Clinical Evaluation of All-Ceramic Onlays: A 4-year Retrospective Study

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Purpose: The aim of the present study was to evaluate the clinical outcome of extensive Empress onlays retained with resin-bonded cement. *Materials and Methods:* One hundred thirty extensive ceramic onlays were placed in premolar and molar regions in 91 patients treated by 2 general practitioners between 1997 and 2000. Seventy-seven percent of the constructions were luted with chemically cured resin composite cement and 23% were luted with dual-cured resin cement. Fifty-nine patients with 81 restorations were clinically evaluated independently by 2 calibrated examiners using the California Dental Association protocol. The mean time in function for all restorations at examination was 49 months. *Results:* Seventy-five (93%) onlays were still in function after 4 years. Six onlays (7.3%) had failed; 1 had lost retention as a result of caries, and 5 had fractured. All failures were in molar regions. *Conclusions:* Ceramic onlay therapy is an acceptable treatment alternative over a 4-year period, but further long-term data are necessary before this treatment should be considered for general dental practice. *Int J Prosthodont 2008;21:40–44.*

The alternatives have increased for restoration of lost tooth substance, mainly as a result of patient demand for more natural-looking, metal-free reconstructions. Dental ceramics are well documented for their biocompatibility and toothlike appearance (translucency, fluorescence, chemical stability, and high compressive strength).¹⁻⁸ With extensive loss of tooth substance, full-crown therapy has historically been a reliable treatment choice. Despite the fact that technicians and clinicians have long experience with the technique and despite the predictable survival rate for full-crown therapy, the treatment does have some disadvantages, for example, its standardized preparation method.

New ceramics with improved mechanical properties can be used to restore even posterior teeth.⁸⁻¹⁰ However, when treatment involves resin-based luting agents, there is still uncertainty with respect to retention and durability. Extensive ceramic onlay therapy must rely on bonding technique with etching of both enamel and dentin and the use of resin composite cement.^{11,12} In recent years, a modified bonding technique has been developed that creates an adequately strong and durable interface between the tooth and porcelain but is difficult and time consuming. Some studies indicate that shear bond strength to dentin does not seem to depend on a hybrid layer formation, but on the contact of the adhesive with the mineralized dentinal surface and partly on the orientation of dentinal tubules.¹³ Therefore, new restorative methods must be evaluated, not only from an optimal controlled clinical research setting but also from the perspective of its use by general practitioners, before they are used on a daily basis. Still, technical failures occur, and the most common cause of failure seems to be porcelain fractures. This occurs mainly in the posterior regions. Ceramics should be restricted in patients in whom extensive occlusal loads are expected, eg, bruxism, rehabilitation of posterior teeth.^{14,15} However, there are at present few studies examining the clinical outcome of IPS Empress restorations (lvoclar Vivadent) manufactured for the onlay technique. Treatment indications for extensive ceramic restorations have been widened based on results from clinical research and improved clinical experience with the material, but long-term results must be investigated with the modified preparation technique. The aim of the present

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study was to retrospectively evaluate the clinical performance of extensive IPS Empress ceramic onlays in premolar and molar regions.

Materials and Methods

Ninety-one patients treated with a total of 130 leucitereinforced pressed glass-ceramic onlays (IPS Empress) in premolars and molars and with a minimum of 4 years in function were invited to participate in a retrospective study. Treatment was performed by 2 private practitioners between 1997 and 2000. Sixty-two patients (25 male and 37 female) with 85 onlays attended a clinical examination. The dropout rate regarding the restorations was 35% (45 restorations), corresponding to a patient dropout of 32% (29 patients). Of the 29 patients who did not participate in the clinical examination, 5 were unable to attend because of work-related problems, 8 had moved from the area, 3 could not participate because of illness, 5 did not want to participate, and 8 could not be reached by mail or phone. At the time of the examination, 3 additional patients with 4 onlays were excluded because of extracted teeth or, in 1 case, replacement of the onlay with a full crown after endodontic treatment. Thus, 59 patients (36 women and 23 men; mean age 50.3 years) with 81 ceramic leucite-reinforced pressed glassceramic onlays were examined clinically.

Two different composite cements had been used: a chemically cured cement (C&B, Bisco) and a dualcured resin cement (Choice, Bisco). The treating clinician had made the choice of composite cement. Seventy-four onlays had been placed on molars and 7 had been placed on premolars.

Clinical Procedures

Treatment was indicated for 3 reasons: (1) following a fracture of tooth substance or a previous restoration, (2) for repair of a caries lesion, or (3) for esthetic rehabilitation. Two general practitioners carried out all restorations in a private clinic and were unaware that the patients would be included in a follow-up examination. Tooth preparation included preparation of all cusps, rounded inner angles, and if possible preparation margins placed in enamel. Impressions were taken with a polyether (Impregum, Penta, 3M/ESPE) or an Asilicone material (Express, 3M/ESPE, or President, Coltene/Whaledent) in a semi-arch tray (Triple Trays, Premier). Intermediate restorations (Fermit, Vivadent) were cemented with eugenol-free cement (Tempbond NE, Kerr). In cases where the nonretentive preparation was covered directly, zinc phosphate cement was used (Hoffmann's) on a damp surface. Shades were selected using the Vita shade guide (Vita Zahnfabrik). Two

different dental laboratories were used; however, the majority of the restorations were processed in one laboratory. The minimum thickness of the restorations was 1 mm, and bonding surfaces were treated with hydrofluoric acid at the laboratory. All onlays were manufactured using the painting technique.

The restorations were tested for marginal fit, stability, and color. The internal surface of the ceramic was cleaned after the try-in with 37% phosphoric acid (Ultra Etch) for 15 seconds, rinsed in water, air dried, and treated with a silane solution (Monobond S, lvoclar Vivadent). Rubber dam was applied on the prepared tooth, and the enamel margins and dentin surface were etched with 37% phosphoric acid for 15 seconds, rinsed with water, and briefly dried with compressed air, leaving a damp surface for wet bonding. The cavity and the internal surface of the ceramic restoration were covered with bonding agents applied consecutively (All-Bond 2, Bisco, and Scotchbond, 3M/ESPE). Two different composite cements were used: a dualcuring cement (Choice, Bisco) or a self-curing luting agent (C&B, Bisco). Onlays that were cemented with the dual-cured luting agent were light cured with a photocuring lamp (VCL 400, Demetron) for a minimum of 60 s directed to all surfaces of the restoration. For the self-curing luting agent, the setting time was 6 min. After being luted, the restorations were adjusted for occlusion and articulation; any excess cement was removed. The final occlusal correction was made on the ceramic restoration with diamond or carbide finishing burs under water cooling, followed by polishing stones and rotary rubber instruments.

Evaluation Procedure

Two calibrated investigators examined independently all restorations using the California Dental Associations (CDA) system for quality assessment of dental care.¹⁶ A restoration was judged as successful when it received either of the CDA ratings Romeo (excellent) or Sierra (satisfactory). A restoration was judged as a failure when receiving either of the CDA ratings Tango (not acceptable/should be replaced or repaired) or Victor (not acceptable/must be replaced or repaired). All fractures, including surface fractures, were judged as failures. The investigators performed the clinical examination and evaluation after a careful calibration procedure in accordance with CDA guidelines. None of the examiners had performed any of the restorations. The examiners reached conformity in cases of initial disagreement, and the interexaminer agreement rating was 96% before joint discussion. Disagreement was resolved by consensus. Registration was also made of the preparation design by measuring the distance to the marginal gingiva in accordance with Silness.¹⁷

Table 1 No. and Locations of Onlays

| | Me | Men | | Women | | |
|----------|----------|-------|----------|-------|-------|--|
| Jaw | Premolar | Molar | Premolar | Molar | Total | |
| Maxilla | 2 | 15 | 2 | 11 | 30 | |
| Mandible | 1 | 16 | 2 | 32 | 51 | |
| Total | 3 | 31 | 4 | 43 | 81 | |

Table 3 No. of Empress Onlays Not Receiving Excellent CDA Ratings Provide the second second

| Color | Surface | | Margi | inal | Anatomic | |
|-----------|-----------|--------|-------------|----------|--------------|--|
| (n & %) | (n & %) | | integrity (| (n & %) | form (n & %) | |
| SMM | SRO | VSF | SCR | SDIS | SOCO | |
| 20 (24.4) | 57 (69.5) | 1(1.2) | 33 (40.2) | 11(13.4) | 6 (7.3) | |

Color: SMM = mismatch between restoration and tooth structure within the normal range of tooth color, shade, and/or translucency. Surface: SRO = surface of restoration is slightly rough or pitted, can be refinished; VSF = surface fractured or flaking. Marginal integrity: SCR = evidence of ditching along the margin, not extending to the dentoenamel junction; the explorer got stuck in one direction; SDIS = discoloration of the margin between the restoration and the tooth structure. Anatomic form: SOCO = restoration is slightly overcontoured.

Table 2 Data of Failed Restorations

| No | Location | Rating | Time in service (mo) | Gender | Vital? | Luting material |
|----|------------|------------------|----------------------------|--------|--------|--------------------|
| 1 | Mand molar | Fracture | 46 | F | Yes | C&B |
| 2 | Mand molar | Fracture | 58 | F | No | C&B |
| 3 | Max molar | Secondary caries | 56 | М | Yes | C&B |
| 4 | Mand molar | Fracture | 50 | F | Yes | Choice |
| 5 | Mand molar | Surface fracture | 47 | М | Yes | Choice |
| 6 | Max molar | Fracture | 45 | F | Yes | C&B |

 Table 4
 Locations of Preparations (Marginal Index)

| Location | > 2 mm supra- gingival (n & %) | 1 mm supra- gingival (n & %) | Level of marginal gingiva (n & %) | Sub- gingival (n & %) |
|----------|---|---------------------------------------|--|-----------------------------|
| Mesial | 10 (13) | 10 (12) | 36 (44) | 25 (31) |
| Buccal | 54 (67) | 15 (18) | 10 (13) | 2 (2) |
| Distal | 11 (14) | 14 (17) | 41 (51) | 15 (18) |
| Lingual | 53 (65) | 10 (13) | 17 (21) | 1 (1) |

Plaque and bleeding indices were registered for the onlay tooth as well as for the contralateral tooth in accordance with Lenox and Kopczyk.¹⁸

Statistical Methods

The CDA protocol was used as the basis of analysis of the quality of the restorations. SPSS software version 10.0 (SPSS) was used to process the data. The characteristics of the onlays were elaborated using descriptive statistics.

Results

In total, 81 ceramic restorations in 59 patients were evaluated 43 to 62 months after insertion (Table 1). The mean age of the onlays was 49.3 months. Nineteen onlays were luted with dual-cured resin cement (Choice) and 62 onlays were luted with self-cured resin cement (C&B). Eighteen of the onlays were seated on nonvital teeth and 63 were seated on vital teeth. Six onlays failed; 1 lost retention because of caries and 5 fractured. Data of the failed restorations are shown in Table 2. The success rate of the examined onlays was 92.7%. All failures occurred in molar regions. According to the CDA criteria, registrations of minor changes in clinical performance were made (Table 3). Slightly rough or pitted surfaces were observed at almost 70% of onlays, chipping fractures at 1%, and margin changes at 40%. Discolorations of the margins were seen at 13% of the onlays. Twenty-four percent of the onlays showed color changes. The anatomic form was regarded as excellent in 93% of the restorations. The overall clinical outcome was acceptable.

Calculation of the Marginal Index showed that 66% of the buccal and lingual/palatal margins were placed more than 2 mm supragingivally (Table 4). Proximal margins were placed at the margin or below the cementoenamel junction in 72% of cases. Plaque was seen at almost 90% of both onlays and contralateral teeth, and bleeding on probing was seen at 50% of the registered teeth. However, there was no difference in bleeding on probing with regard to location of the margin of the onlay (subgingival or not).

Discussion

A number of new tooth-colored materials and techniques have been introduced as alternatives to metallic materials to restore cavities in posterior teeth. Some of these materials permit minimally invasive preparations because they can be adhesively luted and therefore do not require mechanical retention. Because adhesive dentistry is technique sensitive, demanding good clinical skill and accuracy, it is vital to study longterm results when adhesive onlay techniques are used in general clinical conditions. However, few studies have dealt with the clinical outcome of these onlay reconstructions.

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Retrospective examinations are limited by their design but are useful in situations when the aim is to evaluate a clinical method and its applicability and wider use in general dentistry. In the present study, 2 private practitioners performed all-ceramic restorations under ordinary clinical conditions, with no awareness that the data would be investigated in the future. Therefore, treatment bias could be considered eliminated.

To obtain a representative sample, all patients who were treated with ceramic onlays in premolar and molar regions between 1998 and 2000 were asked to participate in a clinical examination. Because the indications for treatment were caries lesions, fracture of tooth substance, or esthetic rehabilitation, one could assume that the investigated sample represents a fairly homogenous group of Swedish patients treated with dental ceramics. The dropout rate was 32%, which could be considered a limitation of the study. Eightyone ceramic onlays were examined and 6 were registered as failures, corresponding to a failure rate of 7.3% after an average of 4 years in function. This result is in agreement with other studies concerning the failure rate of Empress all-ceramic restorations.^{7,9,10,14,19,20} In the present study, as in most previous studies, it was found that porcelain fracture was the main reason for failure. Kaytan et al²¹ showed that indirect resin composite and IPS Empress ceramic onlays could be satisfactory for restoring larger cavities in the posterior area, despite marginal deterioration resulting from the wear of luting cement. The longevity of ceramic partial crowns does not seem to be inferior to that of gold alloy crowns, and ceramic could even be considered as a superior material for esthetic rehabilitation.²² A study by Neiva et al² compared the in vitro fracture resistance of 3 all-ceramic systems: bonded IPS Empress crowns, cemented In-Ceram crowns (Vita Zahnfabrik), and Procera AllCeram crowns (Nobel Biocare). Although the Empress crown is theoretically weaker because of the absence of an alumina core, its fracture resistance was equal and somewhat superior to that of the other materials.² This fact might indicate that it is more important to create a strong bond between the ceramic restoration and the tooth substance than to use stronger ceramic materials to avoid ceramic fractures.

Factors other than the porcelain system may influence clinical performance. Of interest is the preparation design; comparisons of inlay versus onlay preparations have revealed differences in long-term results. After controlling for confounding factors such as age of restoration, porcelain system, and clinician skill, a clear tendency has been reported that onlay restorations perform better than inlays. Arnelund et al⁹ found that the failure rate for onlays was 2%, compared to 6% for inlays.⁹ However, this result is not in agreement with the study of Felden et al,²³ where a significantly higher number of failures was reported on partial ceramic crowns compared to ceramic inlays. On the other hand, other studies of resin-retained ceramic crowns found success rates equal to that seen in the present study.^{7,14}

Other authors have observed a difference in restorations on anterior teeth versus those on posterior teeth.^{7,8} In the present study, the failure rate for molars was 8.1%, and no failures occurred at premolars. However, only 7 of the 81 onlays were luted in the premolar region, indicating an inhomogenous distribution for tooth location. Despite this, the failure rate corresponds with the results of other investigations, even though these studies did not separate failures of onlays in premolar areas from those in molar areas.^{14,15,24,25}

The type of bonding agent used was not always registered in the present study, and therefore it was not possible to examine the effect of the luting agents on failures. However, only 2 different cements were used—1 dual-cured resin cement (Choice) and 1 self-cured resin cement (C&B). Relatively similar conditions existed for all the restorations regarding the luting procedure. Sjögren et al²⁴ showed a statistically significant difference between Cerec inlays luted with dual-cured cement and those luted with chemically cured resin cement. All constructions that required replacement had been luted with the dual-cured resin cement.²⁴

In the present study a simple impression technique was used with a semi-arch tray (Triple Trays-Premier), which provides only a partial cast for the technician. However, the simplified impression technique gave results similar to those of other studies concerning fit of the constructions and marginal integrity.^{9,26}

A factor that has not been investigated is postoperative handling of the ceramic surface. It has been stated that performance of a grinding procedure on an intact surface is likely to induce microcracks, which could lead to crack propagation and later fractures.^{27,28} In the present study, most occlusal adjustments were performed on the ceramic restoration, which might have had a negative influence on the overall result.

Within the limitations of this study it can be concluded that IPS Empress onlays can be an acceptable treatment alternative in general dental practice. However, because of the time-dependent degeneration of the ceramic material and possible crack propagation, it is important to further investigate the material in an oral environment to predict the long-term outcome of resin-retained ceramic restorations.

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Literature Abstract

Precision of fit of two margin designs for metal-ceramic crowns

This study compared the precision of fit of 2 margin designs: porcelain butt-joint (BJ) on the buccal side and metal feather-edge (FE) on the lingual side of 32 extracted premolars. These teeth were prepared with a standardized method, and the metal-ceramic crowns were fabricated with a standardized method as well. A profilometer was used to investigate the marginal opening in the mid buccal and lingual areas of the crowns. Data were analyzed using the paired *t* test. The gap size was 27.93 µm (SD: 15.84) for BJ margins and 42.43 µm (SD: 24.12) for FE margins. The gap of FE margins was statistically significantly greater than the BJ margins. The thinner the metal margin, the more distortion caused by firing the porcelain, especially with high gold alloys. The recommendations are to use a BJ, shoulder-metal, or wide-collar (0.8mm) margin instead of the FE margin. Despite the fact that the gap of FE margins was statistically significantly greater than the BJ margins gap of 120 µm.

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