A Retrospective Assessment of 546 All Ceramic Anterior & Posterior Crowns in a General Practice

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Statement of Problem
There is need to determine whether following a consistent procedural protocol in a private dental practice will result in high success rates for all-ceramic anterior and posterior crowns fabricated from aluminous porcelain veneered to high-alumina content-supporting cores. Aluminous porcelain is known to have poor tensile strength and fracture resistance when subjected to shear forces.

Purpose
This study examined the long-term survivability of alumina core, all-ceramic crowns in both anterior and posterior locations.

Material & Methods
Following a consistent protocol over 6 years, 546 all-ceramic, In-Ceram crowns (32.4% anterior [n = 177] and 67.6% posterior [n = 369]) were consecutively luted with glass ionomer resin hybrid cement and periodically observed by the same dentist who prepared and cemented them.

Results
The overall success rate was 99.1% (n = 541) with a 0.9% (n = 5) failure rate. The success-to failure ratio for anterior all-ceramic crowns was 98.9% to 1.1% (n = 175:2); the posterior crown ratio was 99.2% to 0.8% (n = 366:3).

Conclusion
Following a consistent protocol of careful tooth preparation and crown cementation resulted in high success rates for anterior and posterior all-ceramic crowns. Glass ionomer resin hybrid cement appeared to be a reliable luting agent. All-ceramic alumina core crowns are durable and provide optimum esthetic choices for anterior and posterior locations. (J Prosthet Dent 2001;85:544-50)

Clinical Implications
All-ceramic crowns appear to be suitable and predictable alternatives for both anterior and posterior locations – provided that consistent attention is paid to proper tooth preparation, alumina core design, cementation, and occlusal adjustment. In addition to optimum esthetics, these crowns have success rates that equal or exceed those of ceramometal crowns. Glass ionomer resin hybrid cement appears to be a suitable luting agent for all-ceramic crowns.

Most experienced dental practitioners would agree that the literal standard for long-term full-crown survival is the cast gold restoration. Although the durability of this type of crown has stood the test of time, it has not met ever-increasing patient demands for esthetics. This demand has led to the development and use of various ceramometal and all-ceramic types of restorations.[1] Within these 2 types of restorative categories are a number of viable esthetic dental materials and techniques from which to choose.[2]

Although few persons would challenge the fact that ceramometal crowns have a proven record of strength, long-term durability, and improved esthetics, the metallic component fails to allow for a natural esthetic rendition in all instances.[3] The fact that all-ceramic crowns have no structural metallic phase, which may interfere with the natural transmittance and play of light or need to be opaqued, makes them a logical restorative consideration. Aside from the "metallic smile line" produced by some ceramometal crowns, the metallic substructure may present with oxidation and sag resistance problems during porcelain firing.[2]

All-ceramic crowns have been used for more than 60 years. Feldspathic porcelains generally provide excellent esthetics, biocompatibility, and compressive strength. However, they lack tensile strength and frequently fracture when subjected to shear forces. All feldspathic porcelain crowns are not a structurally suitable consideration for posterior locations due to inherent weaknesses of the material.[4]

Fig. 1 – *Preoperative view of patient with severe attrition and abrasion needing full-coverage restorations to reestablish normal coronal contours and occlusion.*

Fig. 2 – *Same patient seen in Fig. 1 after reconstruction with anterior and posterior ceramic restorations. Note esthetics and healthy coronal contours. Patient was in protrusive position to facilitate view of occlusal contours.*

In addition to anterior teeth, optimum contemporary dental esthetic considerations now include posterior teeth in virtually any situation (Figs. 1 and 2). To accommodate this, a number of unique approaches to strengthening porcelain and innovative all-ceramic fabrication methods have been developed in recent years.[2,5]

Two contemporary, coping-based, all-ceramic approaches have emerged, with great promise for becoming universal anterior/posterior all-ceramic crown systems.[6,7] They are Procera AllCeram (Nobelpharma AB & Sandvik Hard Materials, Stockholm, Sweden), which has a reported 96.9% success rate,[7] and In-Ceram (Vident, Baldwin Park, Calif.), which has a reported 98.4% success rate.[6] Both systems use substrate core or coping materials with a high alumina content for substantial added strength.[8] Procera AllCeram cores are 99.9% aluminum oxide, whereas In-Ceram copings are 70% sintered aluminum oxide saturated with lanthanum glass.[9,10] Procera AllCeram cores are fabricated with CAD/CAM technology,[11] whereas In-Ceram cores are built-up on special plaster dies. The copings of both systems are veneered with aluminous oxide porcelain with the use of traditional condensation methods for final form and refined esthetics.

In-Ceram and Procera AllCeram crowns appear to be viable approaches to providing practitioners with practical, durable, and universal all-ceramic crown systems for both anterior and posterior teeth. This is particularly important in light of the observations of McLean[2] of all-aluminous porcelain crowns having only an 84.4% and 93.6% success rate (15.6% and 6.4% failure rate) for molars and premolars, respectively. This same study reported success rates of 98.7% for canines and 97.9% for incisors (1.3% and 2.1% failure rates, respectively). Traditional porcelain anterior ceramic crowns were reported to have a success rate of 92% (8% failure).12 By way of further comparison, the success rate of ceramometal crowns was reported to be 97.6% over 7 years.[3]

The In-Ceram system provides a zirconia-type coping system with 600 to 800 MPa flexural strength and moderate translucency.[13] The type of In-Ceram alumina copings used in this study has a flexural strength of 320 to 490 MPa and high translucency and should be suitable for most locations.[14] In-Ceram spinell-type copings demonstrate a reduced flexural strength of 378 MPa but have very high translucency.[15] When other all-ceramic alternatives are considered, these appear to be suitable only for single anterior crowns requiring demanding esthetics that cannot be accomplished with other alumina-type coping all-ceramic crowns. Currently, Procera AllCeram produces 1 type of alumina core with a flexural strength of 687 MPa.[8] By way of further comparison, the mean flexural strength for feldspathic porcelain was reported as 56.5 MPa (46.4 to 66.7 MPa) and for aluminous porcelain, 92.2 MPa (69.1 to 115.3 MPa).[2]

Although Procera AllCeram cores have a higher alumina content and theoretically higher strength than In-Ceram cores, Neiva et al[5] found the former's fracture strength (194.20 ± 37.65 kg) to be less than that of In-Ceram (218.80 ± 36.12 kg). Although this differ-

Fig. 3 – Separate solid and die casts. Note typical and essential adequate circumferential butt-shoulder preparation with rounded axial-gingival line angles. Margins of die were marked to help reduce laboratory fabrication errors.

Table I. Number of crowns received by patients

Crowns	Patients	Total Crown
1	140	140
2	55	110
3	19	57
4	14	56
5	6	30*
6	9	54
7	1	7
8	3	24
9	2	18
10	1	10
11	0	0
12	0	0
13	1	13
14	2	28
Total	253†	547‡

*One crown was lost because a tooth was traumatically avulsed.
†175 women, 78 men.
‡Final number of crowns included in this study was 546.

ence was not considered statistically significant, it may have been due, in part, to greater axial wall and marginal opening gaps observed in the study for Procera AllCeram (105 µm and 225 µm gaps, respectively) than for In-Ceram (45 µm and 135 µm gaps, respectively). These differences may have been due to CAD/CAM limitations.

The practical range of acceptability for crown marginal gaps has been cited as 50 to 75 µm.[16] However, larger marginal gaps may still be acceptable, as inferred by successful clinical outcomes of crowns with larger inherent marginal gaps.[7] The best management of reasonable gaps, aside from the obvious improvement of inherent crown fabrication factors, is choice of luting agent. However, there has been no consensus in the literature regarding the best luting agent for optimum crown fit.[17] Depending on the luting agent used, all-ceramic crowns have also been reported to have a higher fracture incidence.[18]

The purpose of this study was to review the survivability of 546 In-Ceram crowns placed on both anterior and posterior teeth over a 6-year period. During this period, a consistent protocol for preparation and cementation was followed. All crowns were prepared, cemented, and subsequently periodically evaluated by the same practitioner in a private practice setting. Crowns were fabricated by several different commercial laboratories and technicians.

Materials & Methods

In the course of a general dental practice, 547 all-ceramic, In-Ceram anterior and posterior crowns were treatment planned for 253 patients by the same dentist over 6 years. The number of crowns received by individual patients ranged from 1 to 14 (Table 1). In the 6 years of this study, no patients were lost from the population. Crown selection and location were made solely on patient need and desire with no distinction based on age, gender, or other factors. One intact anterior crown was deleted from this study because the tooth (a maxillary right lateral incisor) was traumatically avulsed 9 months after the crown was placed. Therefore, the 6-year crown population referenced in this study consisted of 546 all-ceramic In-Ceram crowns (Table 1).

Teeth were prepared with a general 1 to 2 mm overall reduction, except for occlusal and incisal surfaces, which were reduced 2 mm. A 90-degree circumferential shoulder preparation was used with rounded internal line angles. This shoulder was planed with flat end cutting diamond burs, and irregularities were smoothed with hand chisels. Preparation walls were planed and smoothed with carbide finishing burs.

Defects were blocked out with light-polymerized glass ionomer hybrid cement (Vitrebond, 3M, St. Paul, Minn.). Autopolymerizing resin provisional crowns were cemented with eugenol-containing provisional cement (Temp Bond, Kerr, Romulus, Mich.).

Two full-arch reversible hydrocolloid impressions and casts were made of prepared teeth. One cast was used for dies, and the other was used as a solid cast for developing crown occlusion, contacts, and emergence profile (Fig. 3). Dies were trimmed under x10 to 20 magnification. An irreversible hydrocolloid opposing full-arch impression and stone cast were made for the purpose of developing proper occlusion.

Crown Fabrication, Placement & Cementation

Standard In-Ceram crowns were fabricated, by commercial laboratories, on refractory dies. Sintered alumina cores (Fig. 4) saturated with lanthanum glass (Fig. 5) were produced according to the manufacturer's specifications. Outer core forms were designed to prevent an excess of unsupported veneering porcelain, especially in mesial and distal aspects. Veneering porcelain (Vita Dur Alpha, Vident, Baldwin Park, Calif.) (Fig. 6) was maintained at an approximate thickness of 1 to 2 mm: Shade selection and customizing information provided to the laboratory was determined clinically under approximately 52000 K illumination to minimize "bluing-out."

Residual provisional cement was removed from provisionalized teeth with a water and flour of pumice slurry applied with a rotary bristle brush and rubber cup. A eugenol-containing provisional cement was used, though this has not been recommended if resin-modified glass ionomer luting agents are used for final cementation. However, it has been found that eugenol-containing agents have no appreciable affect on resin cements if the provisional cement is removed by thorough cleaning.[19]

After the crowns were tried-in, adjusted, and equilibrated, each crown intaglio surface was lightly air abraded to remove any contaminants, washed with distilled water, and dried.

The resin-modified glass ionomer cements Fuji Plus (GC America, Chicago, Ill.) and Vitremer (3M) had been found to cause no fractures in either feldspathic or In-Ceram crowns.[18] However, Advance cement (Caulk/Dentsply, Milford, Del.), more correctly classified as a fluoride-releasing resin cement rather than a resin-modified glass ionomer cement, fractured 100% of the test feldspathic porcelain jacket crowns

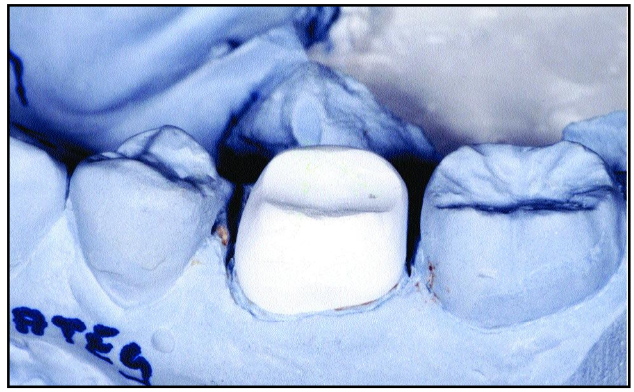

Fig. 4 *– First molar alumina core before sintering.*

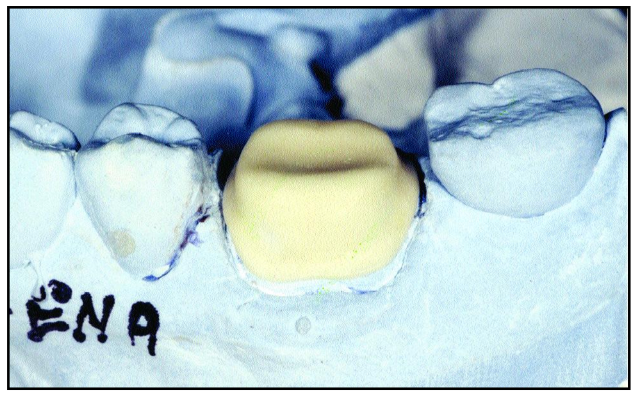

Fig. 5 *– First molar alumina core after sintering and saturation with lanthanum glass. After this fabrication stage, veneering feldspathic porcelain was built up by traditional condensation methods to establish optimum esthetics, contours, and occlusion (see Fig. 6).*

Fig. 6 *– Feldspathic veneering porcelain built up on alumina core seen in Figure 4, after saturation with lanthanum glass. Note natural contours and optimum esthetics.*

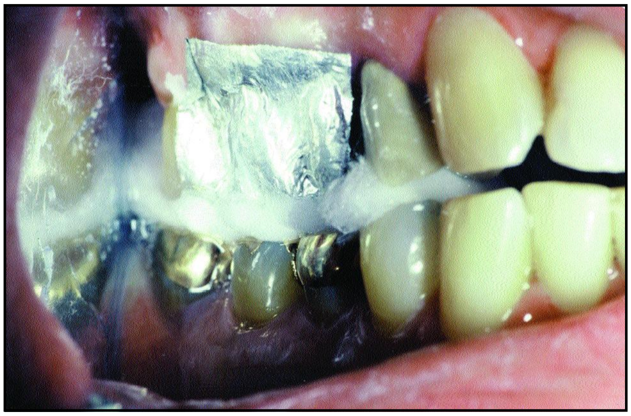

***Fig. 7** – Cementation of upper first molar. Immediately on seating, self-adhesive foil was placed over crown and extruded excess cement. This facilitated isolation from moisture. Patient bit against compressed cotton roll to apply uniform and even pressure to crown during cement setting.*

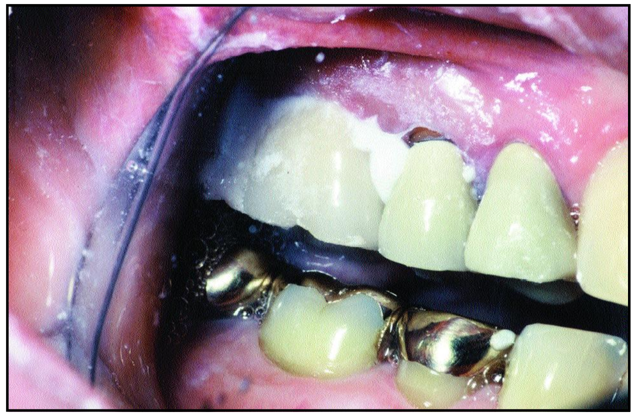

***Fig. 8** – Same patient seen in Figure 7, with self-adhesive foil removed. Note that excess cement (removed later) was not degraded by moisture. Second premolar crown was replaced to correct degenerating buccal margin.*

TABLE II. Crown longevity

Age (y)	Number
6	27
5	63
4	86
3	120
2	88
1	162
TOTAL	546

TABLE III. Original and failed crown locations

	Maxillary arch			Mandibular arch		
Tooth	Original	Replaced	Total	Original	Replaced	Total
Incisor	131	1*, 1†	133	15	0	15
Canine	21	0	21	8	0	8
Premolar	119	1*	120	56	0	56
Molar	103	1†	104	88	1†	89
Total	374	4	378	167	1	168

*Core fracture.
†Veneer fracture.

TABLE IV. Longevity of failed crowns

Type failure	Tooth	Longevity (y)
Core	Maxillary right central incisor	1.4
Core	Maxillary right first premolar	2.0
Veneer	Maxillary right central incisor	3.27
Veneer	Maxillary right first molar	3.6
Veneer	Mandibular right first molar	0.5

and 30% of In-Ceram crowns.[18] This destructive effect apparently was due to unexplained continuing water sorption and expansion.

After several factors were assessed,[20-24] Vitremer (3M) resin-modified glass ionomer cement was selected as the optimum choice for luting In-Ceram crowns in this study because of its thin film thickness, cario-static effect, minimal setting pH change and tooth sensitization, reduced marginal leakage, contribution to enhanced fracture resistance, and ease of use.

Prepared teeth were isolated, and a glass ionomer resin hybrid cement (Vitremer Luting Cement, now known as RelyX Luting Cement, 3M) was mixed. Cement was applied to prepared teeth, and an excess amount of cement was inserted into the crowns. As soon as the crowns were seated, margin areas and excess cement were covered with adhesive foil (Dry Foil, Jelenko, Armonk, N.Y.) to help iso-

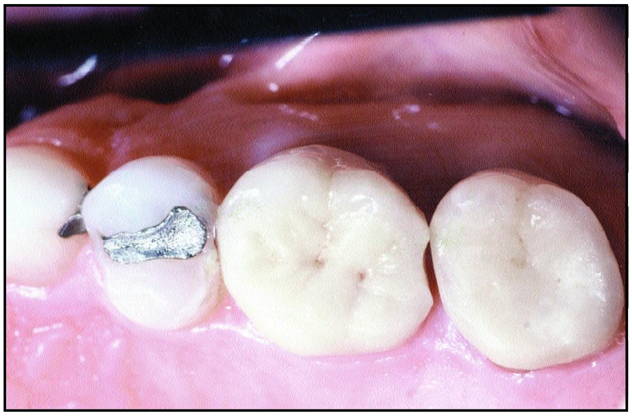

Fig. 9 *– All-ceramic maxillary first molar crown with feldspathic veneer porcelain fracture of distal marginal ridge. Veneering porcelain appeared to be inadequately supported by alumina core, which should have been extended more distally.*

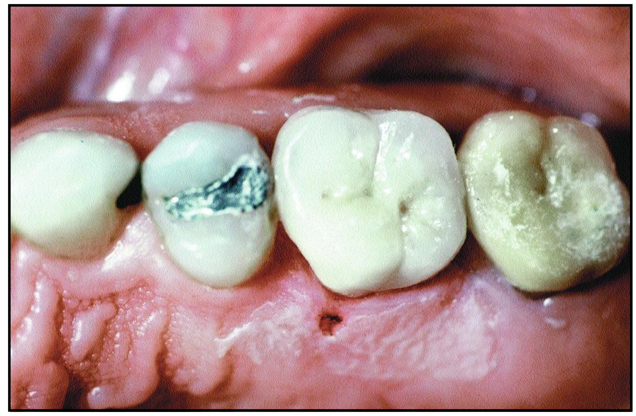

Fig. 10 *– Maxillary first molar all-ceramic crown that replaced fractured crown shown in Figure 9. Note broad and ample form of distal marginal ridge. Ulcer and leukoplakia-like lesion lingual to crown were results of pizza burn and subsequently healed without incident. Second molar crown is much darker than first molar crown because it was fabricated before patient sought tooth bleaching. First molar was fabricated to match patient's new bleached shade.*

late the crown-tooth interface from moisture (Figs. 7 and 8). Crowns were then held under occlusal compression by the patient until luting cement polymerization. After 5 minutes, all isolation agents and excess cement were removed. Occlusion was refined as needed, and any adjusted crown surfaces were polished with pumice-impregnated rubber wheels.

Subsequent to cementation, all crowns were observed at routine 6-month patient recall appointments by the same dentist who prepared and cemented the crowns. Crowns were evaluated for apparent alterations in outward structural integrity (chips, cracks, and fractures) by means of a thorough visual examination and surface probing with a sharp dental explorer. Marginal integrity at the crown-tooth interface was also evaluated with a sharp dental explorer and bite-wing radiographs. No specific examiner reliability protocol was used.

In those instances in which esthetics and/or patient satisfaction were questionable, crowns were provisionally cemented (Temp Bond, Kerr). After questions were resolved, the prepared teeth and crowns were cleansed and cemented as described previously.

Results

Of the 546 In-Ceram crowns followed over a 6-year period (Table II), 69.2% (n = 378) were maxillary and 30.8% (n = 168) were mandibular (Table III). Approximately 32.4% (n = 177) of the crowns were anterior and 67.6% (n = 369) were posterior.

On the basis of actual observation of fractured crown elements, it was determined that 5 crowns (0.9%) failed because of core failure (0.4%, n = 2) or veneer fracture with intact cores (0.5%, n = 3) (Table IV). The anterior crown success rate was 98.9% (n = 175); the posterior crown success rate was 99.2% (n = 366). The total crown success rate was 99.1% (n = 541) with a 0.9% (n = 5) failure rate.

Discussion

The 99.1% overall success rate for anterior and posterior In-Cerams crowns observed in this study is consistent with the 98.4% success rate reported by Scotti et al6 for 63 In-Ceram anterior and posterior crowns over 44 months and the 96.9% coping success rate reported by Oden et al[7] for 97 anterior and posterior Procera AllCeram crowns observed over 5 years.

The likely reasons for the observed 2 core failures are as follows: 1 anterior core was thinned too much on the labial aspect to allow for more veneering porcelain, and 1 posterior core failed because of excessive occlusal parafunctional forces caused by a patient who exhibited extreme bruxism. It was presumed that the 3 veneer fractures were due to occlusal factors and inadequate core support of veneering porcelain. Such factors would have allowed occlusal forces to exceed tensile strength limits of the veneering porcelain (Figs. 9 & 10). This new information contributes favorably to a needed data base.[3]

New developments in all-ceramic systems appear to provide the practitioner with exciting restoration alternatives that are predictable, durable, esthetic, and applicable to both posterior and anterior teeth. The long-term reliability and continuing development of high-strength all-ceramic systems should make the dentist feel comfortable using all-ceramic crowns in all locations, without limitation.

Conclusions

On the basis of the results of this retrospective assessment of 546 all-ceramic In-Ceram crowns, the following conclusions were drawn:

1. Consistently following a protocol of careful tooth preparation with sufficient and properly designed circumferential shoulder preparations, adequate core support of veneering porcelain, proper occlusal adjustment, and careful cementation technique resulted in high success rates for all-ceramic crowns in a general dental practice.

2. All-ceramic crowns provide the dental practitioner with an optimum esthetic choice for anterior and posterior locations.

3. All-ceramic crowns with alumina cores are suitable alternatives for anterior and posterior locations and have success rates that equal or exceed those of ceramometal crowns.

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