months are displayed in Figures 3 and 4.

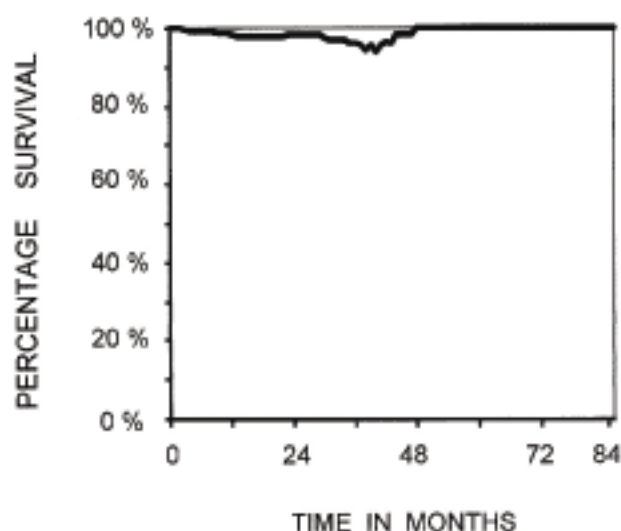


Fig. 2. Survival rates of In-Ceram crowns. Survival rate decreased over first 36 months, but after this point smaller sample sizes rendered survival rates meaningless.

and laboratory records for veracity of the above details. This was performed by university faculty who were not otherwise involved in the study. Patients who were lost to follow-up or who died were removed from the study at the time of last contact. Sample sizes and survival rates were calculated by month for the 86-month duration of the study. On the basis of sample size and survival rate data, life tables were made. In the event that sample size permitted, comparisons among predictor variables were to be made by the log rank test ( $P < .05$ ).

**Table I.** Questions asked in telephone survey for patients who had not attended the office in the last 6 months. After an initial introduction, patients were asked the following questions and the answers recorded on the data sheets. The survey was terminated by asking the patients whether they would like to make an appointment for a check-up or hygiene visit

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Is everything going well?
Have you had any problems since your last visit?
Do you like your In-Ceram crowns?
Have they given you any trouble?
Have you had any problems with cracking or breaking?
Do you still have all of your In-Ceram crowns?
Are your In-Ceram crowns comfortable?
Do you have any sensitivity, discomfort or pain from your crowns?
Do you have any staining or decay around your In-Ceram crowns?
Do your gums bleed on brushing?
When you floss or brush around your crowns do your gums bleed?

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## RESULTS

A total of 408 crowns in 107 patients were studied from periods varying from 1 to 86 months (Fig. 1). Two patients died and 9 patients were lost to follow-up before termination of the study. The deceased and lost patients were removed from the study at the time of last contact. Of the patients successfully followed to the termination of the study, approximately 73% were examined in the office and the other 27% who had not attended the office in the 6 months before study termination completed the telephone survey. The general dentists currently caring for the telephone-surveyed patients reported no previously undocumented In-Ceram failures, and verified the data provided by the patients' telephone surveys. No discrepancies between data sheets and patient charts or laboratory records were found, or did the audits of other practice charts or lab records reveal any missed In-Ceram patients.

Overall results and patient follow-up times are summarized in Table II. The only reasons for loss of service were removal without failure, core fracture, or porcelain fracture. Prosthodontic reasons for removal of satisfactory crowns included conversion of single crowns to be fixed partial denture abutments. One satisfactory In-Ceram crown was removed because the patient elected to have all her anterior teeth crowned to change her tooth shade from its natural color. Another satisfactory crown was lost when the patient elected to have the tooth removed because of a poor long-term endodontic prognosis.

Fracture of In-Ceram crowns was rare (Fig. 2). For example, none of the first 89 crowns placed, with 48 to 86 months of follow-up, failed before termination of the study. Had the study been limited to these patients or terminated earlier, 100% survival rates would have

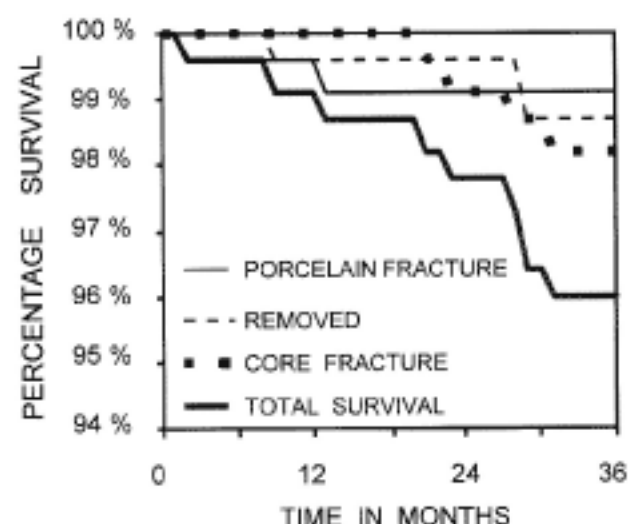


Fig. 3. Reasons for loss of service of In-Ceram crowns followed for 36 months.

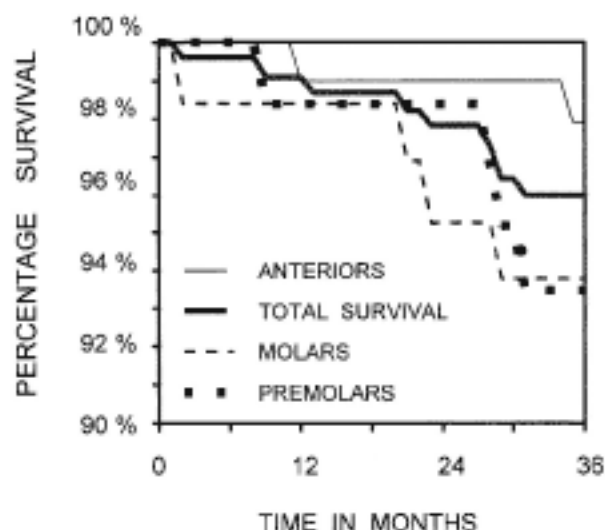


Fig. 4. Effect of tooth type on survival of In-Ceram crowns followed for 36 months.

Table II. Summary of total In-Ceram crown performance data

Follow-up times in months	n	% Core fracture	% Porcelain fracture	% All fracture	% Total not fractured	% Removed without fracture	% Total in service
0	408	0	0	0	100	0	100
12	378	0.8	0.5	1.3	98.7	0.3	98.4
24	309	1.0	0.6	1.6	98.4	0.3	98.1
36	223	1.8	0.9	2.7	97.3	1.3	96.0
48	89	0	0	0	100	0	100
60	31	0	0	0	100	0	100
72	13	0	0	0	100	0	100
84	8	0	0	0	100	0	100
86	8	0	0	0	100	0	100

been reported. Lengthy follow-up periods and a large sample size were needed to plot meaningful life curves or to make comparisons among the predictive variables. Therefore, the results presented later focused primarily on the 36-month data, with a sample size of 223 crowns (Table II and Figs. 3 and 4).

For the 223 crowns in 53 patients with at least 36 months of follow-up, 1.3% of the crowns became unserviceable per year (Table II and Figs. 2 through 4). The breakdown of reasons for loss of service were: core fracture at a rate of 0.6% per year; porcelain fracture at a rate of 0.3% per year; and otherwise sound restorations were removed at a rate of approximately 0.3% per year for prosthetic or other reasons (Fig. 3).

For the 223 crowns in 53 patients with at least 36 months of follow-up, survival curves were compared with respect to crown placement on anterior, premolar, or molar teeth (Fig. 4). Although no statistical difference was discerned ( $P > .05$ ), anterior crowns ( $n = 97$ )

tended to have a slightly higher 3-year survival rate (97.9%) than for premolars ( $n = 36$ , survival rate = 93.5%) or for molars ( $n = 64$ , survival = 93.8%) (Fig. 4). Survival curves were compared for crowns in male patients ( $n = 53$ ) versus crowns in female patients ( $n = 170$ ), but no difference was found (both had 3-year survival rates of approximately 96%) ( $P > .05$ ). Survival curves were also compared for crowns in patients showing signs of excessive wear or bruxing ( $n = 53$ ) versus without such signs ( $n = 170$ ), but no difference was found; both had 3-year survival rates of approximately 96% ( $P > .05$ ).

Other predictive variables had insufficient sample sizes for statistical comparison to be attempted. For example, of the 223 crowns followed for 36 months, 138 were cemented with Panavia, and the remaining 85 crowns were divided among the other 4 cements. Thus, with the low failure rate found, comparisons among groups of such small sample size would have been

meaningless. Similarly, because only 14 buildups were placed in the 223 crowns followed for 36 months, the influence of build-up material could not be usefully analyzed.

Review of the total data on all 408 patients revealed some interesting findings. In contrast to the 3-year data, approximately 79% of all fractures involved molars, which represented approximately 32% of the teeth treated. This indicated that proportionally more crowns with less than 3 years of follow-up were placed on molars, and that proportionally more of them fractured. This data again suggests that molar crowns are at higher risk to fracture than anterior crowns. In total, only 14 fractures were observed among the 408 crowns in 107 patients, of these 8 patients had a single crown fracture and 3 patients had 2 crowns fracture.

## DISCUSSION

Survival rates of In-Ceram crowns were high in this study (Table II and Figs. 2 through 4), but the all-ceramic In-Ceram crowns were not compared with conventional metal ceramic crowns. Metal-ceramic restorations are not susceptible to core fracture. In this study, the risk of core fracture was 0.6% per year (Table II). It is difficult to compare survival rates from our study to prior studies on metal-ceramic crowns because few studies have been prospectively designed, included follow-up rates, described all the reasons for failure, or included criteria.

Coornaert et al<sup>10</sup> reported a 3-year survival rate of 98.3% for 2181 metal ceramic units. However, failures due to caries, periodontal disease, or esthetics were not included. Leempoel et al<sup>3</sup> reported a 95% 11-year survival rate for metal-ceramic crowns. Glantz et al<sup>11</sup> reported a 5-year survival rate of 98% for porcelain and acrylic resin-veneered crowns. However, an additional 10% of surviving crowns in that study were found to be unsatisfactory because of recurrent caries or periodontal problems. It appears that In-Ceram crowns are at slightly greater risk to loss by fracture than metal-ceramic crowns, but this additional risk may be relatively small in comparison to the risk of caries or other hazards faced by all types of crowns. In our study, of up to 86 months, no failures of In-Ceram crowns were attributed to caries or periodontal problems. This may be as much a reflection on the patients' oral hygiene and dietary habits or on the dentist's patient selection and recall/maintenance program as on the fit and performance of the crowns themselves.

Although failure rates of approximately 1% per year were found for each of the 3 years with the larger sample size of this study, long-term predictions should be made with caution. It is possible that most of the potential failures had already occurred early on and that fewer crowns will be lost in the future if a steady state

is reached. Conversely, the effects of fatigue may maintain or even accelerate loss by fracture in the future.

As the posterior In-Ceram crowns in our study performed much better than other all-ceramic systems in prior studies,<sup>2-9</sup> with only a small apparent additional risk of core fracture, the manufacturer's recommended indication for posterior crowns may be justified. However, because no study has prospectively compared all-ceramic In-Ceram crowns with metal ceramic crowns, such an indication has not been scientifically proven. Furthermore, a nonsignificant trend did suggest that anterior In-Ceram crowns will have a lesser risk of fracture than posterior In-Ceram crowns.

Patients with signs of undue wear or bruxing were not placed at additional risk of fracture. Possibly such an effect might be small, and the sample size was insufficient. It is also possible that such signs are more a record of the past than an indication of current para-functional status. Furthermore, patients who clench can do so without obvious clinical signs, so they might not have been identified. Male and female patients also had identical survival rates, so the slightly greater average size and strength of the males did not expose them to measurably greater risk of crown fracture.

A slight tendency for crown failures to be clustered within individual patients was noted. Three patients had 2 crowns fracture, and the other 8 fractures all occurred among separate patients. It is not known whether this clustering tendency was related to the patients themselves, or to the laboratory and clinical procedures that crowns within the same mouth were exposed.

Crowns placed in earlier cases demonstrated better survival rates than later crowns. A "learning curve" might have been expected, but none was found. This may have been due to more stringent patient selection initially. As successes were seen, patient selection may have become less stringent. Certainly, the numbers of In-Ceram crowns being placed per year steadily increased over time (Table II). The greater fracture rates in the later crowns may also have been related to a gradual switch from core fabrication by the treating dentist to fabrication by a commercial laboratory. As for all types of crowns, attention to detail is critical and In-Ceram crown is no exception.<sup>25</sup> It is possible that earlier fractures were related to processing defects (incomplete infiltration) and that later fractures were related to fatigue effects.

Exact fracture mechanisms are unknown. Previous fractographic studies on all-ceramic crowns indicated that most fractures originate from their inner intaglio surfaces.<sup>14-16</sup> In our study, many of the fractures appeared to be related to the external line angles of the tooth preparations, especially with copings of questionable thickness or less well-rounded angles.<sup>20,27</sup> Although coping thickness was routinely measured, the

spring gage used overestimated thickness because the head of the gage did not fully fit into line angles. Some copings may have been further reduced during porcelain application. Therefore, it is recommended that great care be taken to achieve adequate tooth reduction, and rounding of external preparation angles. Should tooth reduction be inadequate, the tooth should be reprepared and the coping must never be thinned below ideal dimensions.

This study had many limitations. Only complete crowns were included and success rates of other types of crowns were not reported. All clinical procedures were performed by a single clinician, so selection biases may have been introduced. Crowns were placed over a period of 7 years, not all at the same time. Telephone surveying of patients who did not attend the office within the past 6 months may have produced some underreporting of unserviceable restorations.

The telephone survey may not have been adequate to assess anything other than catastrophic failure of the crowns, even if the patient could identify the correct crowns. However, the telephone survey was not the sole evaluation mechanism. First, it was only used to contact the 27% of the patients who missed their last 6-month check. Second, it was followed by a call to the patient's current dentist to verify the patient's account. Third, most of those 27% of the patients had attended the office for some check visits, just not for the last 6-month one. It is important to note that the 2 failed crowns were discovered by phone questionnaire. Inclusion of the telephone survey data had the net effect of slightly lowering the 3-year survival rate. The importance of the phone questionnaire was that it allowed almost all the In-Ceram crowns to be accounted for at the termination of the study with only 9 patients being lost to follow-up before termination of the study.

This study had some important advantages in comparison to previously published investigations of In-Ceram crowns. A larger sample size and longer follow-up periods were included. All patients treated with In-Ceram crowns were serially included, and almost all were accounted for at the end of the study. The patients were treated in a private dental office not a university clinic. The patients paid the full office price for their In-Ceram crowns and were not offered any inducements. The data were appropriately analyzed and presented so that it could be compared with other studies.

## CONCLUSIONS

Within the limitations of this prospective clinical trial of the survival of In-Ceram crowns in a private practice, the following conclusions were drawn:

1. Clinical failure of In-Ceram crowns was low, approximately 1.3% per year.
2. Crowns were lost because of core fracture (0.6%

per year), porcelain fracture (0.3% per year), and removal without failure (0.3% per year).

3. Failure tended to be more common for molar and premolar crowns (94%, 3-year survival) than for anterior crowns (98%, 3-year survival), but this trend was not statistically significant.

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