Retrospective Clinical Evaluation of 86 Procera AllCeram™ Anterior Single Crowns on Natural and Implant-Supported Abutments

Fernando Zarone, MD, DDS;* Roberto Sorrentino, DDS;† Francesco Vaccaro, DDS;† Simona Russo, DDS;† Giorgio De Simone, DDS†

ABSTRACT

Background: The Procera AllCeram™ (Nobel Biocare AB, Göteborg, Sweden, and Procera Sandvik AB, Stockholm, Sweden) technique is one alternative to metal-ceramic restorations. However, few long-term evaluations of its use for single crowns on natural and implant-supported abutments are available.

Purpose: The aim of the present study was to assess the clinical performance of Procera AllCeram single crowns when placed in aesthetic sites supported by either natural teeth or implants over a period of 48 months.

Materials and Methods: Eighty-six single crowns were fabricated and used in 51 patients. The restorations were examined according to the California Dental Association's quality assessment system.

Results: One crown was lost after 20 months of follow-up. Of the 85 restorations that completed the 48-month follow-up, only one crown (1.2%) showed a veneering porcelain chip. All crowns were ranked as either excellent or acceptable. The success rates of single crowns supported by natural tooth and implant-supported abutments were 100% and 98.3%, respectively; the total crown success rate was 98.8%.

Conclusion: Within the limitations of the present study, Procera AllCeram crowns proved to be a reliable therapeutic choice for the restoration of anterior teeth on both natural and implant-supported abutments. The hybrid glass-ionomer cement used in the present study appeared to be a reliable luting agent.

KEY WORDS: agenesis, implant-prosthetic treatment, lateral incisor, nonsubmerged implants, prospective study

Gold-ceramic prosthetic restorations have represented a standard in terms of long-term survival for many years[1,2]; however, the presence of the metal framework is to be considered a limiting factor for the final aesthetic result.[3] Owing to patients' increasing demand for aesthetics, in recent decades, all-ceramic restorations have been used more and more in clinical practice and have been well investigated.[4,5] All-ceramic crowns have been used for more than 60 years; owing to the absence of a metallic structure, the use of an opaque mass is not necessary anymore and interference with the natural transmittance of light is unlikely, giving the restorations a much more natural appearance.[2] Feldspathic porcelain usually provides optimal biocompatibility, aesthetics, and mechanical resistance to compressive forces, but it frequently fractures under shear loads owing to its low tensile strength; as a consequence of the unsatisfactory behavior in tension, the use of all-ceramic feldspathic crowns has been contraindicated in posterior teeth for years.[6] To make all-ceramic crowns suitable for all intraoral sites, various innovative all-ceramic–based restorative systems have been developed in recent years.[4,5,7]

In the last decade, Procera AllCeram™ (Nobel Biocare AB, Göteborg, Sweden, and Procera Sandvik AB, Stockholm, Sweden) developed a CAD/CAM technology (computer-aided design/computer-aided manufacturing) to produce densely sintered, high-purity aluminum oxide copings for single crowns, shells for

*Professor and chairman, Department of Fixed Prosthodontics, University of Naples "Federico II," Naples, Italy; †research fellow, Department of Fixed Prosthodontics, University of Naples "Federico II," Naples, Italy

Reprint requests: Fernando Zarone, MD, DDS, Dipartimento di Scienze Odontostomatologiche e Maxillo-Facciali, Ed. 14, Università degli Studi di Napoli "Federico II," Via Pansini, 5 – 80131 Naples, Italy; e-mail: zarone@unina.it

laminate veneers, small-bridge alumina frameworks, and individualized abutments for different implant platforms.[8–12] Procera AllCeram is a leucite-free porcelain containing more than 99.9% alumina. The purity of the aluminum oxide and the sinterization process contribute to reduce porcelain failure.[7–9] Moreover, the homogeneous structure of the Al_2O_3 copings gives the material high mechanical strength in comparison with other ceramic metal-free restorations.[13] Several studies have demonstrated that it has translucency and opalescence characteristics that offer good possibilities of obtaining a natural appearance for the restorations.[13,14]

As for the adaptation of crowns to the periodontal tissues, the range of acceptability for crown marginal gaps has been stated to be 40 to 100 μm[12]; restorations realized with the Procera system show a marginal gap ranging between 60 and 80 μm, which can be considered clinically acceptable.[15,16] Resin luting agents have shown the best in vitro results for the cementation of AllCeram restorations realized with the Procera system[17,18]; however, to date, there is still no agreement in the literature about the best luting agent to be used with all-ceramic crowns.[19]

From the clinical point of view, a success rate of 97.6% for metal-ceramic crowns in the anterior regions of dental arches has been reported after 7 years,[3] whereas all-ceramic feldspathic anterior crowns have shown a 92% success rate.[20] In the anterior regions of dental arches, clinical success rates of 98.7% and 97.9% have been reported for all-aluminous porcelain crowns for canines and incisors, respectively,[4] whereas Procera AllCeram crowns have shown a 100% success rate in the anterior regions of dental arches after 5 years.[10]

The present study was aimed at evaluating the clinical performance of 86 Procera AllCeram single crowns placed on anterior teeth onto both natural tooth and implant-supported abutments over a period of 48 months.

MATERIALS AND METHODS

Eighty-six Procera AllCeram maxillary anterior single crowns were realized for 51 patients (Table 1) by four dentists at the Department of Prosthetic Dentistry of the University "Federico II" of Naples over a period of 18 months.

The crowns had been realized on 28 natural tooth abutments and on 58 implant-supported abutments; the implants used in the present study were both non-submerged (Institut Straumann AG, Waldenburg, Switzerland) and submerged (Nobel Biocare AB). The number of crowns received by each patient ranged from one to six. Crown location was not related to gender, age, or other factors.

TABLE 1 Total Crown Distribution

Crowns	Central Incisor	Lateral Incisor	Canine	Total	Patients
1	22	20	4	46*	32
2	6	6	0	12	13*
4	8	8	0	16	4
6	4	4	4	12	2
Total	40	38	8	86	51

*Seven patients provided with two single crowns received one restoration onto a natural tooth abutment and one implant-supported restoration.

Thirty-three female and 18 male patients were included in the present retrospective study; their ages ranged from 18 to 62 years. All patients were in good general health; 4 of them were smokers, whereas 11 showed occlusal parafunctional habits; the smokers had received no implants. Before being included in the study, the patients had to sign a written consent form.

The prostheses were distributed as follows (Tables 2 and 3): 32 patients had received 1 single crown (n = 32; 3 on natural tooth abutments and 29 on implant-supported abutments), 13 patients had been provided with 2 single crowns (n = 26; 9 on natural tooth abutments and 17 on implant-supported abutments), 4 patients had received 4 single crowns (n = 16; 4 on natural tooth abutments and 12 on implant-supported abutments), and 2 patients had been provided with 6 single crowns (n = 12; 12 on natural tooth abutments and none on implant-supported abutments); 7 of the

TABLE 2 Natural Tooth Abutment Crown Distribution

Crowns	Central Incisor	Lateral Incisor	Canine	Total	Patients
1	7	2	1	10*	3
2	2	0	0	2	8*
4	2	2	0	4	1
6	4	4	4	12	2
Total	15	8	5	28	14*

*Seven patients provided with two single crowns received one restoration onto a natural tooth abutment and one implant-supported restoration.

TABLE 3 Implant-Supported Crown Distribution

Crowns	Central Incisor	Lateral Incisor	Canine	Total	Patients
1	15	18	3	36*	29
2	4	6	0	10	12*
4	6	6	0	12	3
6	0	0	0	0	0
Total	25	30	3	58	44*

*Seven patients provided with two single crowns received one restoration onto a natural tooth abutment and one implant-supported restoration.

13 patients with 2 single crowns had 1 crown on a natural tooth abutment and 1 crown on an implant-supported abutment. Forty crowns had been realized to restore maxillary central incisors, 38 maxillary lateral incisors, and 8 maxillary canines.

After performing the conventional procedures to obtain good oral hygiene, a first impression was taken with an irreversible hydrocolloid (Xantalgin, Heraeus Holding GmbH, Hanau, Germany) to pour the study cast and realize the resin temporary crowns. The casts of both dental arches were mounted into an articulator.

Natural Tooth Restorative Procedure

Tooth preparation of each crown was performed following the Procera clinical protocol. A general 1 to 1.5 mm overall reduction was performed, except for the incisal margins, which were reduced 2 mm. A 1 mm moderate chamfer circumferential shoulder preparation was performed, with rounded internal line angles. The preparation margins were set 0.8 mm deep in the gingival sulcus. The shoulders were prepared using fine diamond burs, and eventual irregularities were smoothed by means of hand chisels. The buccal surface of the teeth was prepared following two different planes of preparation, according to the anatomy of the teeth, whereas the palatal surface was prepared rounding the transition surfaces. Fine carbide finishing burs were used to smooth the axial walls.

Implant Abutment Restorative Procedures

Aluminum oxide Procera abutments were used on submerged implants, whereas titanium abutments were used on nonsubmerged implants. Although light transmission is going to be blocked by metal structures, the choice of seating all-ceramic crowns onto titanium abutments aimed at evaluating the soft tissue response induced by alumina restorations around a nonsubmerged implant platform. Both the resin abutments for the Procera scanning procedures and the titanium abutments were prepared in the dental laboratory according to the clinical needs of each patient.

The Procera custom abutments were realized according to the respective technique.[21] On the contrary, fine diamond burs were used to customize the titanium abutments. The buccal surface of the abutments was prepared following two different planes of preparation, according to the anatomy of the crowns. The main features of the implant abutment preparation geometry were the same as previously described for the preparation of natural tooth abutments.

All of the resin temporary crowns were realized by the same dental technician using autopolymerizing resin (Jet Kit, Lang Dental MFG. CO., Wheeling, IL, USA). The same resin was put into the temporary crowns to fit them intraorally on the prepared teeth; they were smoothed with soft rubber and polishing caps by means of a 10× surgical stereomicroscope (Zeiss OpMi1, Zeiss, Oberkochen, Germany) to obtain optimal marginal adaptation between the crowns and the soft periodontal tissues. All of the temporary crowns were cemented with eugenol-free temporary cement (Temp Bond NE, Kerr Co., Orange, CA, USA); residual provisional cement was removed by means of pumice slurry applied with a rotary bristle brush and a rubber cap under water irrigation. Such resin crowns were worn by patients for 3 weeks.

After the healing period, the temporary crowns were removed and the tooth preparations were refined under the control of a 10× surgical stereomicroscope (Zeiss OpMi1). One-step precision impressions were taken by using polyether materials (Permadyne Penta H, Permadyne Penta L, 3M ESPE, Seefeld, Germany) with custom autopolymerizing acrylic resin trays (SR-Ivolen, Ivoclar, Schaan, Liechtenstein) made by the technician at least 24 hours before the impression; a thin layer of an adhesive specific for polyethers was applied over the internal surface of such trays (Polyether Adhesive, 3M ESPE). Then the impressions were sent to a dental technician laboratory and poured using an extra-stone plaster type IV (Fuji Rock, GC, Tokyo, Japan) after 5 hours to allow an elastic return of polyethers. The resin temporary crowns were readapted using an autopolymerizing resin intraorally; the same finishing and polishing procedures previously described were followed and the

temporary crowns were cemented with eugenol-free temporary cement.

The previously described Procera protocol was adopted to make the aluminum oxide shells. Two weeks later, the alumina copings were realized and checked for a 0.6 mm thickness; they were carefully seated onto their abutments, and the final positional impressions were taken by using the same materials and procedure as previously described. The clinicians selected the shade of the final restorations according to the patients' needs.

All of the final restorations were realized by the same dental technician. The porcelain veneering of the alumina copings was realized in a dental technician laboratory, by using a ceramic material specifically developed for aluminum oxide copings (Procera AllCeram Ceramics, Ducera Dental GmbH, Rosbach, Germany), characterized by a special adaptation to the coefficient of thermal expansion of the aluminum oxide framework (7.0 μm/[m·K]). The thickness of the veneering ceramics ranged between 1 and 2 mm. The inner surface of the copings was silanized before cementation (Silane Primer, Kerr Co.).

The final all-ceramic crowns were tried-in and cemented by means of a hybrid glass ionomer luting agent (RelyX Luting Cement, 3M ESPE). The prepared teeth were isolated with rubber dam, and the cementation procedure was performed strictly in accordance with the manufacturer's instructions. The same cementation protocol was used for metal abutments, ceramic abutments, and tooth structure. The luting agent was inserted into the crowns, and the patients were requested to hold the crowns under occlusal compression until luting cement polymerization. After 5 minutes, excess cement was removed as described for the temporary luting agent; the occlusion was refined as needed, and any adjusted crown surfaces were polished with pumice paste and rubber caps. As for the implant-supported crowns, standardized periapical radiographs (Irix 70, Trophy, Kodak spa, Cinisello Balsamo, Italy) were taken to verify the seating of the restorations.

The cementation was considered the baseline to record data. The patients were recalled for follow-up visits 1 month after the cementation of the crowns and then every 6 months, for a total observation period of 48 months. The function, aesthetics, and marginal adaptation of the restorations were evaluated. The periodontal status was analyzed by means of 4-point periodontal probing (ie, mesial, buccal, distal, and palatal probing) and evaluation of the following periodontal parameters:

- Gingival Index (GI), describing the color and inflammation of gingival tissue[22]; GI is composed of four levels:
  - GI 0 = normal healthy gingiva
  - GI 1 = slight inflammation, slight color change, edema, no spontaneous bleeding
  - GI 2 = moderate inflammation, moderate color change, edema, bleeding on probing
  - GI 3 = serious inflammation, serious color change, serious edema, spontaneous bleeding
- Plaque Index (PI), describing the quantity of dental plaque at the cervical region[22]; PI is composed of four levels:
  - PI 0 = no dental plaque
  - PI 1 = dental plaque to be pointed out only with dental plaque–revealing substances
  - PI 2 = dental plaque to be pointed out at a glance
  - PI 3 = plentiful dental plaque
- Bleeding on probing: probing in the depth of the pocket until a slight resistance is met,[23] evaluated with a yes-no score

The clinical evaluations of the single crowns were performed according to the California Dental Association's (CDA) quality evaluation system[24]; the restoration surface and color, anatomic form, and marginal integrity were evaluated with the CDA system, ranging between not acceptable, acceptable, and excellent. The structural integrity of the crowns was evaluated by means of surface probing with a sharp dental explorer under a 10× surgical stereomicroscope. Moreover, the patients' satisfaction score was assessed, ranging between not acceptable, acceptable, good, and excellent.

RESULTS

During the 48-month follow-up, only 1 (1.2%) of the 86 Procera AllCeram single crowns was lost, because the patient moved to another town. Until the crown was controlled, it satisfied all of the functional and periodontal parameters evaluated in the present study. In only one crown, a slight chip of the porcelain veneering was observed; because after accurate trimming and polishing such a fracture was interfering with neither function nor aesthetics, the crown was not considered failed.

Over the observation period, the color and surface characteristics of 82 crowns were considered excellent, whereas three restorations were judged to be acceptable (Table 4); among the latter, 2 were set onto natural

tooth abutments, whereas 1 was an implant-supported crown. As to the anatomic form, all of the 85 restorations, which survived for the whole observation period, were judged to be excellent (Table 5). The marginal integrity after 48 months was considered excellent in 84 crowns, whereas 1 restoration supported by a natural tooth abutment was judged to be acceptable (Table 6).

As to the periodontal parameters evaluated in the present study, all of the crowns scored 0 for both the GI (Table 7) and the PI (Table 8); none of them was positive to bleeding on probing (Table 9). As to the satisfaction score, all of the 85 restorations that reached the 48-month follow-up were considered excellent by the patients (Table 10).

TABLE 4 California Dental Association Rating for Surface and Color (Natural Tooth Abutment Crowns/Implant-Supported Restorations)

Rating	1 mo (n = 86)	6 mo (n = 86)	12 mo (n = 86)	24 mo (n = 85)	36 mo (n = 85)	48 mo (n = 85)
Not acceptable	0	0	0	0	0	0
Acceptable	1 (1/0)	1 (1/0)	2 (1/1)	3 (2/1)	3 (2/1)	3 (2/1)
Excellent	85 (27/58)	85 (27/58)	84 (27/57)	82 (26/56)	82 (26/56)	82 (26/56)

TABLE 5 California Dental Association Rating for Anatomic Form (Natural Tooth Abutment Crowns/Implant-Supported Restorations)

Rating	1 mo (n = 86)	6 mo (n = 86)	12 mo (n = 86)	24 mo (n = 85)	36 mo (n = 85)	48 mo (n = 85)
Not acceptable	0	0	0	0	0	0
Acceptable	0	0	0	0	0	0
Excellent	86 (28/58)	86 (28/58)	86 (28/58)	85 (28/57)	85 (28/57)	85 (28/57)

TABLE 6 California Dental Association Rating for Marginal Integrity (Natural Tooth Abutment Crowns/Implant-Supported Restorations)

Rating	1 mo (n = 86)	6 mo (n = 86)	12 mo (n = 86)	24 mo (n = 85)	36 mo (n = 85)	48 mo (n = 85)
Not acceptable	0	0	0	0	0	0
Acceptable	1 (1/0)	1 (1/0)	2 (2/0)	2 (2/0)	2 (2/0)	1 (1/0)
Excellent	85 (27/58)	85 (27/58)	84 (26/58)	83 (26/57)	83 (26/57)	84 (27/57)

TABLE 7 Gingival Index (GI) Score (Natural Tooth Abutment Crowns/Implant-Supported Restorations)

Score	1 mo (n = 86)	6 mo (n = 86)	12 mo (n = 86)	24 mo (n = 85)	36 mo (n = 85)	48 mo (n = 85)
GI 0	81 (23/58)	86 (28/58)	86 (28/58)	85 (28/57)	85 (28/57)	85 (28/57)
GI 1	5 (5/0)	0	0	0	0	0
GI 2	0	0	0	0	0	0
GI 3	0	0	0	0	0	0

TABLE 8 Plaque Index (PI) Score (Natural Tooth Abutment Crowns/Implant-Supported Restorations)

Score	1 mo (n = 86)	6 mo (n = 86)	12 mo (n = 86)	24 mo (n = 85)	36 mo (n = 85)	48 mo (n = 85)
PI 0	79 (22/57)	82 (24/58)	83 (25/58)	85 (28/57)	85 (28/57)	85 (28/57)
PI 1	7 (6/1)	4 (4/0)	3 (3/0)	0	0	0
PI 2	0	0	0	0	0	0
PI 3	0	0	0	0	0	0

TABLE 9 Bleeding on Probing (BOP) Evaluation (Natural Tooth Abutment Crowns/Implant-Supported Restorations)

Index	1 mo (n = 86)	6 mo (n = 86)	12 mo (n = 86)	24 mo (n = 85)	36 mo (n = 85)	48 mo (n = 85)
BOP +	4 (4/0)	0	0	0	0	0
BOP –	82 (24/58)	86 (28/58)	86 (28/58)	85 (28/57)	85 (28/57)	85 (28/57)

TABLE 10 Patients' Satisfaction Score (Natural Tooth Abutment Crowns/Implant-Supported Restorations)

Score	1 mo (n = 86)	6 mo (n = 86)	12 mo (n = 86)	24 mo (n = 85)	36 mo (n = 85)	48 mo (n = 85)
Not acceptable	0	0	0	0	0	0
Acceptable	0	0	0	0	0	0
Good	3 (2/1)	1 (1/0)	0	0	0	0
Excellent	83 (26/57)	85 (27/58)	86 (28/58)	85 (28/57)	85 (28/57)	85 (28/57)

The success rate of single crowns supported by natural tooth abutment was 100% (n = 28); the implant-supported restorations had a success rate of 98.3% (n = 57); the total crown success rate was 98.8% (n = 85), with a 1.2% (n = 1) failure rate.

DISCUSSION

In the present study, the use of the Procera system confirmed both the clinical and the aesthetic advantages described in the literature. The CAD/CAM technology allowed the dental technician to shorten the laboratory working time compared with the conventional procedures needed to realize a metal framework. The patients' demand for aesthetics in the anterior regions of dental arches was satisfied with both natural tooth abutments (Figures 1 to 4) and implant-supported restorations (Figures 5 to 8).

The 98.8% overall success rate for anterior single crowns observed in the present study was consistent with data published in the scientific literature,[10] con-

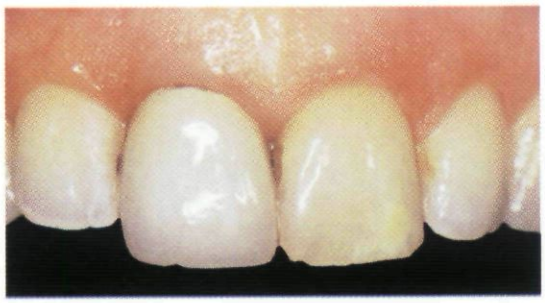

Figure 1 Case 1: incongruous prosthetic crown in region 11 and discromic crown in region 21.

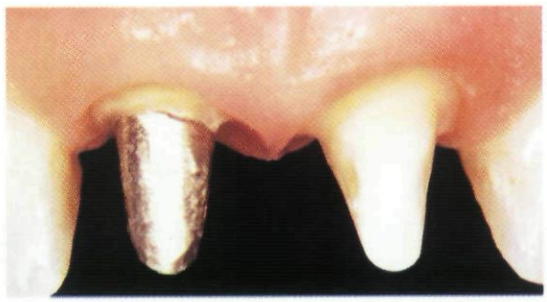

Figure 2 Case 1: the natural tooth abutments after the tooth preparation.

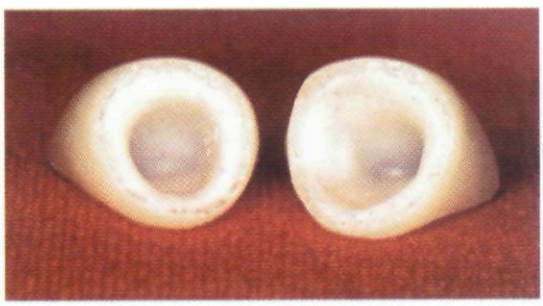

Figure 3 Case 1: the Procera AllCeram crowns.

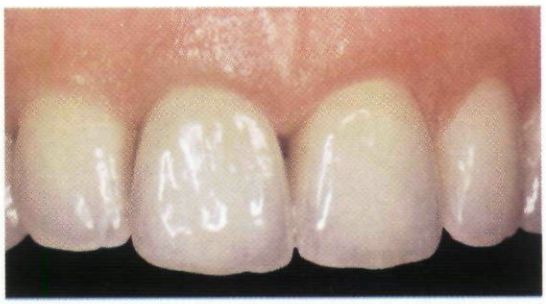

Figure 4 Case 1: the Procera AllCeram crowns in regions 11 and 21 3 years after the cementation.

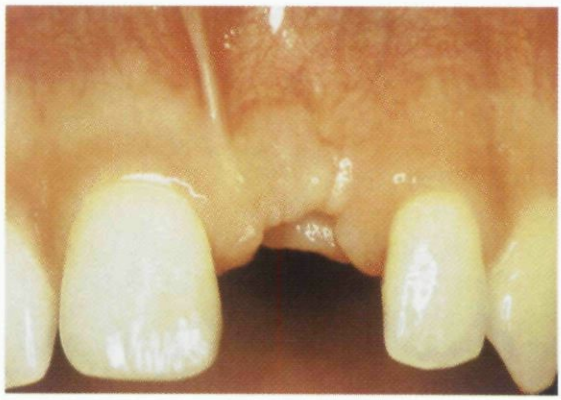

Figure 5 Case 2: traumatic avulsion of the maxillary central incisor in region 21.

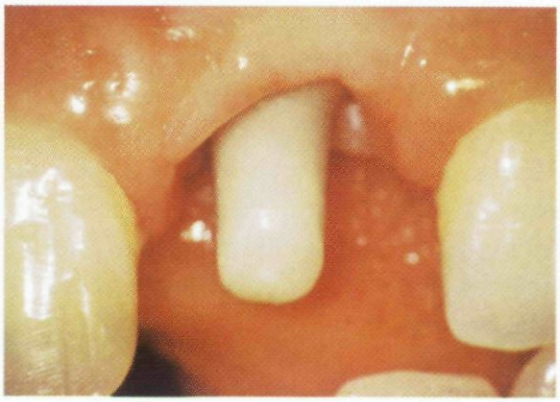

Figure 6 Case 2: the aluminum oxide coping set onto the nonsubmerged implant-supported abutment.

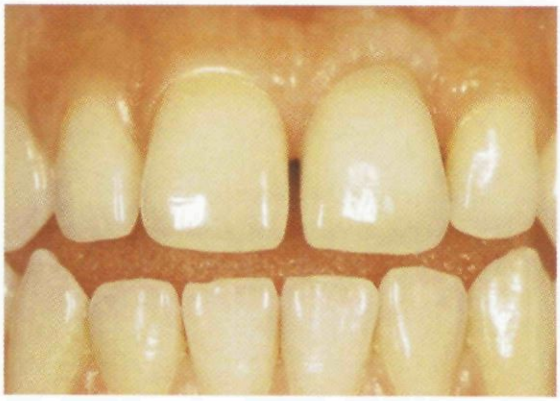

Figure 7 Case 2: the Procera AllCeram crown in region 21 3 years after the cementation.

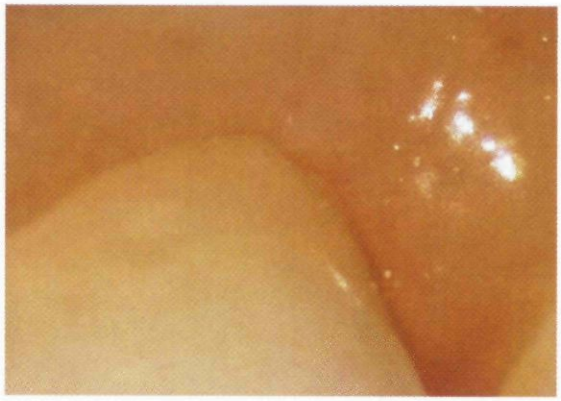

Figure 8 Case 2: marginal adaptation control with a 10× surgical stereomicroscope 3 years after the cementation.

firming the advantageous mechanical performance of alumina in tolerating both occlusal static and dynamical loads for anterior teeth.

In the present study, 28 single crowns had been cemented onto natural tooth abutments, 15 onto maxillary central incisors, 8 onto maxillary lateral incisors, and 5 onto maxillary canines; none of them failed over a period of 48 months, and they were considered satisfactory by both the clinicians and the patients. Moreover, 58 single crowns were used to replace missing teeth after the placement of dental implants; 25 restored maxillary central incisors, 30 were seated in maxillary lateral incisor sites, and 3 replaced maxillary canines. One of them was affected by a chip of porcelain and another was lost; both had been used to restore the function of a maxillary central incisor.

The only crown that was fractured during the entire observation period did not fail because it was affected by a slight chipping of the veneering porcelain, which was intraorally refined; the cohesive fracture did not involve the aluminum oxide core. This occurrence was likely due to the excessive occlusal parafunctional forces exhibited by this male patient, who was affected by severe bruxism; such a condition allowed the parafunctional loads to exceed the tensile strength of the veneering porcelain. The chip of the ceramics occurred in an implant-supported maxillary central incisor; the fracture took place at the level of the incisal margin, which is well known to be a high tensile stress concentration area owing to the occlusal function of incisal guidance.

Over the 48-month period, only one crown was withdrawn. A patient provided with an implant-supported restoration replacing a maxillary central incisor moved to another town 20 months after the cementation of the crown; until that time, the restoration had been considered excellent according to all of the parameters previously described.

Although there is still no consensus about the luting agent to be used with all-ceramic restorations, the glass ionomer cement used in the present study proved to be easy to use and reliable for the medium-term success of the restorations. No crown loss occurred during

the 48-month follow-up period. As for the durability of the luting agent, no difference was noticed in the performance of the hybrid glass ionomer cement on metal abutments, ceramic abutments, and tooth structure.

As to the periodontal parameters evaluated in the present study, a slight soft tissue inflammation was observed during the first month after cementation. A small amount of plaque was evidenced by means of dental plaque–revealing substances on three crowns set onto natural tooth abutments up to 12 months after cementation; such an occurrence was likely due to the patients' fear of damaging the restorations, which was later eliminated through an increase in the patients' motivation toward oral hygiene.

The color of three restorations was considered unacceptable, likely owing to the fact that the three patients who had received these crowns were heavy smokers.

CONCLUSION

Within the limitations of the present study, on the basis of the results of the retrospective evaluation of 86 Procera AllCeram single crowns, the following conclusions were drawn:

- Of 85 restorations completing the follow-up period of 4 years, only 1 crown (1.2%) experienced porcelain chip at the level of the incisal margin. The chip involved the veneering ceramics without affecting the alumina core.
- High success rates were achieved for crowns on both natural tooth and implant-supported abutments.
- The crowns provided excellent aesthetics and color stability in the medium-term observation period.
- Healthy soft tissues were observed around both natural tooth abutment and implant-supported restorations.
- The hybrid glass ionomer luting agent used in the present study proved to be efficacious for the cementation of the crowns, showing proper mechanical behavior and no interference with the shade of the restorations.

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