All-Ceramic Full-Coverage Restorations: Concepts and Guidelines for Material Selection

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High-strength, all-ceramic systems for full-coverage restorations use all-ceramic core materials for the fabrication and processing of infrastructures (eg, crown copings, fixed partial denture frameworks) that are then veneered with porcelain. Not all of these all-ceramic core materials are alike, and as such, they present with different properties that may affect their indications and limitations, the laboratory procedures used for their processing, and their clinical handling. This article reviews their clinically relevant properties and discusses the effect of these characteristics on their indications and recommended clinical procedures.

Learning Objectives:

This article provides an overview of the clinically relevant properties of high-strength, all-ceramic systems used for aesthetic restorative dentistry. Upon reading this article, the reader should:

- Be able to differentiate among the principal all-ceramic material systems
- Understand the clinical indications for contemporary, high-strength ceramics

Key Words: all-ceramics, aesthetics, core, fracture toughness

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High-strength, all-ceramic systems for full-coverage restorations such as crowns and fixed partial dentures (FPDs) are available for clinical use. These systems use various core materials, each with different mechanical and optical properties, for the fabrication of full-coverage tooth- and implant-supported crowns as well as tooth- and implant-supported FPDs. In addition, different systems use different technologies (eg, heat pressing, slip-casting, conventional waxing and CAM, CAD/CAM) for the fabrication and processing of the core materials. With the advent of CAD/CAM technology, various fabrication techniques have been developed for enhancing consistent and predictable restorations in terms of strength, marginal fit, and aesthetics, and for machining high-strength, all-ceramic core materials that could not otherwise be processed. The continuous evolution in adhesive systems and composite resin cements also plays a significant role in the ability of clinicians to predictably deliver high-strength, all-ceramic restorations with adequate longevity.

High-strength, ceramic core materials may be classified according to their chemical structure into three major groups:

1. Glass-ceramics—Multiphase materials that contain an amorphous, glassy phase and crystalline constituents.
2. Glass-infiltrated ceramics—A product of infiltrating molten glass to partially sintered oxides (eg, alumina, magnesia-alumina, alumina-zirconia).
3. Polycrystalline ceramics—Materials with densely packed particles and no glassy components. They cannot be processed to shapes without the use of computer-assisted machining.[1]

As a general rule, the higher the glass content, the better the optical properties of the material—though the mechanical properties may be diminished. Some of these core materials can be etched with 9.5% hydrofluoric acid and then silanated to create a favorable substrate for bonding the ceramic core to the tooth structure. These materials rely on successful adhesive cementation procedures for increasing the strength of the restoration and the tooth-restoration complex to provide adequate function and longevity.[2] Thus, the importance of immaculate gingival health is amplified to facilitate the creation of an optimal bonding environment that facilitates moisture control and minimal contamination while bonding the restoration.

Figure 1. Facial view of a failing metal-ceramic fixed partial denture. Note the ridge-lap type pontic and the visible metal margins.

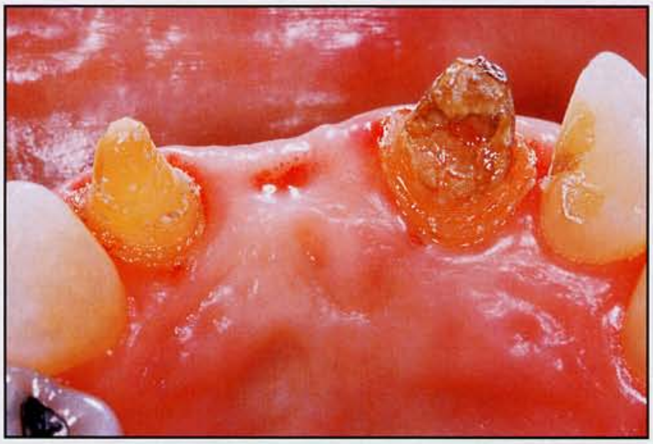

Figure 2. An occlusal view of the abutment teeth after removal of the failing restoration. Note the severe decay and the Seibert Class II defect.

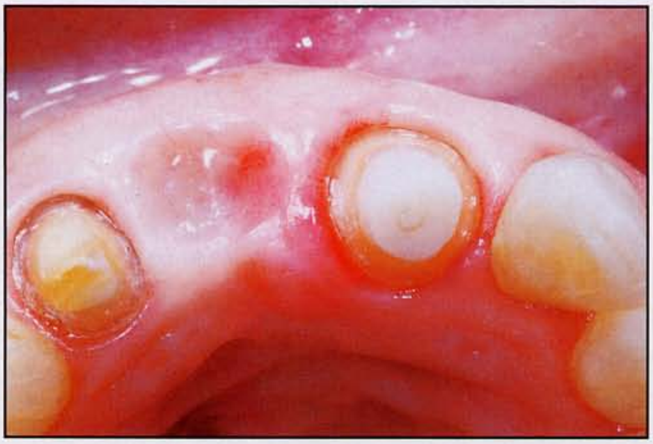

Figure 3. View demonstrating the resolution of the Seibert Class II defect, and the maturation of the soft tissue at the ovate pontic site.

Figure 4. View of abutments after endodontic therapy, post-and-core buildups, and preparation. Note the adequate gingival levels.

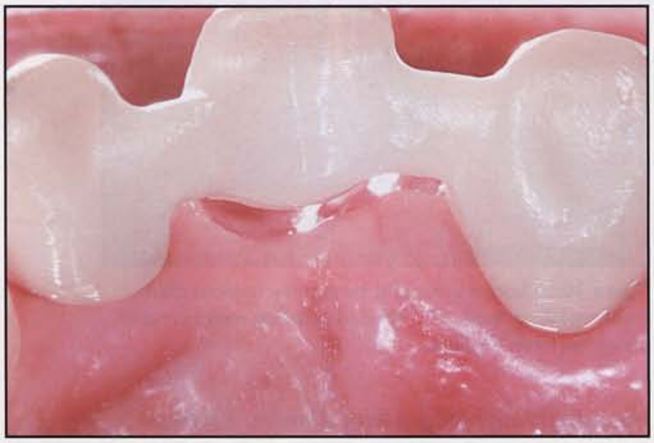

Figure 5. A lingual view of the framework. Note the space between the intaglio surface of the pontic and the ovate pontic site.

Figure 6. Using the Y-TZP framework and acrylic resin, an impression of the edentulous site is made. Note the blanching of the soft tissue.

The long-term stability of glass-containing ceramics is closely related to subcritical crack propagation and stress corrosion caused by water in the saliva and the dentin tubules that may react with the glassy phase. In glass-containing systems, this reaction results in the decomposition of the glass structure and increased crack propagation.[3] Polycrystalline ceramic cores, however, are glass-free and do not exhibit this phenomenon.[4] The lower the glass content, the better the mechanical properties (eg, flexural strength) of the material. More importantly, the lower glass content results in higher fracture toughness—a mechanical property associated with the resistance of brittle materials (eg, ceramics), to the catastrophic propagation of flaws under an applied stress. In contrast, the optical properties (eg, translucency) of these materials are diminished.

Materials Overview

Leucite-Reinforced Glass-Ceramics (LRG)

LRG core materials (eg, IPS Empress, Ivoclar Vivadent, Amherst, NY; OPC, Pentron Laboratory Technologies, Wallingford, CT) use leucite crystalline filler to reinforce glass ceramics structures. These restorations are highly translucent,[5,6] and therefore provide the potential for a highly aesthetic restoration. Due to their high translucency, however, these restorations are not recommended for cases where the underlying abutment is a discolored tooth, a metallic-core buildup, or a metal implant abutment. The flexural strength of this core material has been measured at 105 MPa to 120 MPa,[7-9] and the fracture toughness (K_{Ic}) ranges from 1.5 MPa $\times$ $m^{1/2}$ to 1.7 MPa $\times$ $m^{1/2}$.[1] The results of a clinical study demonstrated a high success rate for these restorations when used for fabricating full-coverage crowns in the anterior segment.[10] The strength of these restorations rely on a successful bond to the tooth structure and, therefore, must be adhesively cemented. While preparing teeth for such restorations, it is recommended that the finish line be placed either at, or slightly below, the free gingival margin to facilitate the maintenance of a healthy gingiva with the provisional restoration. Excellent health of the gingiva will enhance moisture control and facilitate predictable bonding procedure. Copings may be fabricated by using either a heat-pressing procedure or via CAD/CAM technology.

Lithium Disilicate Glass-Ceramics (LDG)

The LDG core material (ie, IPS Empress 2, Ivoclar Vivadent, Amherst, NY) demonstrated a flexural strength

Figure 7. A frontal view of the definitive restoration.

Figure 8. A facial view of the patient's new smile (With Dr. Marriana Pascuitta, LSUSD).

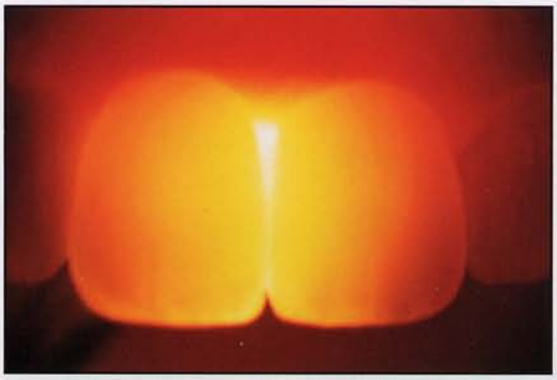

Figure 9. Transillumination demonstrates light transmission through the restoration.

Figure 10. A buccal view of a temporary implant abutment replacing tooth #11(23) and a failing metal-ceramic crown on tooth #12(24).

of approximately 300 MPa to 400 MPa,[11] and a fracture toughness ranging between 2.8 MPa $\times$ $m^{1/2}$ and 3.5 MPa $\times$ $m^{1/2}$.[11,12] The core is fabricated with the lost-wax and heat-pressure technique, and it is recommended that these restorations be etched with 9.5% hydrofluoric acid and adhesively cemented.[13] The system is recommended for anterior and posterior crowns as well as for three-unit FPDs confined to replacing a missing tooth anterior to the second premolar.

Glass-Infiltrated Alumina (GIA)

The GIA (ie, In-Ceram Alumina, Vident, Brea, CA) is a high-temperature, sintered-alumina glass-infiltrated infrastructure for anterior and posterior crowns, as well as for three-unit anterior FPDs.[14,15] The flexural strength of its core material ranges from 236 MPa to 600 MPa,[10,16-18] and the fracture toughness ranges between 3.1 MPa $\times$ $m^{1/2}$ and 4.61 MPa $\times$ $m^{1/2}$.[19,20] In order to fabricate the coping or framework, the ceramist can use either the slip-casting technique or CAD/CAM technology.

Glass-Infiltrated Magnesium Alumina (GIMA)

The GIMA (ie, In-Ceram Spinell, Vident, Brea, CA) core material demonstrated a flexural strength that ranges from 283 MPa to 377 MPa.[11,21,22] To fabricate the coping, the laboratory technician uses the slip-casting technique or CAD/CAM technology. The Spinell core material is twice as translucent as the In-Ceram Alumina core and may therefore be used in clinical scenarios where maximum translucency is required. The Spinell cores are weaker than the conventional GIA cores and are thus recommended for use only as anterior crowns where they have proven to be successful over extended periods.[23]

Glass-Infiltrated Alumina With Partially Stabilized Zirconia (GIAZ)

The In-Ceram Zirconia system (Vident, Brea, CA) combines the use of glass-infiltrated alumina with 35% partially stabilized zirconia as the core material for posterior crowns and FPDs. The flexural strength of the core material ranges from 421 MPa to 800 MPa, and the

Figure 11. A buccal view of the custom metal abutment #11 and the preparation of a full- coverage crown #12 (Surgery: Michael S. Block, DMD, LSUSD).

Figure 12. An occlusal view demonstrating the masking ability of Y-TZP copings on a metal implant abutment and adjacent nondiscolored tooth.

Figure 13. A lateral view of the definitive restorations. Note the excellent gingival health.

Figure 14. A postoperative radiograph of the definitive zirconia-based restorations. Note the metal-like radiopacity of the core material.

fracture toughness ranges between 6 MPa × $m^{1/2}$ and 8 MPa × $m^{1/2}$.[17,18,24] Slip-casting technique or CAD/CAM technology may be used for the infrastructure fabrication. However, in terms of translucency, the GIAZ core demonstrated high opacity.[6] Since the primary rationale for using all-ceramic restorations is to enhance the light transmission and depth of translucency,[25] the advantage of using this core material may be questionable.

Densely Sintered High-Purity Aluminum-Oxide (DSHPA)

The DSHPA core material (ie, Procera AllCeram system, Nobel Biocare, Yorba Linda, CA), is one of the two polycrystalline ceramics available.[26] It is a glass-free high-strength ceramic core material with a flexural strength of 500 MPa to 650 MPa[27,28] and a fracture toughness of 4.48 MPa × $m^{1/2}$ to 6 MPa × $m^{1/2}$.[19,29] This system is recommended for anterior and posterior crowns and its use for three-unit FPDs is questionable. As a polycrystalline ceramic, CAD/CAM technology is used for the fabrication of the ceramic infrastructures.

Yttrium Tetragonal Zirconia Polycrystals (Y-TZP)

Y-TZP is a glass-free, high-strength polycrystalline ceramic material indicated for the fabrication of anterior and posterior crown copings and FPD frameworks.[30] The strength of Y-TZP is attributed to a process known as *transformation toughening* and to the material's small-grain structure, which ranges between 0.3 μm and 0.5 μm.[29] In vitro studies of Y-TZP specimens indicated a flexural strength of 900 MPa to 1200 MPa[29] and a fracture toughness of 9 MPa × $m^{1/2}$ to 10 MPa × $m^{1/2}$.[29] Infrastructures may be designed using either conventional waxing techniques or CAD technology.

Several Y-TZP-based restorative systems are available for fabricating infrastructure for full-coverage crowns and FPDs. The majority of the systems use CAM of partially sintered Y-TZP blanks (eg, Lava, 3M Espe, St. Paul, MN; Cercon, Dentsply Ceramco, York, PA; Cerec InLab, Sirona, Charlotte, NC; Procera AllZirkon, Nobel Biocare, Yorba Linda, CA). The size of partially sintered milled infrastructures is increased to compensate for prospective shrinkage (20% to 25%) that occurs during final sintering. The DCS-Precident, DC-Zirkon (Smartfit Austenal, Chicago IL) infrastructures are milled from fully sintered Y-TZP blanks. While no shrinkage is involved in the milling of a fully sintered blank, microcracks may be introduced to the infrastructure.[30] The milling of partially sintered blanks is faster and results in less wear and tear to the hardware.[31]

Clinical Considerations

Regardless of the type of all-ceramic material used, some general concepts related to the preparation design of full-coverage, all-ceramic restorations must be maintained. All line angles should be rounded, all sharp edges eliminated, and the recommended finish line is either a deep chamfer or a 90-degree, rounded shoulder. The finish line may be placed at or slightly below the free gingival margin to maintain adequate gingival health and predictable bonding when required. Although desirable, such finish-line placement may not be possible in many clinical cases due to a deep previous restoration, an extensive core buildup, or cervical decay.

A well-designed preparation is required to provide adequate resistance and retention form as well as an adequate design for an infrastructure that will promote a uniform thickness for the veneering porcelain and thus impede the formation of unsupported porcelain that may be prone to fracture (Figures 1 and 2). As with any full-coverage restoration, a preparation with adequate foundation with resistance and retention form is a must. In cases where failing restorations with inadequate resistance and retention form are encountered, a new foundation restoration (ie, core, post and core) must be fabricated (Figures 3 and 4). Adequate definitive impressions with no voids and a definitive recording of the finish line are a must as in the case of metal-ceramic restorations. In addition, as with any implant-supported restorations or tooth-supported FPDs, an accurate recording of the soft tissue is essential in providing the ceramist with the optimal information for fabricating an aesthetic and functional restoration (Figure 5). Therefore, additional procedures must be employed to ensure a successful restoration (Figures 6 through 8).

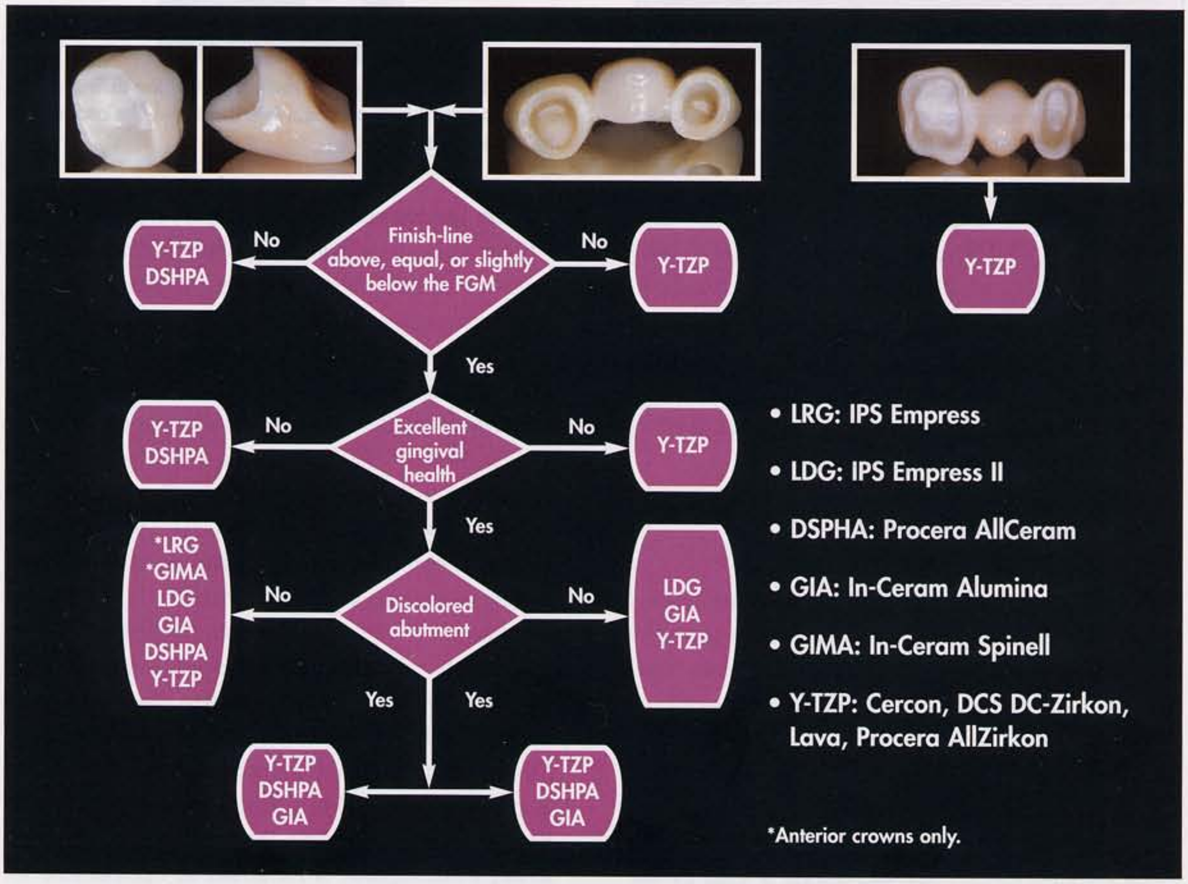

Figure 15. A flowchart demonstrating the decision-making process in selecting the type of all-ceramic restoration.

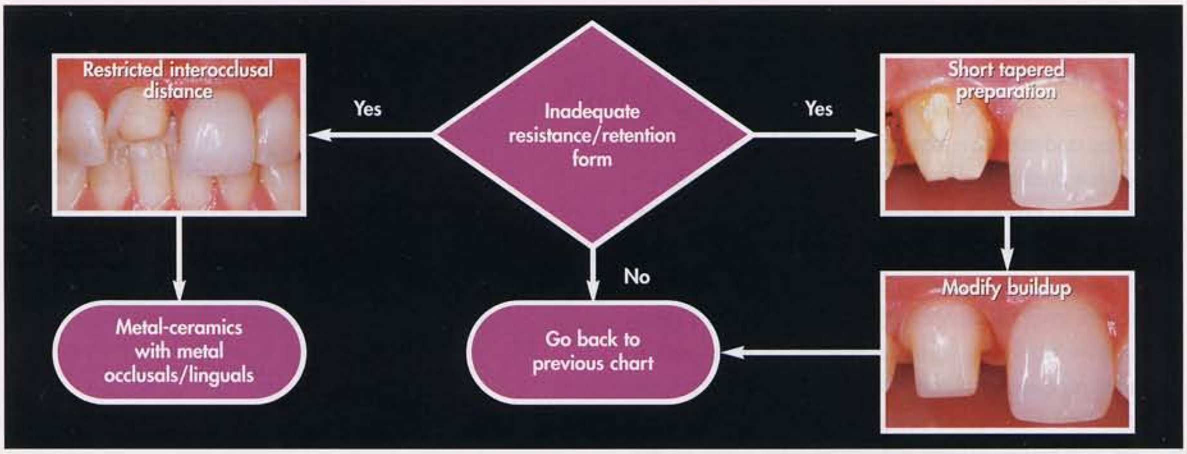

Figure 16. A flowchart demonstrating the decision-making process in selecting restorative materials when a clinician is presented with less-than-ideal abutments in terms of resistance and retention form.

Generally, different core materials allow different levels of light transmission. Polycrystalline ceramics such as the DSHPA and the Y-TZP allow light transmission (Figure 9).[32] They also successfully mask underlying discolored abutments. As such, they can be successfully used for their respective indications to conceal underlying discolored teeth, metallic cores, and metal-alloy implant abutments (Figures 10 through 12). GIA cores present a similar masking ability. Other core materials such as GIMA, LRG, and LDG present with a higher level of translucency and should be used where high translucency is required.

The cementation protocol is related to both the composition and the strength of the core materials. Glass-ceramic cores can be etched and bonded to the tooth structure. This is not the case with glass-infiltrated ceramics and polycrystalline ceramics, which cannot be etched due to the lack of glass in their microstructure. Because they present with a higher strength related to their respective indications, they may be conventionally luted, and adhesive cementation using techniques other than the one used for glass-ceramics is optional.

For cement-retained, implant-supported restorations, clinicians may use a temporary cementation protocol for metal-ceramic restorations. Since removal of implant-supported, all-ceramic restorations (either with or without a ceramic abutment) is not predictable and fracture of the restoration may occur, definitive cementation is recommended. In these cases, especially when metal abutments are used, the highest strength ceramics are recommended if all ceramics is the restorative material of choice (Figure 13). While most all-ceramic core materials present with dentin-like radiopacity, Y-TZP infrastructures present with metal-like radiopacity that enhances radiographic evaluation of the restoration (Figure 14). When patients present with parafunctional habits, the use of all-ceramic restorations must be carefully evaluated. If a patient insists on being restored with a metal-free restoration, the highest-strength core material should be selected with optimal preparation and core design. Such patients must be committed to the use of an occlusal guard.

When selecting the core material for a full-coverage, all-ceramic restoration, clinicians must make an independent decision for anterior and posterior crowns, for anterior FPDs, and for posterior FPDs. Selection of the core material is based on the mechanical properties of the material and involves the evaluation of three principal clinical considerations:

1. Is the finish line above, even with, or slightly below the free gingival margin? This will affect the predictability of moisture control and contamination during adhesive cementation.
2. Is the gingival health adequate? This will also affect the predictability of moisture control and contamination during adhesive cementation.
3. Is the abutment tooth-colored or not? Is high translucency a requirement? Or is concealing the color of the abutment of major consideration?

Based on an understanding of the advantages and limitations of the different ceramic core materials and by addressing the above clinical considerations, clinicians can select the appropriate material for each individual clinical scenario (Figure 15). If several core materials are selected, such as in the case of a full-mouth reconstruction, a challenge is presented to the ceramist in terms of color-matching all-ceramic restorations with different types of core materials.

Another question clinicians must ask is: Are the resistance and retention form adequate?[11] In cases where the patient presents with a short and tapered preparation due to a previous restoration and the interocclusal distance is not restricted, clinicians cannot rely on bonding procedures alone for ensuring the longevity of the restoration, and the foundation restoration must be modified while applying basic concepts of preparation design. If a patient presents with a restricted interocclusal distance and inadequate resistance and retention form, the use of a metal-ceramic restoration with metal on the occlusolingual surfaces should be considered (Figure 16).

Conclusion

Clinicians are confronted with a variety of high-strength, all-ceramic core materials. These materials have different properties that affect their indications and limitations, the laboratory procedures for their use, and their clinical handling. Clinicians should not abandon basic concepts of preparation design and foundation restorations and rely only on adhesive cementation for long-term success. The color of the underlying abutment and the translucency required, as well as the predictability of different types of cementation procedures, should play a major role in the clinician's selection of all-ceramic materials for successfully and predictably restoring their patients.

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