Six Years of Clinical Experience With an All-Ceramic System

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ABSTRACT

The search for tooth-coloured and metal-free restorations is one of the major challenges in dental research. For several decades, ceramic has been used as a restorative material because of its aesthetics and stability. Unfortunately, the survival rate of most all-ceramic systems seems unsatisfactory; due to the natural brittleness of ceramic, fractures have been the primary reason for the high failure rate. Since 1988, the University of Zurich Dental School, Switzerland, has been working with the IPS Empress™ all-ceramic system (Ivoclar, Schaan/Liechtenstein). This article reports the clinical and research data from approximately 3,000 all-ceramic restorations.

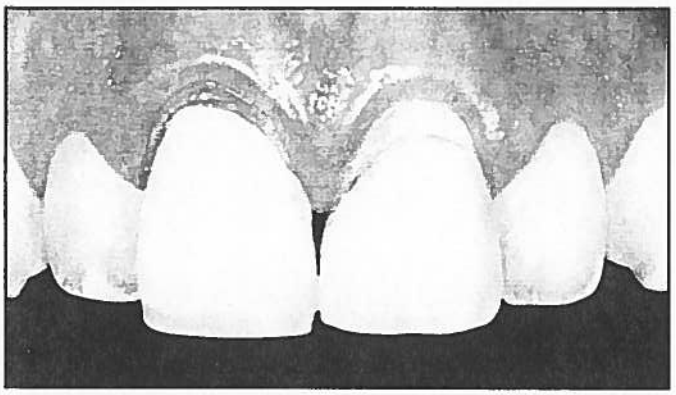
The technology to bond ceramic restorative material to a metal framework was first introduced in 1962, using the sintering technique.[1] This porcelain-fused-to-metal (PFM) design proved to be suitable for individual crown and multi-unit bridge restorations.[2] However, the metal framework is not translucent and obstructs light transmission making it difficult to reproduce the light dynamics of natural dentition at the gingival interface. The development of a metal-free restorative material made the achievement of hard and soft tissue aesthetics comparatively simple.[3] Only a translucent material can offer the "chameleon effect" and thereby produce a flawless colour adaptation of the restoration (Figures 1 through 3).

In addition to aesthetic considerations when selecting a restorative treatment method, patients have questioned the use of amalgam and nonprecious alloy. As a result of such interest, new all-ceramic systems have been introduced.[4] Most of these systems can achieve externally aesthetic restorations; however, as long-term studies indicate, only a few of the systems as of yet can replace gold, amalgam, or PFM restorations with regard to long-term durability.

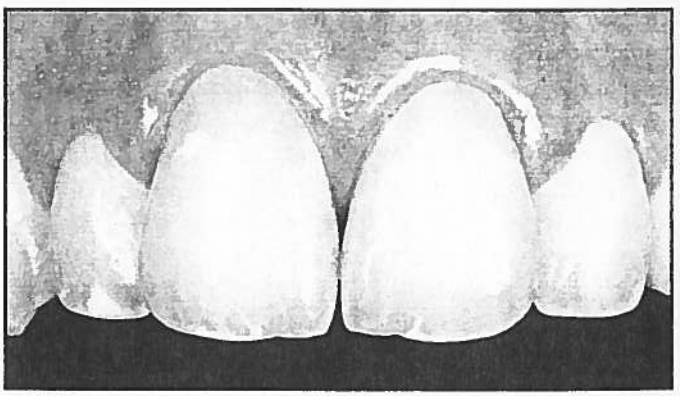
Fractures have generally been responsible for the high failure rate of all-ceramic restorations. During a 4-year clinical evaluation, favourable clinical results were obtained in regard to porcelain laminate veneer restorations.[5] Sinter ceramics were fired to a heat stable die and were bonded using a composite cement. For inlays, onlays and all-ceramic crowns, the results after a short period were mostly unsatisfactory, according to the published data.[6-8] The computer-milled all-ceramic material (Cerec-Inlay®, Siemens Pelton & Crane, Charlotte, NC, USA) demonstrated acceptable results over a 5-year period.[9] Since 1988, the University of Zurich Dental School has been successfully working with the all-ceramic system (IPS Empress™, Ivoclar, Schaan/Liechtenstein). The published 3-year results,[10,11] as well as the 4-year results[12,13] are encouraging. The inlays and the full-coverage crown restorations achieved a survival rate in excess of 95% (Figures 4 through 7).[14]

MATERIAL

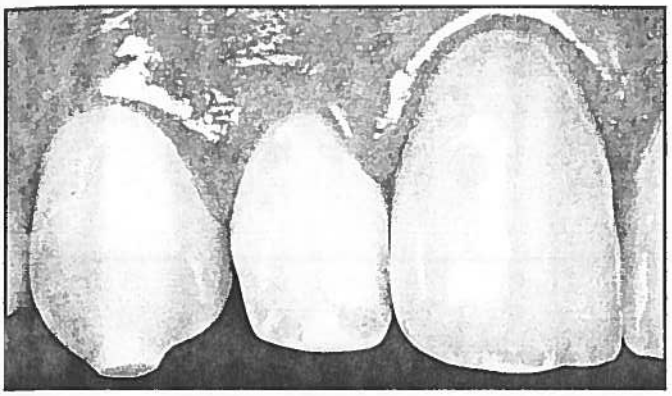
The all-ceramic system (IPS Empress™, Ivoclar, Schaan/Liechtenstein) was first introduced in 1990 as a new alternative in the fabrication of all-ceramic crowns, inlays, onlays, and veneers.[15,16]



1. Pretreatment view of the maxillary anterior dentition. The patient is dissatisfied with the nonaesthetic restorations of the central incisors.

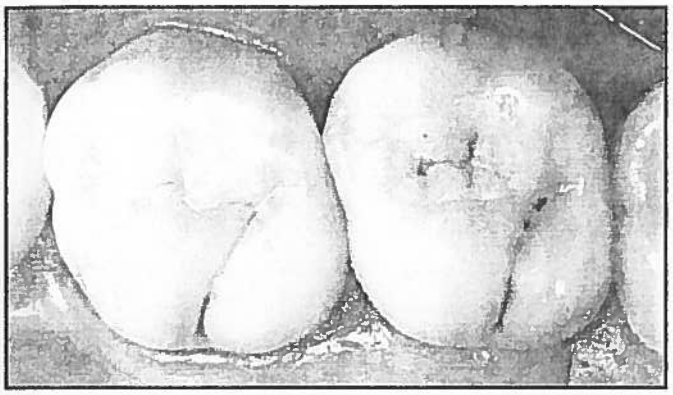


2. Posttreatment view of both maxillary central incisors, restored with layered all-ceramic crowns. The restorations are in harmony with the adjacent teeth. (Technician: N. Pietrobon.)

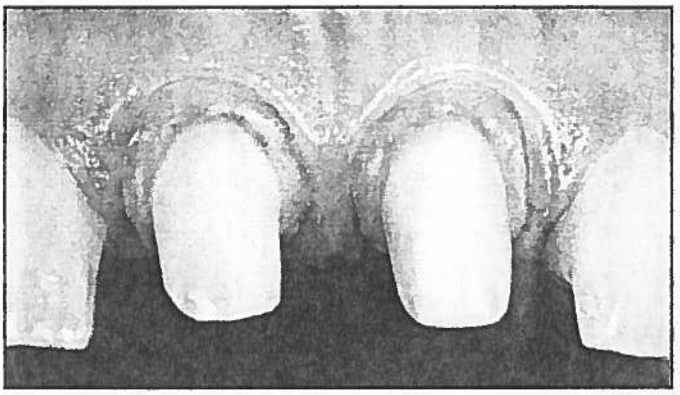


3. Posttreatment view of the maxillary right central incisor, restored with an all-ceramic crown. (Technician: N. Pietrobon.)

4. Pretreatment occlusal view of the amalgam restorations in teeth #14(26) and #15(27) prior to tooth-coloured replacement.



5. Posttreatment occlusal view of the all-ceramic restorations in teeth #14(26) and #15(27) after 5 years of flawless function and aesthetic appearance. (Technician: Tom Riedel.)



6. The circular step preparation is ideal for all-ceramic, metal-free crowns. A thread has been placed in the sulcus for the cementing process.

During manufacturing, leucite crystals 5 μm long are homogeneously dispersed in the glass phase; hence the name "leucite reinforced glass ceramic." The strength of the material is achieved by a pressing process and subsequent firing procedures. The pressed core material is identified by its optimum homogeneity. There is no visible porosity; this situation is contrary to the use of any other laboratory fabricated sintered ceramic, where porosity promotes the advancement of fissures within the material and has an overall negative effect on the mechanical properties of the material.

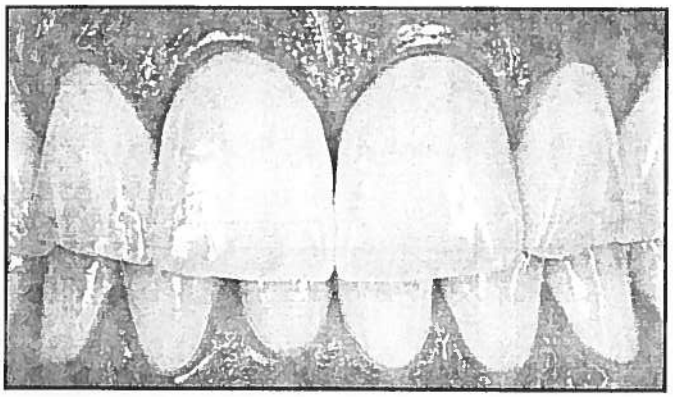
In abrasion tests, the material of this new system, whether polished or glazed, has exhibited the same properties as natural tooth enamel.[17] Due to the homogeneity and fineness of the material, the concern of excessive wear of the restoration or the opposing dentition has been eliminated. Regarding marginal fit, the all-ceramic system (IPS Empress™, Ivoclar, Schaan/Liechtenstein) used demonstrated superior results in comparison with other all-ceramic systems. Full-coverage crown restorations exhibited a median value of under 50 μm, with a homogeneous distribution and a small standard deviation.[18] The marginal integrity of the all-ceramic inlays were measured within approximately the same size range of 50 μm.[17]

The all-ceramic system eliminates the time-consuming duplication of the master models needed to make a refractory die.

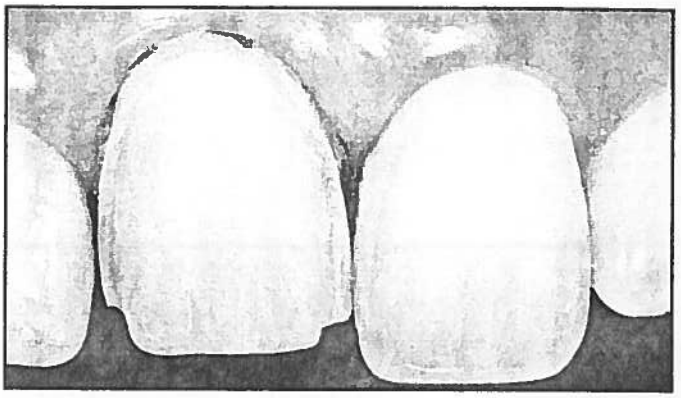
In the three-point transverse-bending test, the new all-ceramic system exhibited a flexural strength of approximately 200 MPa.[19,20] In comparison, conventional ceramics (either attached to a heat stable die or fired to a metal or extruded all-ceramic framework) produced a value of approximately 70 MPa, and another castable glass ceramic (Dicor®, Dentsply International, Inc., York, PA, USA), produced a result of 125 MPa.[21] The enhanced strength of the pressed core material is not solely responsible for the improved long-term clinical results; other parameters more difficult to determine, such as ductility and fatigue, may also be contributing factors. The entire measurement data produced under laboratory conditions cannot be transferred to the clinical application unconditionally.[2] The in-vivo long-term trial is the first to exhibit the overall usefulness of an all-ceramic restorative material with applications in everyday practice; no elaborate test apparatus yet exists that can faithfully simulate actual clinical conditions.

TECHNICAL PROCEDURE

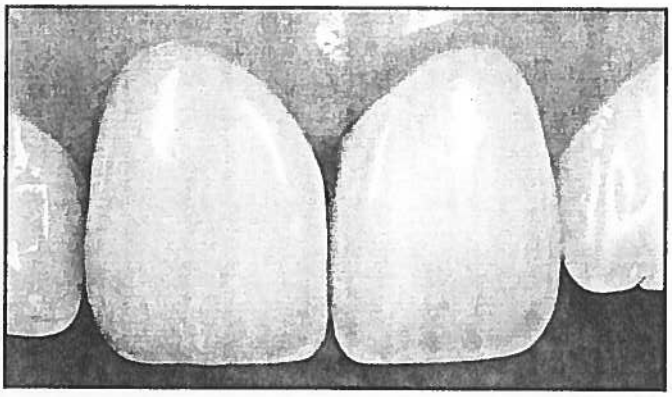
The technique utilized for pressed ceramics corresponds with the casting of gold, which is a cornerstone of dental training. The desired restorative treatment



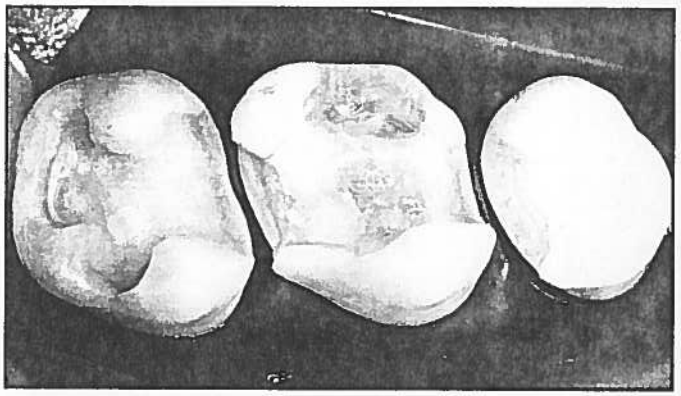
7. Posttreatment view of teeth #8(11) and #9(21), with layered all-ceramic crowns. (Technician: Arnold Wohlwend.)



8. Preparation of tooth #8(11) for the incorporation of a porcelain laminate veneer.



9. Posttreatment view of tooth #8(11), 4 years after placing porcelain laminate veneer. (Technician: Mario Sisera.)



10. Inlay preparation on teeth #13(25) and #15(27), onlay preparation on tooth #14(26).

(inlays and onlays, porcelain laminate veneers, and full-coverage crowns) is wax formed directly on the master model. The type of wax used by the all-ceramic system burns off easily without leaving a residue. The waxed units are sprued and invested and placed in a furnace. The ceramic material is available in a variety of ingots with varying opacities and colours. In an oven developed specifically for this process, the ingots are pressed into their final form under vacuum at a temperature of approximately 1,100°C and a pressure of 5.0 bar. The ceramic is never liquefied during this process. Its contour is formed while it still has the consistency of plastic.

Once the material has been formed, each individual pressed component is either painted or glazed (colouring technique) or, in the middle of the layering technique, it is built up further, as is commonly done with PFM fabrication techniques. The colouring technique is recommended for full-coverage crown restorations in the posterior region as well as for inlays and onlays. For anterior crowns, either the shading or layering techniques can be used. The all-ceramic material is firing stable; therefore, if changes such as building up contact points or contour corrections are required, sharp edges or margins will not be lost as a result of repeated firings.

All-ceramic inlays and onlays exhibited the same survival rate as amalgam restorations over the same time span.

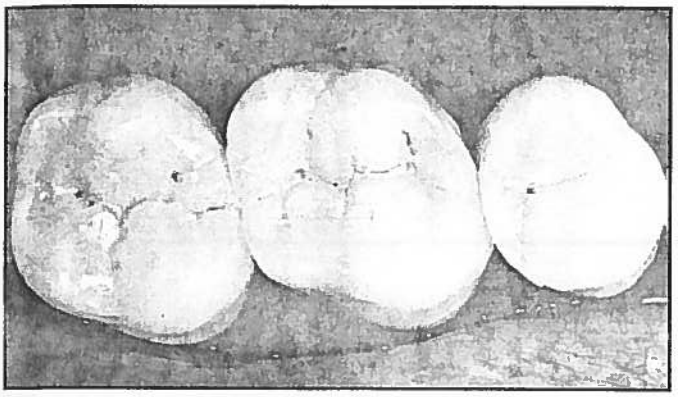
The expertise in using the all-ceramic system can be easily acquired by experienced dental technicians. This procedure eliminates the time-consuming duplication of the master models needed to make a refractory die, and multiple restorations can be fabricated simultaneously. These two factors highlight the cost-effectiveness associated with this all-ceramic system.

CLINICAL PROCEDURE

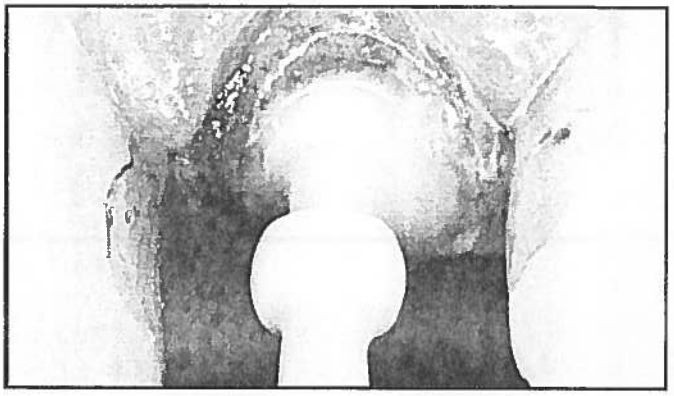
As with most of the failures outlined, the primary reason for fractures were neither the material nor the fabrication process. Generally, faulty preparation and/or failure to adhere to all established parameters of successful adhesive bonding often results in prosthetic failure. The two primary elements needed to achieve successful all-ceramic restorations are proper preparation of the tooth itself and mastering the adhesive technique.

Preparation

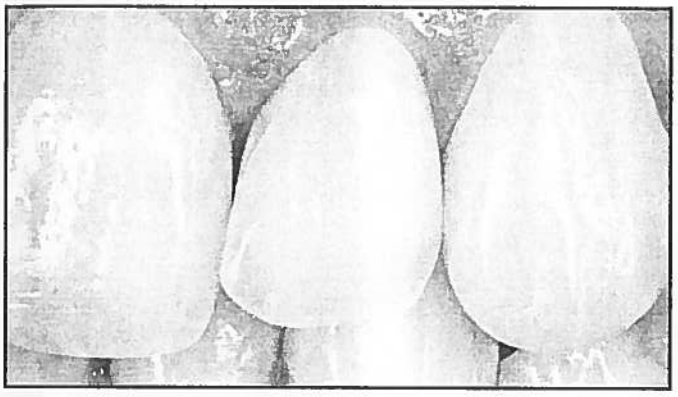
All-ceramic restorations require a preparation technique that is entirely different from the techniques used in gold restorations or PFM restorations. Ceramic is fundamentally brittle and



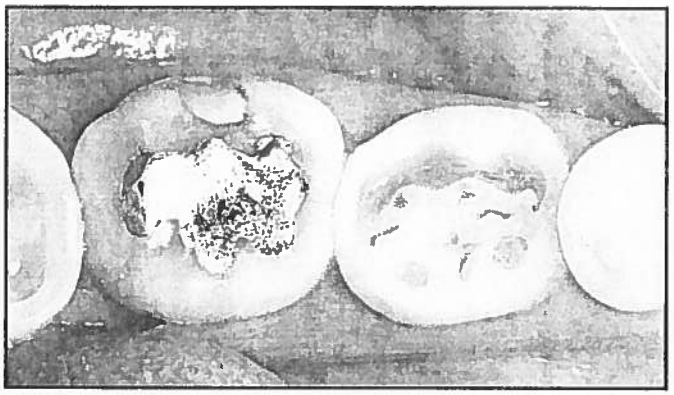
11. Posttreatment view of the all-ceramic restorations cemented in place, inlays on teeth #13(25) and #15(27), onlay on tooth #14(26). (Technician: Arnold Wohlwend.)



12. A zirconia post mounted with composite cement to anchor the root.



13. A layered all-ceramic crown restores tooth #10(22). (Technician: Arnold Wohlwend.)



14. Pretreatment view of occlusal problems in the left mandible of a 28-year-old patient.

is unable to reach the ductility values of metal. Although marginal areas that sharply depart from the peak, such as feather margins or bevels, can be fabricated without difficulty using the all-ceramic material, there is a high risk of fracture during the placement of adhesive procedures. For this reason, preparation margins should be formed at a right angle whenever possible, thereby effecting the optimum stability of the restoration as well as the prepared tooth. This indicates the use of butt joined margins for inlays, onlays, and full crowns and chamfer margins for porcelain laminate veneers. In contrast, within the preparation margins, rounded internal line angles are indicated. This preparation design will avoid stress areas in the remaining tooth structure and the ceramic restoration.

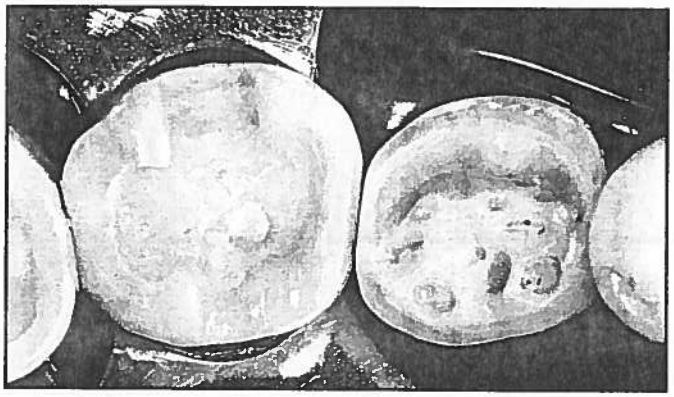
For proper preparation thickness, it must be determined whether the anticipated restoration resides in direct contact with enamel or dentine. The cementation process guarantees the reinforcement and strengthening of the ceramic only if a tight bond is achieved. Optimal adhesive values at this time can be expected only if the preparation remains in the enamel. If the preparation lies primarily on the enamel layer (occlusal, proximal, or buccal),

The cementation process guarantees the reinforcement and strengthening of the ceramic only if a tight bond is achieved.

a reduction of 0.5 mm is sufficient to incorporate a porcelain laminate veneer (Figures 8 and 9).

The preparation of a retention form can be omitted. Contrary to bonding to enamel surfaces, the minimum anticipated bond strength values are not adequate for a dentine adhesive to sufficiently reinforce a thin ceramic restoration. Therefore, if a ceramic restoration is cemented to dentine, it does not have an equally stable foundation for adhesion, since the elasticity modulus is significantly lower than that of natural enamel. Therefore, the restoration should maintain sufficient thickness when there is an insufficient amount of enamel and dentine. In this case, the restoration must be able to withstand mastication without any reinforcement from the adhesive.

The standard values for the minimum thickness of all-ceramic restorations bonded to dentine are as follows: For crowns in the occlusal region, 1.5 mm; axially, 1.0 mm; and for inlays or onlays that cover cusps and partial crowns, 2.0 mm. A retentive preparation design (parallel walls, minimal prep length) is necessary only for full-coverage crown restorations, when there is no enamel available to guarantee the retention of the restoration to



15. Preparation of partial crowns is achieved with minimal loss of enamel and dentine.

16. Posttreatment view of the restorations. A natural Spee curve is created. (Technician: Mario Sisera.)

the dentine substructure after the adhesive cementing process. If the tooth is built up using composite, glass-ionomer cement or gold, the same parameters apply as for dentine.

Cementation Procedure

All-ceramic restorations should be placed using a translucent or minimally tooth coloured, dual cure composite cement. In order to avoid postoperative sensitivity, a fifth-generation dental adhesive is used to seal the dentinal tubules. To achieve optimal bond strength, the internal surface of the ceramic restoration is first etched with a buffered liquid acid and silane is then applied. The use of a composite luting cement is recommended not merely for aesthetics but to improve strength as well. A clinical study demonstrated that bonded castable glass ceramic restorations (Dicor®, Dentsply International, York, PA, USA) had a significantly higher survival rate than those placed with a conventional cementing procedure utilizing glass ionomer or zinc oxyphosphate.[22] Laboratory research has confirmed that bonded all-ceramic restorations withstand a greater amount of force.[23]

When ceramic inlays are seated with adhesive material, the primary cusps are actually reinforced by the intense bond between the ceramic, composite, and tooth structure; as a result, the fracture strength achieved is comparable to that of a natural tooth.[24,25] Even the ceramic inlay is strengthened by the adhesive cementation process and exhibits higher fracture resistance.[26]

Since many of the steps required for the successful bonding of ceramic to tooth structure are sensitive to moisture, the working field for all Class II inlay techniques must remain dry; therefore, proper isolation techniques must be employed.

CLINICAL LONG-TERM RESULTS

At the University of Zurich Dental School, clinical follow-up examinations of all-ceramic restorations are performed on a regular basis, and all published works involve prospective studies. Each of the all-ceramic restorations is thoroughly examined using an intra-oral mirror and a probe, radiograph, and silicone model. The 3-year results were published in 1992[10,11] and reported a survival rate of 98% for inlays and onlays and 95% for full-coverage crown restorations.[14] The report of the 4-year data will be published this year. The survival rates remained equally as high. The 6-year results cannot as yet be scientifically evaluated. Observations made during the patients' hygiene visits are encouraging: all-ceramic inlays and onlays exhibited the same survival rate as amalgam restorations over the same time span (Figures 10 and 11).[27,28] All-ceramic crowns in the anterior region exhibited a life expectancy similar to conventional PFM restorations and therefore they are considered to be an acceptable alternative.[29,30]

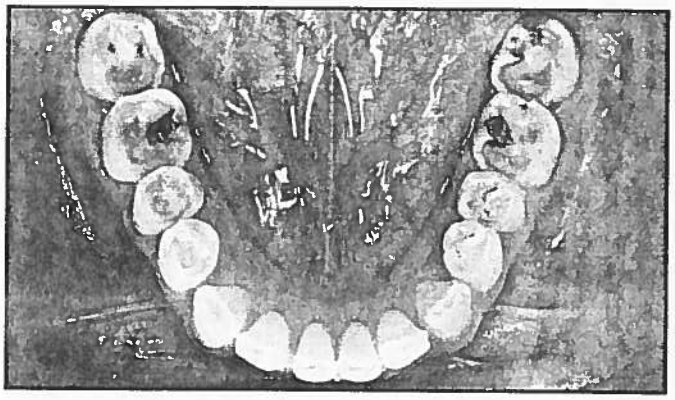
Even the ceramic inlay is strengthened by the adhesive cementation process and exhibits higher fracture resistance.

Clinical Determinations

Due to its favourable long-term results, the all-ceramic system used (IPS Empress™, Ivoclar, Schaan/Liechtenstein) is the preferred material for ceramic inlays and onlays, veneers, and all-ceramic crowns in the anterior region. Until now, the full-coverage restorations in the posterior region have not shown an increased fracture rate. However, it is necessary to exercise caution, as a higher failure rate was noted with both the molars and premolars with the use of other all-ceramic systems. When working in the posterior region, the shading technique should be used in order to achieve the most consistent strength (Figures 5, 11, and 16). The layering technique is used for most anterior restorations (Figures 2, 3, 7, 9, and 13) for critical aesthetics. When using the layering technique, there is a slight possibility of incorporating porosity during laboratory fabrication, which may compromise the ultimate flexural strength.

The number of porcelain laminate veneers, partial crowns, and onlays placed is influenced by the cost of full-coverage restorations. The preparation procedure described for all-ceramic

17. Preoperative facial view of the maxillary and mandibular teeth. Abrasion and erosion have led to massive enamel and dentine loss.



18. Preoperative occlusal view of the mandibular arch. The patient requested a complete reconstruction to enhance function and aesthetics.

restorations has proved to be an excellent concept for preserving tooth structure. Molars and premolars do not require excessive preparation when cusp losses are involved; most of the problems associated with an increase in endosteal and periodontal complications are a result of this practice.

Dentists as well as dental technicians were at first critical of the shading technique. It was feared that the surface characterization would not be sufficiently resistant to abrasion and would therefore lead to aesthetic failures. Aesthetically, this method has proved to be equal to the layering technique. Since 1993, the minimally tinted all-ceramic ingots (TC1-TC5, Ivoclar, Schaan/Liechtenstein) have been available for use with the shading technique. The absence of grinding after placement has not been an aesthetic disadvantage; once polished with rubber polishers, the materials are hardly noticeable.

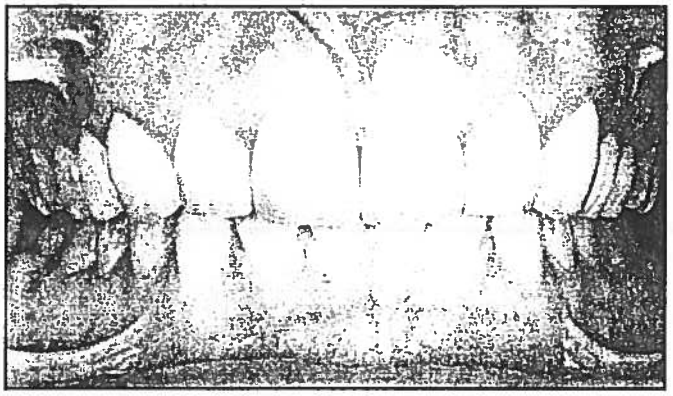
Before 1991, postoperative sensitivity along with occlusal discrepancies were often noted with inlays and onlays. In most cases, the sensitivity disappeared within several weeks or months. Since the arrival of the advanced-generation dental adhesives, these problems have rarely surfaced, as these improved products seem to effectively seal the dentine tubules. "Dentine desensitizers" would be a more appropriate term for these adhesives; the present name can be misleading, because all long-term trials performed to date report that a reliable adhesive value is still nonexistent.

Dental adhesives cannot be utilized in the same fashion with indirect all-ceramic restorations as they are with direct composite fillings. With the direct composites, the dental adhesive is placed, then immediately polymerized using a light-curing unit, which is directed with full intensity at the material. Next, the restorative composite is placed incrementally, using a layered technique to ensure intimate contact with the restorative material and the gingival seat and to minimize shrinkage forces. In contrast, the fit of an indirect all-ceramic restoration could be compromised by polymerizing the dental adhesive prior to seating if the film thickness of the dental adhesive is significant. With a precision fit for a restoration being between 0 μm and 100 μm, even a minimal increase in the cavity dimension can make proper placement impossible.

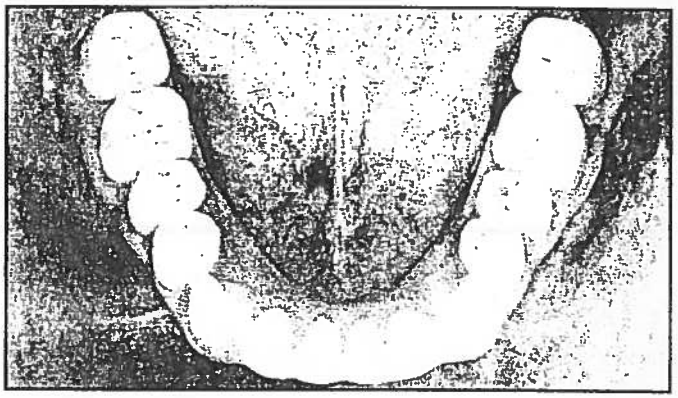
The patients as well as the dental clinicians and technicians are satisfied with the aesthetics of the all-ceramic system.

The weak spot of any seated all-ceramic restoration is the composite in the marginal gap. Marginal ditching may develop, particularly with inlays and onlays in the posterior region, as the less wear-resistant resin cement seeks refuge between the ceramic and the tooth enamel ("protective trench phenomenon"). The eroding action, upon which the marginal gap size measurement depends, seems to terminate at a depth of approximately 20 μm to 100 μm. Examinations in the laboratory confirm this observation.[32] Numerous publications demand the "perfect margin" as a prerequisite for long-term success of adhesively bonded restorations. Whether the "perfect margin" has any clinical relevance to long-term success is still under debate.

Patients as well as dental clinicians and technicians are satisfied with the aesthetics of the all-ceramic system. The inlays and onlays appear to fuse with the remaining tooth structure and resemble natural dentition. Due to the enhanced translucency of the ceramic, the "chameleon effect" can be recognized (Figures 17 through 20). One of the major challenges for any dental professional is a single tooth restoration surrounded by natural dentition (Figures 14 through 16). It is especially difficult to achieve hard or soft tissue aesthetics in young patients who have highly translucent teeth in combination with a high lip line. It has been demonstrated that a more natural replica of the tooth to be replaced is achieved more easily with the use of all-ceramic material. Dark discoloured roots that are eventually restored with a metal post present an obstacle too difficult to overcome for optimal aesthetics. Even



19. Two-year postoperative facial view; 26 all-ceramic restorations completed. Ceramic layering was performed only in the anterior region of the maxilla. (Technician: Andreas Karth.)



20. Two-year postoperative view of the mandible, restored with 14 all-ceramic restorations (partial crowns, porcelain laminate veneers, onlays). (Technician: Andreas Karth.)

the use of a metal-free system in the development of the full-coverage crown restoration will not allow sufficient light to penetrate the root and the periodontium in order to prevent the disturbing grey discolouration of the gingiva. A high-strength composite should be used to cement the post so that light can be successfully transmitted (Figures 12 and 13).[33]

CONCLUSION

For the past 7 years, the University of Zurich Dental School has successfully worked with the IPS Empress all-ceramic system, which is universally suited for the fabrication of inlays and onlays, laminates, and partial and full-coverage crown restorations. The technical work that must be performed in the laboratory is easy to master. The potential difficulties are with the modified clinical preparation technique, developed for all-ceramic restorations, and mastering the adhesive bonding procedure. The survival rate of the all-ceramic inlays and onlays has exhibited the same durability as conventional amalgam restorations. By observing all general guidelines and instructions, the patient may be offered durable all-ceramic restorations that provide aesthetics which rival the natural dentition and can provide long-term function and performance.

ACKNOWLEDGMENTS

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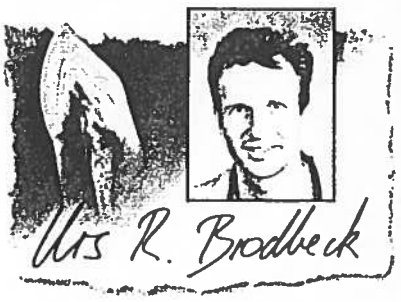

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