All-Ceramic Alternatives to Conventional Metal-Ceramic Restorations

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Abstract: *In the search for the ultimate esthetic restorative material, many new all-ceramic systems have been introduced to the market. One such system, In-Ceram®, is primarily crystalline in nature, whereas all other forms of ceramics used in dentistry consist primarily of a glass matrix with a crystalline phase as a filler. In-Ceram® can be used to make all-ceramic crowns and fixed partial denture frameworks. Three forms of In-Ceram®, based on alumina, spinel (a mixture of alumina and magnesia), or zirconia, make it possible to fabricate frameworks of various translucencies by using different processing techniques. This article discusses clinical indications and contraindications for the use of In-Ceram® Alumina and In-Ceram® Spinell all-ceramic restorations. Particular attention is given to cement considerations using several clinical examples.*

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Many new ceramic materials and techniques have been developed recently for both conservative and full-coverage all-ceramic restorations. Because of poor physical properties, conventional materials used for all-ceramic restorations have been fraught with problems, specifically, early catastrophic failure. Increased crystalline-filler content within the glass matrix, with a more even distribution of particles and finer particle size, has yielded significant improvements in the flexural strength of ceramic materials.[1,2] Nevertheless, strength improvements are limited by the inherent weakness of the glass matrix. All ceramics fail because of crack propagation at a critical strain of 0.1%.[3] Applied stresses can cause crack growth through the glass matrix with ultimate failure of the restoration. Acid etching and adhesive luting can greatly limit crack growth,[4] probably through a process of crack-bridging by the luting composite at the bonded interface of the porcelain.[5]

In 1988, a completely new form of ceramic was introduced to dentistry.[6,7] Marketed under the name In-Ceram®,[a] the system was developed as an alternative to conventional metal ceramics and has met with great clinical success.[8,9] The system uses a sintered crystalline matrix of a high-modulus material in which there is a junction of the particles in the crystalline phase (Figure 1). This is unique in that the crystalline filler used in previous ceramic materials had no such junction of particles (Figure 2).

The crystalline phase consists of alumina or a mixture of alumina and magnesia appropriately named Spinell. It is fabricated by a process called slip casting (Figure 3)[10] or can be milled from a presintered block of either material (Figure 4).[11] The alumina or spinel framework is then infiltrated with a low-viscosity lanthanum glass at high temperature (Figure 5). Extremely high flexural strengths have been reported for this new class of dental ceramic, three to four times greater than any other class of dental ceramic.[1,2,12] It is theorized that this high strength results from the primarily crystalline nature of this material and its minimal glassy phase. A flaw would have to propagate through either the high-modulus alumina or spinel to cause ultimate failure.

When glass-infiltrated in an air environment, as the manufacturer recom-

[a]Vita Zahnfabrik, Bad Sachingen, Germany (distributed in US by Vident™, Brea, CA 92621)

Learning Objectives:

After reading this article, the reader should be able to:

- explain how altered processing techniques can affect the flexural strength of an all-ceramic restoration.
- contrast the basic microstructural characteristics of In-Ceram®-type ceramics and conventional or glass ceramics.
- describe the selection criteria for using all-ceramic restorations.
- identify the techniques and cements that will increase bond strength of In-Ceram® Alumina and Spinell restorations.

Dr. McLaren presented this topic at the 1997 Henry M. Goldman Symposium at Boston University.

Figure 1—Scanning electron microscopy (SEM) of In-Ceram® core material demonstrating a junction of alumina particles.

Figure 2—SEM of conventional ceramics showing the amorphous nature of the glass.

Figure 3—Building In-Ceram® "slip" on special plaster.

Figure 4—Milling a coping from a preformed monoblock of In-Ceram® Alumina.

Figure 5—View of framework after firing of infiltration glass.

mends, In-Ceram® Alumina[a] creates a core that is roughly 50% as translucent as dentin.[13] In clinical situations where there is a discolored preparation or a cast post and core, this increased opacity over dentin is advantageous (Figures 6A and 6B). Conversely, when maximum translucency is necessary, In-Ceram® Alumina is problematic.

According to the manufacturer's recommendations, In-Ceram® Spinell[a], a mixture of alumina and magnesia, should be glass-infiltrated in a vacuum environment. In-Ceram® Spinell is more than twice as translucent as In-Ceram® Alumina because the refractive index of its crystalline phase is closer to that of glass, and the vacuum infiltration leaves less porosity. The translucency of a Spinell core more closely matches that of dentin.[13] In clinical situations where maximum translucency is paramount, Spinell is ideal (Figure 7). In other cases, this level of translucency is excessive and can lead to an overly glassy, low-value appearance. Altering the vacuum for both the In-Ceram® Alumina and In-Ceram® Spinell can increase or decrease the translucency of the cores, as described later in this article.

Conventional etching with hydrofluoric acid is not possible with In-Ceram® Alumina or In-Ceram® Spinell because of the minimal glassy phase of the materials.[14] Hydrofluoric acid etching of conventional ceramics primarily etches the glassy phase, leaving microretentive features around exposed leucite crystals as in feldspathic ceramics. These microscopic undercuts are subsequently filled with a resin luting agent, creating a strong micromechanical bond. Previous studies have described the inability to adhesively lute In-Ceram® Alumina with either acid etching or silane coating.[14] Other studies have found that it is possible to obtain high bond strengths with In-Ceram® Alumina and In-Ceram® Spinell when specific surface treatment/resin combinations are used.[15,16]

Few clinical studies have been published on survival data of these all-ceramic restorations.[8,9] Recommendations for their use have been purely empirical.[17,18] The purpose of this article is threefold. First, it discusses the selection criteria, clinical considerations, and design parameters that promote clinical success with the new ceramic materials based on an analysis of 729 In-Ceram® Alumina and In-

Figure 6A—Extremely discolored teeth with a cast post in tooth No. 8. (Author performed lab work only.)

Figure 6B—Completed air-infiltrated In-Ceram® Alumina crowns with porcelain margins on teeth Nos. 8 and 9.

Figure 7—Spinell crowns on teeth Nos. 8 and 9 with normal-colored substrate.

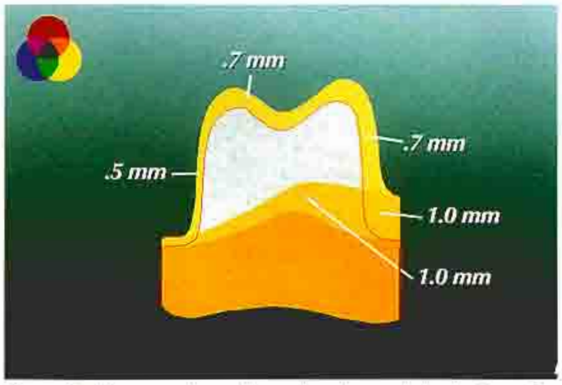

Figure 8—Diagram of core dimensions for posterior In-Ceram® core.

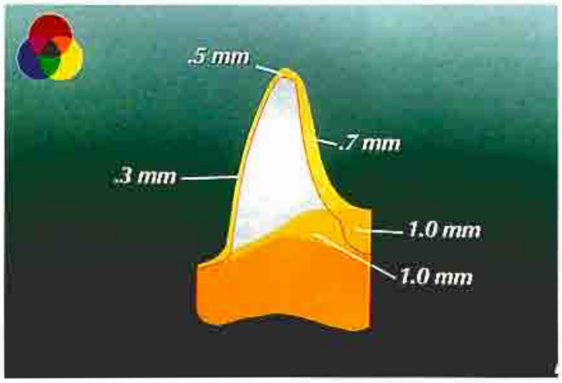

Figure 9—Diagram of core dimensions for anterior In-Ceram® core.

Ceram® Spinell restorations placed by the author since February 1990. Second, the article suggests possible esthetic enhancements to the core system and reports data obtained from flexural tests on altered core-processing techniques. Third, it explains cement considerations both from an optical perspective and in terms of increased adhesion from various surface treatment/cement combinations.

Selection Criteria

Many different criteria are involved in choosing a particular restoration material or technique. They can be grouped into three categories: mechanical, biologic, and esthetic requirements.

Mechanical requirements vary depending on where the restoration is to be placed and the dynamic occlusal and chemical forces that will be applied to it. A review of the literature reveals high clinical success rates for any all-porcelain system used on incisors, especially systems that include adhesive techniques.[18-20]

One critical issue is identifying the inherent physical properties needed for the successful use of all-ceramic materials in the posterior areas. According to McLean,[21] flexural strengths of conventional porcelains and pressable ceramic materials, which have flexural strengths around 150 MPa, are inadequate for molar crowns. Flexural strengths from 300 MPa to 600 MPa have been reported for In-Ceram® Alumina, with 15% to 40% lower strength values reported for In-Ceram® Spinell.[2] From a flexural-strength perspective, it is clear that In-Ceram® Alumina would be indicated for both anterior and posterior single-tooth restorations, but In-Ceram® Spinell would be indicated for anterior crowns only.

The In-Ceram® materials are not used as a core alone; the core is veneered with a lower-strength material to achieve the final esthetic result. Evaluations of the effects on strength of

Figure 10—Preoperative view of failed restorations.

Figures 11A—Cemented Spinell crowns on teeth Nos. 7 through 10.

Figures 11B—Closer view of cemented Spinell crowns.

Figure 12—In-Ceram® anterior three-unit framework demonstrating correct design criteria.

Figure 13—Clinical case of zirconia framework veneered with Vitadur Alpha[a].

Figure 14—Transilluminated section of natural tooth showing diffuse translucent areas of high and low value.

veneering concluded that there was a minimal drop in strength for the In-Ceram® Alumina material if the core remained at least 1 mm thick.[22] When the core was thinned to 0.5 mm and then veneered with 1 mm of porcelain, the flexural strength dropped to 225 MPa.[22] This would be adequate for incisors and bicuspids, but not for molars. Thus, in the molar region, core framework design is critical as well as a material with the inherent physical properties required for that region. The recommended 0.5-mm thickness for the core is not adequate for molars.

A careful review of the author's failed samples showed that all failures had a core dimension of less than 0.7 mm. Core dimensions in lower-stress areas of posterior teeth, like the facial aspects, can be thinned to 0.5 mm as long as the occlusal and palatal areas are thicker than 0.7 mm. Ideally, the framework should have a lingual and proximal collar for strength and support of the porcelain. The collar should be 1 mm thick and 2 mm high (Figure 8). For anterior teeth, core dimensions can be trimmed to 0.3 mm on the facial aspects (a low-stress area) as long as the interproximal, palatal, and incisal-edge thickness remains at 0.7 mm and there is a 1-mm thick collar of the lingual (Figure 9).

Review of the failed samples also revealed

Figure 15A—Three-unit metal-ceramic FPD on teeth Nos. 6 through 8 with reduced metal framework and 360-degree porcelain margin.

Figure 15B—Magnified view of teeth Nos. 6 through 8 with reduced metal framework FPD.

Figure 16A—Prepared natural tooth with black line painted to simulate severe discoloration.

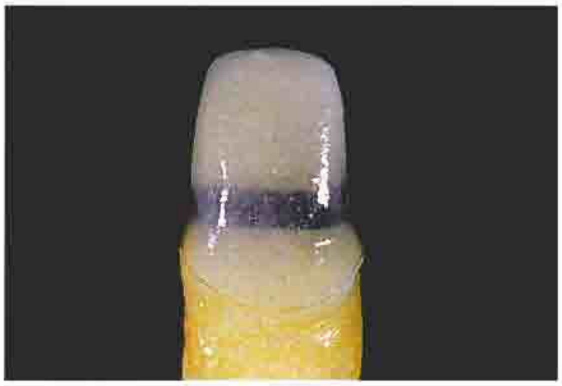

Figure 16B—Spinell coping processed as recommended with vacuum.

Figure 16C—Spinell coping infiltrated in air. Note the significant increase in opacity.

that all failures originated from an occlusal line angle or that an internal flaw was evident in the core. When the slip casting fabrication technique is used, it is possible to trap air and create porosity that can weaken the core. It is important for the technician and/or dentist to inspect the inside surface of the core and reject it if there are obvious porosities or flaws. In the clinical cases where the restoration was fabricated by milling prefabricated alumina or spinel monoblocks, none have failed to date, regardless of the core dimensions. The benefit of a premanufactured block is that there is no residual porosity in the finished core that could act as a weak point and lead to catastrophic failure.

Another factor to consider in choosing an all-ceramic restoration is the nature of the cementation substrate. The veneering porcelain is the weak link and is subject to brittle failure. The porcelain gets its strength by being bonded to a high-strength substrate: an enamel, metal, or ceramic core. If the preparation is thin or has minimal remaining dentin, or if the tooth is built up with a lower modulus material like a composite, the tooth will most likely flex under a load. This will concentrate stress in the higher modulus ceramic. Laminated structures such as porcelain/enamel, porcelain/dentin, or porcelain/ceramic cores are by definition constant strain systems.[23] When stress is applied in such a system, the material with the highest modulus of elasticity (ie, the stiffest material), absorbs the most stress. Ceramics are brittle and fail at a small critical strain of 0.1%.[3] Thus, bonding a low- or medium-strength ceramic to the more flexible dentin or composite could lead to early failure, unless a high-strength core is used.

In an interesting study that looked at the failure load of a bonded pressed ceramic to materials of different elastic moduli, it was concluded that the failure load was propor-

Figure 17A—Vacuum-infiltrated Spinell with Luminaries fired.

Figure 17B—Air-infiltrated Spinell with Luminaries.

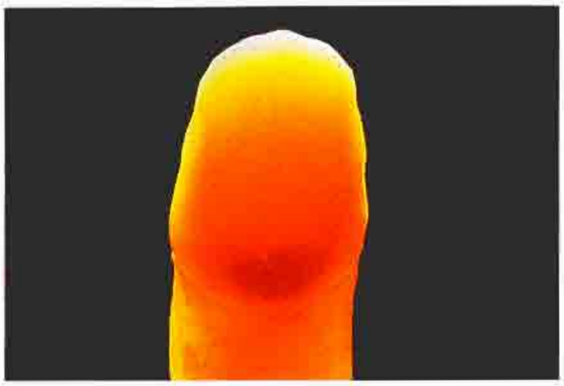

Figure 17C—Transilluminated Spinell with Luminaries, demonstrating iridescent fiberoptic properties.

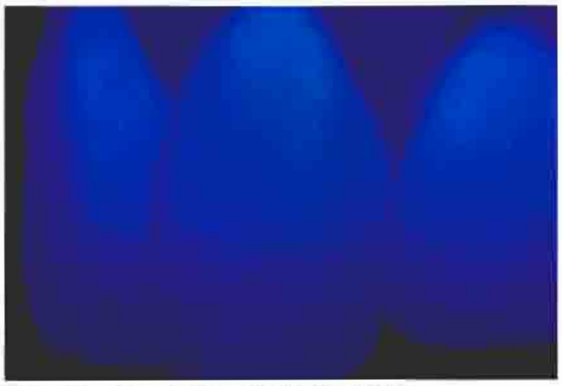

Figure 18—Fluorescent effect of the Luminaries.

tional to the flexibility of the substrate.[24] The more flexible the substrate, the lower the failure load. Thus, thin or extremely broken-down teeth should not be considered for a low- or medium-strength ceramic, especially in the posterior areas because of the increased likelihood of flexure. In these situations, a high-strength ceramic core or metal framework is indicated to support the veneering porcelain (Figures 10, 11A, and 11B).

Fixed Partial Dentures

In-Ceram® Alumina is recommended for the fabrication of anterior three-unit fixed partial dentures (FPDs).[25] Specific framework design is significantly more critical here than for conventional metal-ceramic versions. The connectors for the framework should be a minimum of 4 mm occlusal/gingivally and 3 mm buccal/lingually to allow for adequate strength. The palatal aspect should be at least 0.7 mm thick with the facial aspect a minimum of 0.5 mm thick (Figure 12). Analysis of laminated beams of In-Ceram® veneered with porcelain clearly showed that placing porcelain on the tensile surface significantly weakened the beam.[26] Laminated beams leaving In-Ceram® on the tensile surface and porcelain on the compressive surface had minimal effect on the strength, relative to a solid beam of In-Ceram®. Thus, no porcelain should be placed on the gingival (tensile) surface of the connector area in the gingival embrasures. The lingual embrasures should not be covered with porcelain because this space is necessary for core material to achieve proper framework dimensions. Exposed core areas should be glazed and polished after porcelain application. Glazing and polishing In-Ceram® Alumina produces a significant increase in flexural strength.[27]

Mobile abutments should not be considered for In-Ceram® bridges because this will concentrate stress in the connector areas, leading to premature failure. In-Ceram® is not recommended for posterior FPDs, as one clinical study clearly demonstrated.[28] This finding has been confirmed by the author and S.N. White (unpublished data, 1997). Unless the specific requirements for anterior In-Ceram® bridges can be met, a metal-ceramic restoration is preferred.

Zirconia-Based Ceramics for FPDs

Experimental materials containing zirconia, which can be slip cast as in the conventional In-Ceram® technique or milled from

Figure 19A—Air-infiltrated In-Ceram® Alumina core on discolored tooth.

Figure 19B—Vacuum-infiltrated Alumina core demonstrating increased translucency.

Figure 19C—Alumina core with Luminaries showing a complete masking of the black discoloration.

preformed blocks of zirconia, are now undergoing clinical testing. Zirconia has a physical property called transformation toughening (strengthening). Zirconia exists in a tetragonal form of crystal. When an external energy source is applied to the material, it goes through a phase transformation to a monoclinic form of zirconia. The monoclinic form of crystal is 3% to 5% larger. In areas of microscopic cracks, this process can actually seal cracks. Zirconia's fracture toughness and flexural strength are more than twice that of alumina.[17] Fracture toughness is the measure of a material's ability to resist crack growth. The greatly improved physical properties of zirconia-based materials should be adequate for posterior three-unit bridges with proper framework design. It is important to note that no clinical data yet exist on this new material. Figure 13 shows an experimental use of the zirconia material for posterior applications.

Esthetic Requirements

For many years, development of dental ceramics has centered on creating materials with the same optical properties as natural teeth.[29-31] Clinicians have achieved excellent esthetic results in the anterior region using older-generation, all-porcelain restorations. This was because the all-porcelain restoration most closely matched the translucency and value of the natural dentition. Translucency and value are the critical optical properties to match for esthetic success (Figure 14). Even with new-generation metal-ceramic porcelains that closely match all the optical properties of natural teeth, the average metal-ceramic restoration rarely matches the translucency and value of the adjacent teeth. The problem is the opaqueness of the metal core and lack of space for the porcelain because of inadequate tooth preparation. This can be overcome with reduced metal framework design and a more aggressive preparation (Figures 15A and 15B).[32] Practically, it is easier for the technician to match the shade of the existing dentition on a nondiscolored tooth using a core system that closely matches the translucency and value of dentin. In situations where maximum translucency is necessary (eg, in the anterior region), In-Ceram® Spinell is indicated.

In-Ceram® Alumina is much less translucent than Spinell, especially when it is air-infiltrated. In esthetically critical areas where maximum translucency is necessary, In-Ceram® Alumina is problematic. Conventionally processed In-Ceram® Alumina is best suited for single posterior crowns as long as core dimensions are maintained as previously discussed.

Esthetic Enhancements

A major difficulty in esthetic rehabilitative dentistry is that most full-coverage restorations are done on teeth with significant discolorations. The Achilles' heel of all-ceramic crown techniques remains the inability to mask dark teeth without an overly opaque appearance. Early all-ceramic core systems were too opaque and resulted in high-value opaque final restorations, which were no better than metal-ceramic systems. The newer cast-glass or pressed-glass systems are too translucent to effectively cover discolored teeth.

The ability to alter the translucency of the core to differentially mask the existing clinical situation would be ideal. The author accidentally found that it was possible to alter the translucency of the In-Ceram® Alumina and In-Ceram® Spinell cores by differentially pulling vacuum during the glass-infiltration process. The manufacturer's recommendation for Alumina is that infiltration be performed in an air environment. This produces a core where a 1 mm-thick segment is 20% translucent.[13] The recommendation for Spinell is infiltration in a vacuum environment. This results in a core that is twice as translucent as Alumina. When Spinell is infiltrated in air, instead of in a vacuum environment, the resultant core is significantly more opaque (Figures 16A through 16C). By altering the vacuum from 0% to 100%, it is possible to create a continuum of varying translucencies. Clinical trial and error has led to the realization that even the most severe discolorations can be masked with air-infiltrated Spinell and optical brightener porcelains (Luminaries[a]).[33]

Figures 17A through 17C demonstrate the effect of air- and vacuum-infiltration on the translucency of the Spinell core material, and the application of Luminaries to create chroma and mask discolorations. The Luminaries are porcelain materials that are highly fluorescent (Figure 18). Fluorescence in a material tends to give a bright iridescent effect when used properly in dental porcelain. This effect can be used to brighten dark teeth without negatively affecting the translucency.

In-Ceram® Alumina has physical properties adequate for use in single-tooth posterior applications, but its relative opacity can create an esthetically unpleasing result in the anterior region. Glass-infiltrating the Alumina material in a vacuum environment was found to create a core that was significantly more translucent (Figures 19A and 19B). The translucency of vacuum-infiltrated Alumina was found to be only slightly less than air-infiltrated Spinell. (Application of Luminaries to the vacuum-infiltrated Alumina and the subsequent masking of the underlying discoloration is shown in Figure 19C.) Figures 20A through 20F demonstrate the myriad of core translucencies that can be created.

Table 1—Effect of Vacuum vs Air Infiltration on Flexural Strength

Group	Ceramic Material	Modulus of Rupture (MPa)
1	Air-Infiltrated In-Ceram® Alumina	562.08 (48.4)
2	Vacuum-Infiltrated In-Ceram® Alumina	560.86 (70.5)
3	Air-Infiltrated In-Ceram® Spinell	462.34 (37.9)
4	Vacuum-Infiltrated In-Ceram® Spinell	386.13 (82.6)

In a further enhancement of the esthetic potential of the In-Ceram® system, the author found that by cutting back the facial aspect of the core for a porcelain butt margin, a highly translucent material could be fired in this region. When the restoration is in place, the marginal area blends in with the existing tooth

Figure 20A—Prepared teeth with severe discolorations and cast post and core.

Figure 20B—Try-in of vacuum-infiltrated Spinell copings that are inadequate to effectively mask the discolorations.

Figure 20C—Try-in of air-infiltrated Spinell copings, which adequately mask the discolorations.

structure by the so-called "chameleon effect" (Figure 21).[34]

Effect of Altered Processing on Physical Properties

One concern about altering the manufacturer's recommendations for the processing of their materials is the effect it may have on strength. The impact of altering the air or vacuum environment during the infiltration process has been reported[27] and is summarized here (Table 1). The results of a three-point flexural test demonstrated that there was no effect on the flexural strength of In-Ceram® Alumina by altering the vacuum. For Spinell, there was a significant increase in strength with air infiltration vs vacuum infiltration.

Cement Considerations

As a result of its high strength, conventional cements can be used with In-Ceram® Alumina. Glass ionomer cements have been used with great clinical success.[35] The physical properties of glass ionomer cements are extremely sensitive to powder/liquid ratios; even small alterations can affect their clinical performance. Glass ionomers are susceptible to early moisture attack, which requires strict saliva control until the cement is completely set. Pre-encapsulated versions are available, such as Applicap[b]; they eliminate the problems associated with proper powder/liquid ratio and are preferred over the hand-mixed versions. Experience with zinc phosphate cement has led to discontinuing its use because of a high incidence of microleakage and staining at the margins. The only correlation to cement type and fracture of restoration in the author's clinical samples was with zinc phosphate. One explanation is that in the presence of moisture, ceramics are subjected to stress corrosion or chemically assisted crack growth.[36] Thus, because of the microleakage that occurs with zinc phosphate cement and subsequent stress corrosion, the ceramic failed at a much smaller load. The physical properties of polycarboxylate cement probably make it inadequate for use with In-Ceram® Alumina, and there are no reported data to support its use.

Recently, there have been anecdotal reports about compomers causing cracking of all-ceramic crowns shortly after cementation.[37,38] There are high amounts of hydroxyethylmethacrylate (HEMA) in these cementation products, which expand significantly on exposure to moisture. It is theorized that stresses developed because expansion of the HEMA was sufficient to cause the cracking. In a laboratory study,[37] all-ceramic crowns were fabricated and cemented with various compomer classes of cements and stored in water. The cements also were placed in capillary tubes and stored in water. Several of the crowns fractured after a few days stored in water; no exact percentages or sample sizes were given. Of the capillary tubes filled with cement, 71% of the Advance™,[c] samples fractured, 25% of the FUJI Plus[d] samples fractured, and none of the Vitremer[e] samples fractured. The linear expansion of these materials also was measured in this study. The compomers expanded five times more than conventional

Figure 20D—Finished case of air-infiltrated Spinell with Luminaries that effectively masked the discolorations.

Figure 20E—Enlarged view of air-infiltrated Spinell crowns with Luminaries.

Figure 20F—Smile view of finished restorations of air-infiltrated Spinell with Luminaries.

[b] ESPE, Norristown, PA 19404
[c] Dentsply®/Caulk®, Milford, DE 19963
[d] GC America, Inc, Alsip, IL 60803
[e] 3M Dental Products Division, St. Paul, MN 55144

cements or the pure resin cement Panavia 21™,f. Based on this and anecdotal reports of fracture, this class of cement should not be used for any all-ceramic restoration. Many dentin bonding agents contain HEMA, but because of the thin film thickness of these materials, no problems exist when they are used with conventional resin cements and In-Ceram®.

The ability to acid etch and adhesively lute conventional ceramics has greatly increased their clinical predictability. Hydrofluoric acid dissolves the glassy matrix, leaving microscopic undercuts around leucite crystals. Low-viscosity resins are used, which fill these retentive areas, thus creating a strong micromechanical bond. Because of the minimal glassy phase in In-Ceram® Alumina and In-Ceram® Spinell, hydrofluoric acid etching and silane coating have proved ineffective in promoting increased adhesion.[14] A recent study[16] reports high bond strengths of In-Ceram® Alumina to a new resin or to various surface treatments designed to increase the silica content on the surface of In-Ceram®.

A study by the author found that with specific surface treatment/resin combinations, both In-Ceram® Alumina and In-Ceram® Spinell had the same shear bond strength as conventionally etched porcelain.[15] The surface treatment protocol to adhesive lute In-Ceram® Alumina or In-Ceram® Spinell is as follows: air abrade the internal surface of the core with 50 µm aluminous oxide at 50 psi for 10 seconds. Any other surface treatment lowered the bond strength. Hydrofluoric acid or silane should not be used as a surface treatment on these materials because both significantly lowered the bond strength. The only cement that exhibited high bond strength was Panavia 21™ TC[f]. Clinically, it is necessary to use a dentin bonding agent on the tooth; this will minimize the potential for postcementation sensitivity. No other material is placed in the crown other than the mixed Panavia 21™ TC. When the crown is placed, excess cement is removed and Oxyguard II[f] is placed. Oxyguard II contains a catalyst that facilitates the set of the Panavia 21™.

Optical Considerations

Although certain conventional cements appear strong enough to use, problems associated with their optical properties have become apparent. The relatively opaque nature of these cements (Figure 22) can negatively affect the optical characteristics of the final cemented restoration. The main rationale for using these restorations is to match translucency and value to the natural dentition. Thus, in situations where maximum translucency is needed, translucent resin cements are indicated (Figure 23). The optical properties of Panavia 21™ TC and Variolink[g] have been found ideal for use with the In-Ceram® system.

Summary and Conclusions

Treatment planning for any restorative material involves careful consideration of several criteria, not the least of which is the mechanical requirements of a material to withstand the stresses placed on it in the oral environment. We as practitioners must become

[f] J. Morita, Tustin, CA 92780

[g] Ivoclar Vivadent, Amherst, NY 14228

[h] Den-Mat, Santa Maria, CA 93456

Figure 21—In-Ceram® Alumina teeth Nos. 8 and 9 with porcelain margins.

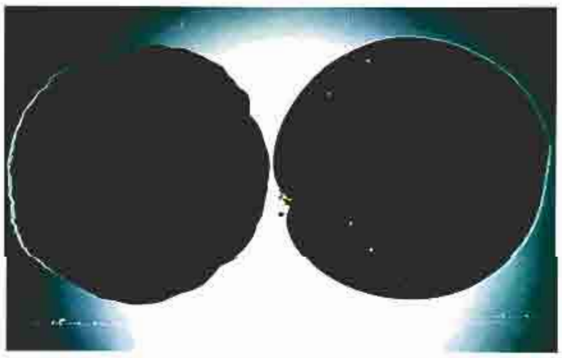

Figure 22—Transilluminated samples of 50 µm-thick discs of zinc phosphate and glass ionomer that clearly show the opaque nature of these cements.

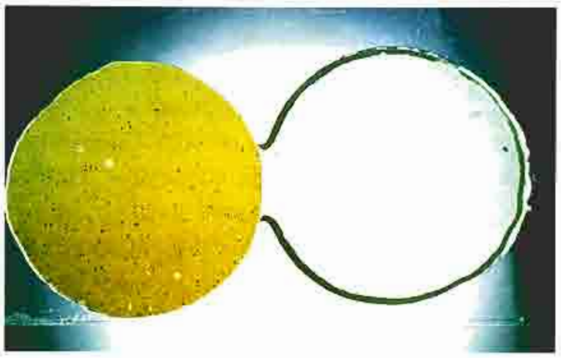

Figure 23—Transilluminated samples of Panavia 21™ TC and Infinity[h], which was the most translucent cement tested.

dental engineers. One definition of an engineer is a person who uses materials and forces to benefit mankind.[39] We constantly use various materials that are subjected to a myriad of forces, both physical and chemical. Very different requirements exist for materials placed more distally intraorally, which is compounded by the nature of the cementation substrate. We must, therefore, have a basic understanding of the structural elements of a material and its concomitant physical properties. With this knowledge, and an idea of the forces the material will be subjected to, we can better predict how it will perform.

Clinical studies have demonstrated good survival rates for most all-ceramic systems on anterior teeth. Poorer performance by these materials, and even high-leucite materials,[18,20] in the more critical posterior areas could be predicted. The mechanical properties of In-Ceram® Alumina are well-documented. Flexural strengths and fracture toughness of In-Ceram® Alumina are 2.5 to 3.5 times that of conventional or high-leucite materials. Other factors, such as eliminating processing flaws and proper framework design, are critical with any all-ceramic system. With proper processing and core dimensions of at least 0.7 mm, In-Ceram® Alumina has adequate strength for single-crown molar situations.

In-Ceram® Alumina can be used for anterior three-unit bridges, but only in very specific situations. Connector design of 4 mm gingival/incisally and 3 mm buccal/lingually is critical. No porcelain should be placed in the gingival or lingual embrasure, and the exposed core material should be glazed and polished. Millable versions of In-Ceram® Alumina have significantly improved physical properties over slip-cast Alumina. This is because of the more homogeneous nature and increased density of the preprocessed blocks. Zirconia-based ceramics have physical properties adequate to consider its use for three-unit posterior FPDs. However, no clinical data yet exist for zirconia-based materials.

The ideal esthetic restorative material should have optical properties similar to natural teeth. The critical optical properties are value and translucency. Clinical difficulties arise when there is a discolored tooth or a cast post and core. Most all-ceramic systems are not able to alter the translucency of the core to differentially mask discolorations. The translucency of both In-Ceram® Alumina and In-Ceram® Spinell can be altered by pulling differential vacuum in the infiltration process. There was no significant difference in the flexural strength of In-Ceram® Alumina with air or vacuum infiltration. Air-infiltrated Spinell was significantly stronger than vacuum-infiltrated Spinell. The best esthetic results for the anterior region can be obtained with air-infiltrated Spinell in conjunction with the Luminary porcelains. For vital nondiscolored abutments, vacuum-infiltrated Spinell with the Luminaries is preferred because of the chameleon effect.

Acid etching and adhesive cementation of conventional and high-leucite all-ceramic restorations are paramount for their long-term clinical success. The high flexural strength of In-Ceram® Alumina and In-Ceram® Spinell allows luting with more conventional cements. Pre-encapsulated glass ionomer cement is the material of choice for conventional cementation. In the author's clinical cases, several crowns exhibited microleakage and staining at the margins with zinc phosphate cement. The only correlation to cement type and failure by fracture was with zinc phosphate. Thus, zinc phosphate should not be used with the In-Ceram® system. Bond strengths similar to etched porcelain can be obtained by aluminous oxide air abrading of either the Alumina or Spinell copings and by using Panavia 21™ TC, although the long-term nature of the bond is not known.

In a subsequent article, analysis of 7-year survival data of 729 In-Ceram® Alumina and Spinell restorations will be detailed.

Note: All clinical and ceramic work was personally performed by the author.

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