Five-Year Evaluation of Two Resin-Retained Ceramic Systems: A Retrospective Study in a General Practice Setting

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Purpose: This study performed a clinical evaluation of two ceramic systems retained with resin-bonded cement, observed clinical outcomes over time, and compared the two systems used (IPS Empress and Vitadur Alpha) and differences between inlays and onlays. ***Materials and Methods:*** Three general practitioners placed 317 restorations (215 IPS Empress and 102 Vitadur Alpha) in 153 patients. The first clinical registration was performed 6 to 36 months after placement of the restorations by calibrated investigators using the CDA criteria. A second follow-up was performed 36 months later. The mean time in function for all restorations at follow-up was 60 months. ***Results:*** At the first examination, five restorations were not clinically acceptable because of fractures and caries. At follow-up, another 16 restorations were judged as failures. The most significant changes over time were an increase in rough surfaces, evidence of increasing marginal discrepancy, and slight mismatch in color between restored tooth and ceramic restoration. When comparing IPS Empress to Vitadur Alpha, there was no difference in clinical performance. When comparing inlay and onlay restorations, there was a tendency toward a higher number of failures in the inlay group. The overall success rate was 92%. ***Conclusion:*** Ceramic restorations performed well after 5 years in function and provide a good treatment alternative that can be successfully managed in general dental practice. *Int J Prosthodont 2004;17:302–306.*

In modern general dentistry, esthetics is assuming an increasing role in the choices that patients make when seeking restorative dental care. This "cosmetic" focus has resulted in widespread use of porcelain laminate veneers, inlays, onlays, crowns, and short ceramic fixed partial dentures (FPD).[1,2] Another reason for the growing interest in ceramic solutions is the declining use of dental amalgam in Sweden and can be attributed to concerns about health hazards expressed largely by the lay public, but also to the environmental concerns related to mercury waste. The latter issue has brought about government regulations controlling its management.[3]

The use of reinforced porcelain for dental restorations was first described in 1965, through the infiltration of dental porcelain with aluminum oxide.[4,5] In subsequent years, research resulted in various approaches aimed at increasing the fracture resistance of ceramic materials, and, with that, increasing the availability of stronger dental ceramics. Different ceramic materials can be classified according to their composition or by the way in which they are used to fabricate restorations. Feldspathic porcelain is built up in layers on some type of metallic or ceramic coping on refractory die material. To obtain a more fracture resistant material, leucite-reinforced heat-pressed ceramics have been introduced. A crucial difference between conventional complete coverage crown therapy and ceramic inlay and onlay restorations is the luting technique. The clinical performance of phosphate cement is well-documented, and it has been shown to be a predictable luting agent with good long-term results,

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Table 1 Distribution of Restorations by Location, Type, and Ceramic System

Parameter	Incisors	Canines	Premolars	Molars	Total
Jaw					
Maxilla	44	6	67	80	197
Mandible	0	1	29	90	120
Type					
Inlay	0	0	69	112	181
Onlay	44	7	27	58	136
Ceramic system					
Vitadur Alpha	19	2	32	49	102
IPS Empress	25	5	64	121	215
Total	44	7	96	170	317

whereas treatment with acrylic resin–based luting agents is still a matter of uncertainty with respect to retention and durability.[6]

After many years of development, a total-etch approach of the enamel and dentin surfaces and the use of a resin cement is considered to be a safe method for creating a strong bond between the ceramic restoration and tooth substance.[7] The pulpal response to phosphoric acid has been studied. Etching for 15 seconds is not related to adverse reactions of the pulp, even in deep cavities.[8–11] The biologic compatibility of adhesive systems has been evaluated in animal studies, and they have been shown to be nonirritating to nonexposed and exposed pulps.[12] Furthermore, in teeth with severely reduced crown height, a strong retention of the restoration can still be achieved if a modern multistep total-etch adhesive system is applied.[13]

In all dental treatments when restorative materials are used, both technical and biologic failures may occur. Several prospective and retrospective studies have focused on the evaluation of acrylic resin–retained complete ceramic restorations, with promising results regarding success rates, gingival health, and patient satisfaction.[14–16] The most common reasons for failure are material fractures. Some studies conclude that this occurs mainly in the posterior regions. It has therefore been suggested that ceramic restorations should be avoided in patients who brux and in the rehabilitation of posterior teeth.[17]

The aim of the present study was to retrospectively evaluate the long-term clinical performance of two adhesively cemented ceramic systems used for restorations placed by general practitioners, and to compare the two systems with respect to preparation technique.

Materials and Methods

From 1992 to 1996, a total of 200 patients were treated with ceramic restorations at two Public Dental Health Service clinics in the northern part of Sweden. All patients were asked to participate in a retrospective study. Of those invited, 153 agreed to attend the first clinical examination. The remaining 47 patients had either moved from the community, had work-related reasons for not attending, or could not find the time to participate in the study. The final study material comprised 98 women and 55 men with a mean age of 48 years (range 24 to 78 years). In total, 317 restorations, constructed of two different ceramic systems, were examined. One system was a leucite-reinforced pressed glass-ceramic (IPS Empress, Ivoclar Vivadent), and the other was a conventional sintered build-up porcelain (Vitadur Alpha, Vita). The choice of ceramic material was at the discretion of the treating clinician. Similarly, two dual-cure luting resin cements were used (Variolink Dual Cement, Ivoclar Vivadent; and Sono-Cem, ESPE), with the choice of cement made by the treating clinician. The majority of restorations were placed in the premolar/molar area and more often in the maxilla than in the mandible (Table 1). Of the ceramic materials used, IPS Empress restorations were twice as common as Vitadur Alpha ones.

Clinical Procedures

All restorative procedures were carried out by three general practitioners and performed under routine clinical conditions. None of the clinicians were aware that a follow-up examination was to take place. The indications for treatment were a need for tooth restoration because of caries, fracture of tooth substance or of the previous restoration, or a need for esthetic rehabilitation. Tooth preparation was performed by using standard preparation techniques for ceramic restorations, with due consideration of the manufacturers' recommendations. Special care was taken to avoid sharp cavity line angles. In a few cases, undercuts were blocked out with glass-ionomer cement, followed by inlay construction. In most, however, onlay preparations were performed in the presence of undercuts. Polyvinyl siloxane impressions (Provil, Heraeus Kulzer) of the preparations were taken using a putty-wash technique in a perforated metal stock tray (Coe), while the opposing arch was replicated with an irreversible hydrocolloid impression. The restorations were fabricated in the three different dental laboratories normally used by the respective clinicians, and according to the manufacturers' instructions.

At the time of cementation, the ceramic restoration was tested for marginal fit, stability, color, and occlusion. Rubber

dam was then applied, and the fit surface of the ceramic was etched with 37% phosphoric acid, cleansed, dried, and treated with a silane solution (Monobond S, Ivoclar Vivadent). Enamel margins and dentin surfaces 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 dentin surface was covered with dentin bonding agents applied consecutively (Syntac Primer and Syntac Adhesive, Ivoclar Vivadent) according to the manufacturer's recommendations. The cavity and fit surface of the restorations were covered with bonding agent (Heliobond, Ivoclar Vivadent), and one of two dual-cured composite cements was inserted. The luting agent was then light cured with a photo-curing lamp (VCL 400, Demetron) for a minimum of 60 seconds, directed to all surfaces of the restoration. After complete setting, the restorations were checked for harmonious occlusion and excess cement was removed. Whenever possible, the final occlusal correction was made on the opposite tooth to maintain the glazed ceramic surface.

Evaluation Procedures

In total, 317 ceramic restorations were primarily evaluated 6 to 36 months after insertion (Ex 1), and a second evaluation was performed 36 months later (Ex 2). Two calibrated investigators examined the restorations using the California Dental Association's (CDA) system for quality assessment of dental care, using a blinded test approach.[18] Each restoration was first rated by one examiner, with the other not knowing the result. After completed registration, the examiners changed and a second evaluation on each restoration was performed. If there was disagreement after initial evaluation, the examiners reached conformity by mutual agreement. Before the investigation, the examiners carried out an interexaminer calibration procedure according to CDA guidelines, and great care was taken to avoid restorations being examined by the clinician who had performed the treatment. The agreement rating between examiners was 89% without a need for joint discussion.

A restoration was judged a success when it received a CDA rating of R ("excellent") or S ("satisfactory"). A restoration was judged a failure when it received a T ("not acceptable, should be replaced or repaired") or V ("not acceptable, must be replaced or repaired") rating.

At the first examination (Ex 1), the mean functional time of the 317 restorations in 153 patients was 1.7 years (range 0.5 to 3.0 years). At the second examination (Ex 2), 258 restorations in 129 patients were examined, giving a dropout of 59 restorations (19%), corresponding to 24 patients (16%). Of the 24 patients lost to the study, 1 had died, 6 were unable to attend because of work-related problems, 5 had moved and were not able to be reached, 6 were abroad, 3 were ill, and 3 did not wish to participate in the study without giving any explanation. The mean age of the restorations at the second examination was 5.1 years (range 3.3 to 7.0 years).

Statistical Methods

The CDA ratings were used as the basis for analyzing differences between posterior and anterior treated teeth, ceramic systems, and preparation techniques, with the Mann-Whitney *U* test. In addition, a partial correlation analysis was performed when testing the associations between preparation design and failure rate while controlling for age of restoration, ceramic system, and treating clinician. All statistical analyses were performed on an IBM personal computer using SPSS version 11.0 (SPSS).

Results

The success rate at Ex 1 was 98%, arising from a failure of 5 restorations. The corresponding figure at Ex 2 was 92% because of the failure of a further 16 restorations (Table 2). Thus, if individuals who attended Ex 2 are considered (and including the failures recorded at Ex 1), the overall success rate was 92%.

Seven restorations exhibited substantial fractures of the porcelain with no possibility for repair, and a new restoration was therefore constructed. The additional 14 restorations judged as failures included caries, undercontoured anatomic form, large excess of the luting agent, severe surface roughness, and absence of proximal contact with the adjacent tooth.

Restorations that received the CDA rating S, while judged as clinically acceptable, had minor material changes/defects. The most common rating regarding surface and color was "surface of restoration is slightly rough or pitted"; for anatomic form the most common rating was "restoration is slightly overcontoured"; and for marginal integrity the most common rating was "visible evidence of ditching along margin." The overall most frequently registered ratings were visible evidence of ditching along margin (32%) and slightly overcontoured restoration (30%).

There was no statistically significant difference in ratings between inlays and onlays, the two materials used, or failures for molar and premolar restorations. None of the failures occurred on incisors or canines. No associations were found in the partial correlation analysis between inlays and onlays and failure rate when controlling for age of restoration, ceramic system, and clinician.

Discussion

In the present study, all-ceramic restorations were performed under routine clinical conditions by three general dental practitioners. Although there are several weaknesses in a retrospective study, we find this design appropriate in a situation where the aim is to evaluate the

Table 2 Distribution of Restorations Related to Failures at First Examination (Ex 1) and Second Examination (Ex 2)

	Maxilla		Mandible		Inlay		Onlay		IPS Empress		Vitadur Alpha	
Tooth*	Ex 1	Ex 2	Ex 1	Ex 2	Ex 1	Ex 2	Ex 1	Ex 2	Ex 1	Ex 2	Ex 1	Ex 2
Incisors	44	32	0	0	0	0	44	32	25	16	19	16
Canines	6	4	1	1	0	0	7	5	5	3	2	2
Premolars	67	61	29	22	69	59	27	24	64	51	32	32
Failures	2	4	0	0	2	3	0	1	2	3	0	1
Molars	80	68	90	70	112	87	58	51	121	93	49	45
Failures	1	4	2	8	3	8	0	4	1	8	2	4

*No failures occurred in restorations on incisors or canines.

applicability of a clinical method for use in the broader context of general dental practice. The fact that the treating clinicians did not know that an investigation was to take place could be considered a strength by elimination of treatment bias. Bearing in mind that adhesive dentistry is a technique-sensitive method that demands good clinical skill and accuracy, it is of great importance to study the long-term result when the technique is performed under general clinical conditions.[19] To obtain a representative sample, all patients who were treated with ceramic constructions from 1992 to 1996 were asked to participate. Although 47 of the 200 invited patients never attended the examination, information obtained from these patients did not reveal any discomfort with the treatment as a reason for not participating in the study. With the relatively low dropout rate, this suggests that the sample represented a fairly homogeneous group of Swedish patients treated with ceramic restorations by Public Dental Health Service general practitioners.

At the time of the follow-up examination, 258 ceramic restorations had been observed, with 21 restorations registered as failures, corresponding to a failure rate of 8% after a mean of 5 years in function. This result is in agreement with other studies concerning failure rate,[14,15,17,20,21] although there were some differences regarding reasons for failure. While most previous studies have reported porcelain fracture as the main reason for failure, in the present study caries was responsible for 9 of the 21 failures. One possible explanation could be poor patient selection, inadequate bonding between the porcelain and tooth surface, or insufficient operator experience with the treatment modality. As caries was detected during examination with a probe, these restorations were regarded as failures even though these small lesions were repairable using a direct restorative technique. However, this must be considered a failure, as the original marginal integrity had been modified.[22–24]

Two of the restorations were judged as undercontoured to the extent that proper oral hygiene could not be practiced. A large excess of the luting agent was observed in one restoration that was consequently judged a failure even though subsequent adjustment led to an acceptable clinical situation. The two remaining failures were recorded as severe surface roughness and absence of proximal contact with the adjacent tooth.

Regarding the failure rate within the total group, there was no significant difference between the conventional porcelain (Vitadur Alpha) and the leucite-reinforced porcelain (IPS Empress). This is in accordance with the results from similar studies. For example, sintered ceramic and glass-ceramic inlays processed by the Cerec computer-aided design/manufacturing (CAD/CAM) system (Siemens) had failure rates similar to our results.[16] This could indicate that the choice of ceramic material is of secondary concern for predicting long-term outcome, and that other factors such as preparation design and bonding technique might be of greater importance. At variance with the results of the present study, Empress inlays in one study exhibited a higher frequency of failures than Cerec and Mirage (Chameleon Dental) systems, although the authors did not provide any plausible explanation for their findings.[15]

Although reinforced ceramic materials such as the IPS Empress system perform better in laboratory flexure strength tests than do materials with less reinforcement, there is a question about the clinical relevance of such a difference. The in vitro fracture resistance of IPS Empress is similar to that of In-Ceram (Vident) and Procera AllCeram (Nobel Biocare).[25] While this may be surprising on the basis of Empress being theoretically weaker because of the absence of aluminum oxide, it could well be that, rather than using ever stronger materials to avoid fractures, it is equally important to create a strong bond between the ceramic restorations for a successful outcome.

Although not statistically significant, the failure rate for onlays was 2%, compared with 6% for the inlays. This result is somewhat in contradiction to a previous report of a significantly higher number of failures of partial ceramic crowns compared to ceramic inlays.[26] In another study, acrylic resin–retained ceramic crowns exhibited a similar success rate as in the present study.[17] More long-term studies are needed to evaluate the clinical performance of inlay versus onlay restorations in different clinical situations.

Clinical performance is affected by the site of ceramic restorations. In the present study, the failure rate was 2% for premolars and 5% for molars, while no failures were

registered on incisors or canines. This corresponds with the results from other investigations,[14,17,21] although the difference between premolars and molars in the present study did not reach statistical significance. This could be of clinical importance even though the difference could not be verified in a statistical analysis.

The effect of choice of luting cement on failure rate was not recorded in the present study and represents a weakness. On the other hand, only two different cements were used, and both were dual-cured resin cements (Variolink and Sono-Cem), although with different viscosities. Nevertheless, by virtue of uniform isolation techniques during cementation, relatively similar conditions existed for all restorations regarding the luting procedure. Another factor that was not investigated is the postoperative handling of the ceramic surface. A grinding procedure on an intact surface is likely to induce microcracks, which could lead to crack propagation and later fractures.[27] In the present study, when needed, the opposite tooth was checked and sometimes adjusted for sharp occlusal form to minimize the risk of porcelain surface deterioration. This procedure might have had a positive influence on the overall result but was not considered because of lack of prestudy planning.

Since it is known that continuous cyclic stresses operating in the oral environment increase the risk of failure of acrylic resin–retained ceramic material over time, it is important to continue with follow-up studies that investigate the many factors that may be of relevance to long-term clinical outcome. Ceramic restorations performed well after 5 years in function and provide a good treatment alternative that can be successfully managed in general dental practice.

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