Synergy in Dentistry

In This Issue:

The Lava™ All-Ceramic System: CAD/CAM Zirconia Prosthodontics for the 21st Century
by John A. Sorensen, DMD, PhD

Achieving Clinical and Esthetic Success by Placing a Zirconia-Based All-Ceramic Three-Unit Anterior Fixed Partial Denture
by Thomas K. Hedge, DDS

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Dear Readers:

Zirconia for all-ceramic single crowns and fixed partial dentures (FPDs) has arrived. Once envisioned as a bridge to a distant future, zirconia is now touted as the present day Holy Grail. For many years all-ceramic restorations have been gaining acceptance as technologies improve, to the point where clinical durability for single crowns for both anterior and posterior restorations rivals metal-ceramic restorations in published clinical studies. Concomitantly, porcelains and alternate metal substrates for metal-ceramics have improved drastically in their esthetic potential in the last few years, and, in the right ceramist’s hands, they can rival any all-ceramic restoration. The problem remains that the average ceramist has a difficult time dealing with the opaque metal substructure; relatively few ceramists have mastered this technique.

The ideal esthetic solution is to have a more translucent substrate that will have the long-term clinical durability of metal-ceramic restorations, especially for anterior crowns and FPDs. This appears to be the case for single-unit restorations, as several clinical studies demonstrate clinical success for these types of restorations—especially ceramic core systems that are generated by computer-assisted design/computer-assisted manufacture (CAD/CAM). Until now, no all-ceramic system demonstrated the physical properties considered necessary for long-term clinical success for posterior FPDs. Solid, sintered, monophase zirconia has the apparent physical properties necessary for use in posterior bridge applications where ideal connector dimensions can be maintained. Clinical trials are being conducted at several universities; one published study from the University of Zurich has been extremely promising, with no failures to date. It is important to note that only 2-year data is available with these new systems and, while the early data is excellent, no long-term conclusions should be drawn.

As a long-awaited adjunct to conventional technologies because it allows clinicians to automate some of the more mundane tasks and use industrial-quality ceramics that could not be used by conventional techniques, CAD/CAM is here to stay. Zirconia has unique properties in that it does not undergo corrosive weakening, as do many other ceramics, and it has a self-healing property against cracks. In this issue of Synergy in Dentistry, both of these points are explained elegantly by Dr. Sorensen. In addition, Dr. Hedge gives an excellent overview of some of the historical developments in ceramics and demonstrates the use of the Lava™ All-Ceramic system with a case report. Dental Learning Systems would like to thank 3M ESPE for sponsoring this clinical series.

Sincerely,
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Learning Objectives

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

• describe the “transformation toughening” mechanism that strengthens zirconia ceramics.
• compare zirconia ceramics to other metal-free prosthodontic systems for posterior bridges.
• describe the different methods for fabricating and milling zirconia ceramic substructures.

The last decade has witnessed significant improvements in the strengths of ceramics and fabrication technologies for all-ceramic, fixed prosthodontic systems. Although manufacturers have claimed that ceramic systems are strong enough to make fixed partial dentures (FPDs) to replace missing molars, to date clinical studies have not supported these claims. One study measuring the strength of all-ceramic systems found that in three-point bend tests, the strongest material available at the time was In-Ceram® Aluminaa at 450 MPa. A clinical trial using In-Ceram® Alumina demonstrated no failures of anterior three-unit FPDs. However, a high failure rate of 11% for premolar pontic FPDs and 24% for molar pontic FPDs occurred. All of these FPD failures occurred in the connector between the retainer and the pontic. Similarly, the IPS Empresst Lithium disilicate all-ceramic system is primarily indicated for anterior single-tooth replacement and requires rather large occlusal–gingival connector heights for premolar pontic FPDs. This author is unaware of any significant clinical studies that would support the systematic use of a fiber-reinforced composite resin system to fabricate FPDs for replacing molars. Until recently, no system has possessed sufficient physical properties to make all-ceramic posterior FPDs.

Zirconia All-Ceramic Systems

A number of companies have recently developed zirconia all-ceramic systems. These zirconia polycrystalline ceramics are a significant departure from earlier all-ceramic systems. One way of measuring the strength of a ceramic material is through its fracture toughness. Fracture toughness is a measure of the material’s ability to resist the propagation of cracks. Zirconia undergoes an unusual phenomena called transformation toughening that contributes to its remarkable strength. Zirconia can exist in three forms—monoclinic, tetragonal, and cubic. The addition of a stabilizing agent, such as 3% yttrium oxide, allows sintering of a fully tetragonal-phase ceram-
ic known as partially stabilized zirconia. When a crack attempts to propagate through the ceramic, there is a high-energy stress state at the leading edge of the crack. This high-energy field in the area of the crack causes the zirconia to transform from a tetragonal crystal configuration to a monoclinic configuration. Because the monoclinic crystal is 3% to 5% larger, it places this region in compression (Figure 1). This is a perfect mechanism for strengthening the ceramic because the transformation occurs exactly at the location where the crack needs to be stopped, which helps to combat the crack propagation.

Zirconia undergoes an unusual phenomena called transformation toughening that contributes to its remarkable strength.

While many ceramic systems show fairly high strength, one major problem with dental ceramics is that their strength can drop significantly when stored in water. A study where the author and his colleagues stored ceramic disks in water for only 1 week demonstrated just how significantly this chemically assisted, slow crack growth can reduce the strength of ceramics. Table 1 demonstrates how all of the ceramics except zirconia had significant strength reductions after only 1 week in water storage. The resistance to moisture-induced degradation in strength makes zirconia ceramics especially appealing as a posterior FPD material.

The Lava™ system is designed for mass production.

Unlike some of the other systems on the market that require waxing up the substructure, the Lava system is a true CAD/computer-aided manufacture (CAM) system (Figure 2A). The FPD dies (Figures 2B through 2D) are scanned with a system that then allows for determination of the tooth preparation margins and design of the pontic and FPD connectors (Figure 3). The edentulous areas that were formed with an ovate pontic are also scanned for design of the antaglio surface of the framework (Figure 4). Additionally, the opposing bite registration can be scanned to design the lingual occlusal surface of the framework (Figure 5).

When designed, the appropriate
Zirconia block is selected, which has a plastic holder labeled with a bar code (Figure 6A). The technician registers the unique design in the server with this bar code (Figure 6B), and then moves over to a separate milling machine. The Lava system is designed for mass production. As many as 20 zirconia blocks in plastic holders can be loaded in the machine because the handling of the blocks is completely automated for the milling process. Because the zirconia block has a chalky consistency, carbide cutting burs can be used for milling. The cutting instruments experience very little wear, which contributes to the accuracy of the milling.

Zirconia ceramic has the best physical properties of any dental ceramic available today.

After the milling process is complete, the framework is separated from the remaining holding portion of the zirconia block and fully sintered for approximately 7 hours (Figure 7). The framework has now undergone the 20% sintering shrinkage, which was compensated for in the CAD process. Figure 8 shows the virtual framework design from the CAD process and the actual sintered framework. The framework has been designed to take into account soft tissue contours, the opposing occlusion, tooth preparation design, and margins so that minimal, if any, adjustment will have to be made to the framework before applying the veneer porcelain (Figure 9).

The Lava™ All-Ceramic System is unique because the appropriate shade can be inherently achieved in the zirconia substructure (Figure 10), whereas the Cercon® Smart Ceramics™ System zirconia is white and opaque, and therefore must be modified with stain and dentin modifiers. The CEREC® system⁶ for CAD/CAM fabrication of In-Ceram® zirconia substructures allows for the infiltration glass process of conferring shade; however, the substructure tends to be slightly gray or green in color. The inherent natural shades of the Lava substructure help the ceramist to achieve a natural shade for the crown or FPD. Lava Ceram veneering porcelain is then artistically applied to the zirconia substructure (Figures 11 through 14).

The shade of the framework can be inherently achieved rather than extrinsically modified.

Conclusion

The Lava™ All-Ceramic System uses zirconia ceramic, which has the best physical properties of any dental ceramic available today. The transformation toughening phenomena specific to zirconia ceramics and its resistance to degradation in water make Lava zirconia the most promising all-ceramic posterior PFD material. Using the zirconia in the semisintered state facilitates a rapid milling process, while the CAD system allows for a virtual PFD design that is 20% larger than the actual PFD to compensate for the sintering shrinkage and provide...
highly accurate fitting frameworks. The zirconia frameworks are esthetic because the shade of the framework can be inherently achieved rather than extrinsically modified, as with a white and opaque ceramic. Therefore, the resulting shade of the veneered FPD is enhanced by the appearance of the zirconia substructure. The Lava system, a fully CAD/CAM zirconia system, is a major advance for fixed prosthodontics in the 21st century.

Acknowledgments
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References

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Learning Objectives

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

• discuss how the minimal survival rate that all-ceramic systems must demonstrate was determined.

• describe the ideal preparation for a three-unit fixed partial denture using the Lava All-Ceramic System.

• discuss the enhancements to all-ceramic systems that have resulted from the need to provide patients with biocompatible, esthetic, and durable restorations.

Without question, porcelain restorations have been an essential component of dental care for decades, even centuries. Successful attempts to seat a porcelain tooth replacement date back to the 17th century. In the 19th century, Charles Henry Land developed the porcelain jacket crown based on a feldspathic composition that is still used today, although in a modified form. Years later, reinforcement of the jacket crown was achieved with aluminum oxide-based ceramics.

Further developments in ceramic restorations concentrated on addressing the inadequate fracture resistance of the veneering ceramics and were based on increasing the material’s crystalline content with leucite (IPS Empress®, a), mica (DICOR®, b), hydroxyapatite, or mixed glass-infiltrated oxides (In-Ceram®, c). Pure polycrystalline oxide ceramics (Procera®, d) were introduced into clinical practice about 10 years ago.

Of these, pressed ceramics (such as IPS Empress®) have been used successfully for anterior applications for more than a decade, and other porcelain systems have had similar long-term success, but for posterior crowns and fixed partial dentures (FPDs), they have not. Given the success of porcelain-fused-to-metal (PFM) restorations during the last 30 years, all-ceramic systems must demonstrate comparable longevity; a minimum survival rate of 85% after 10 years in vivo is required, even for posterior teeth.

As a result of the need to provide patients with biocompatible, esthetic, and durable restorations, further enhancements to all-ceramic systems have ensued. Today, all-ceramic restorations in the posterior region have become an increasingly important part of modern esthetic restorative dental care. However, truly fracture-resistant and esthetic ceramics for such indications or for commercially viable processing procedures have not been previously available. Further, a strong, translucent FPD material has been previously an elusive goal in dentistry.

The quest to fabricate all-ceramic crowns and multiunit FPDs that demonstrate favorable clinical characteristics and long-term stability in the posterior region has been limited by the mechanical properties of glass ceramics and infiltrated ceramics. Further, requirements for accuracy of fit and versatility (ie, can be reliably placed in all posterior as well as anterior situations) have been difficult to meet.

The polycrystalline ceramic frameworks fulfill the demands placed on all-ceramic restorations, and it is zur-
conia oxide, in particular, that provides suitability as the current framework material of choice. Additionally, a computer-assisted design/computer-aided manufacture (CAD/CAM) system that does not require the laboratory technician or dentist to deviate from standard preparation, impressioning, and conventional cementation protocol further enhances the prospects of zirconia-based all-ceramic restorations to satisfy these multiple needs. To this end, precise scanning and milling technologies, combined with thorough knowledge of zirconium oxide ceramics, have resulted in the creation of the Lava® All-Ceramic System, which provides the dentist, laboratory, and patient with durable, versatile, and esthetic all-ceramic restorations for a variety of anterior and posterior indications.

The Lava System

With the Lava All-Ceramic System, all-ceramic bridge restorations for anterior and posterior regions have become a reality. The system is based on machining presintered zirconia, which is then sintered to a dense state. Because of its outstanding mechanical properties, biocompatibility, and excellent esthetics, Lava zirconia is an ideal material alternative for all-ceramic indications. Lava restorations are indicated for anterior and posterior crown-and-bridge applications.

All-ceramic restorations in the posterior region have become an increasingly important part of modern esthetic restorative dental care.

Specifically, the system uses a CAD/CAM processing technique (scanning, CAD, and milling) for fabricating all-ceramic crowns and FPDs for anterior and posterior indications. The zirconia framework is enhanced by a specially designed veneering ceramic. As a result, the system produces high-strength restorations with excellent fit and superior esthetics.

Zirconia—the cornerstone of the Lava All-Ceramic System—is one of only two polycrystalline ceramics suitable for use in dentistry as a framework material, able to withstand high load-bearing stress in both the anterior and posterior areas. For example, a veneered three-unit zirconium-dioxide posterior FPD demonstrated high fracture resistance, even with an overall frame thickness of 0.5 mm. Additionally, marginal gap studies have shown that zirconia restorations demonstrate an exceptional accuracy of fit. They also provide the necessary esthetic characteristics (e.g., tooth shade, opacity, translucency) and material properties required of a modern esthetic restoration (Figures 1 and 2).

Zirconia is able to withstand high load-bearing stress in both the anterior and posterior areas.

The Lava frame and veneer ceramic have been specifically developed to complement each other and cannot be combined with other ceramic materials. The frameworks are available in 8 shades, and the veneering ceramic is available in 16 Vita® Classic shades. The color range consists of 7 shoulder materials, 16 framework modifiers, 16 dentin materials, 10 Magic intense materials, 4 incisal materials, 2 enamel effect materials, and 4 Transpa-Opal materials. The system also includes 1 Transpa-Clear material, 10 extrinsic colors, 1 glaze, and accompanying liquids to ensure the ability of the technician to perfectly match the clinician’s color mapping requirements.

Case Presentation

A 45-year-old woman presented with a variety of complicating and interrelated health issues, including lupus, chronic pain, allergies, asthma, a history of headaches, temporomandibular joint and facial pain, and clenching/bruxing. The patient also had neuromuscular pain. Her chief concern was the appearance of her teeth (Figure 1). Clinical examination revealed numerous broken-down restorations resulting from bruxism. All of the porcelain had broken off one PFM crown. Further,
she presented with an old FPD replacing tooth No. 10.

**Treatment Considerations**

Before restorative treatment, the patient underwent a series of scans that included joint sonography, electromyography, and computerized mandibular scans. A comfortable neuromuscular position was identified and an orthotic was fabricated. The patient was placed in this appliance, which she wears 24 hours a day and, since April 2002, remains pain-free.

A number of esthetic restorative challenges were presented with this case. First, to deliver to the patient the “dazzling” smile she desired, teeth Nos. 6 through 11 would have to be restored at a minimum, requiring the mixing and matching of shades for one three-unit FPD and three porcelain veneers. Traditionally, anterior FPDs required some form of metal reinforcement, necessitating blocking out the metal and creating an opaque situation. Although generally easy to prepare and cement, these restorations were rarely esthetic and required subgingival margins or porcelain butt-joints, adding additional challenges. Further, because of financial constraints, treatment options were limited.

The dentist and patient were able to choose an esthetic shade because the six maxillary anterior teeth were to be covered with porcelain. The selected shade did not deviate significantly from the mandibular anterior teeth or the bicuspid region of the maxillary teeth. The ShadeScan™ System was used to map translucency and color variation of the mandibular natural teeth.

**Preparation and Temporization**

The patient was prepared to receive one three-unit all-ceramic FPD and three pressed-ceramic veneers. The ideal preparation for the Lava three-unit FPD is a shoulder or chamfer preparation with a circumferential step or chamfer placed at a more than 5-degree angle horizontally. The vertical preparation angle was 4 degrees or more, and the inside angles were rounded. Provisional restorations were fabricated with Protex™ 3 Garant™ temporization material, shade A1, using a polyvinyl siloxane (PVS) putty matrix relined with light-body PVS wash over the wax-up.

Marginal gap studies have shown that zirconia restorations demonstrate an exceptional accuracy of fit.

Digital photographs were taken of the preoperative condition, preparations, and provisional restorations using a Canon EOS D60, with a 100-mm macro lens and a Canon Macro Ring Lite MR-1EX ring flash. Standard views as recommended in the author’s text, Digital Dentistry (published by tomhedge.com publications and available at The Las Vegas Institute and Norman Camera), were used.

The color-mapping analysis and photographic information were forwarded to the laboratory for use in fabricating the final restorations.

**Laboratory Fabrication**

Using impressions delivered from the dentist, the laboratory technician created a working model. The sectioned model was then positioned in the Lava Scan, a PC-based system for creating Lava restorations. Individual preparations and the ridge were recorded automatically by the scanner and displayed on the monitor as a three-dimensional image, including gingival and occlusal records. The virtual design of the framework—including the insertion of the pontic and design/modeling of the connections—was completed using the computer keyboard and mouse.

The data were then transferred to the Lava Form milling unit, followed by framework coloring according to the shade prescribed. The framework was sintered and then prepared for application and layering of the veneering ceramic and, ultimately, finished and fired.
Cementation

At the seating appointment, the patient’s provisional restorations were removed, the preparations were properly cleansed, and the three-unit Lava restoration and the pressed ceramic veneers were readied for placement. In this case, the three-unit FPD was cemented into place using a self-adhering cement (RelyXTM Unicem®), and the veneer restorations were placed with an adhesive bonding cement (RelyXTM ARCe). The Lava FPD restoration required no finishing after cementation (Figures 2 through 4).

Traditional cementation with glass ionomer cements (Ketac™-Cem® or RelyX™ Luting Cement®) is also recommended for cementing crowns and FPDs fabricated from the Lava system material, regardless of location or type of restoration. The use of phosphate cements is contraindicated for Lava restorations because of esthetic considerations.

Figures 5 through 10 show a second case that was prepared, impressioned, fabricated, and cemented in the same manner using the Lava system.

Conclusion

As with all indirect restorations, preparation and laboratory fabrication techniques added to the success of this case, in addition to the laboratory technician’s ability to match the new Lava ceramic material shade to the traditional pressed-ceramic veneers. Colorable frameworks of the ideal translucency, and thin coating thickness to which color can be applied, ensured the natural appearance and harmonious blending of the FPD with the patient’s adjacent natural dentition as well as the pressed-ceramic veneer restorations.

As a result of the remarkable strength and stability of zirconia, a three-unit Lava bridge restoration can be confidently placed in either the anterior or posterior region. Preparation can be achieved conservatively, and cementation can be completed using conventional methods. Additionally, Lava restorations deliver exceptional physical properties, including fracture toughness and transformation toughening to prevent crack propagation, and highly accurate-fitting frameworks. Further, the esthetic capability and biocompatibility of Lava restorations represent the optimum in all-ceramic systems.

References

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**Dr. Sorensen**

1. Which of the following is a measure of a material's ability to resist the propagation of cracks?
   a. fracture transformation
   b. aspect ratio
   c. fracture toughness
   d. stoichiometric value

2. Zirconia undergoes what unusual phenomenon that contributes to its remarkable strength?
   a. transformation toughening
   b. yttrium perfusion
   c. hydrogen uptake
   d. crystal precipitation

3. When a crack attempts to propagate through the ceramic, there is a high-energy stress state:
   a. in the middle of the crack.
   b. at both ends of the crack.
   c. at the leading edge of the crack.
   d. at the trailing edge of the crack.

4. One major problem with dental ceramics is that their strength can drop significantly when stored in:
   a. saline.
   b. water.
   c. oil.
   d. room temperature air.

5. Semisintered zirconia has the consistency of:
   a. chalk.
   b. putty.
   c. gelatin.
   d. dough.

**Dr. Hedge**

6. All-ceramic systems must demonstrate a minimum survival rate of:
   a. 75% after 10 years.
   b. 75% after 15 years.
   c. 85% after 10 years.
   d. 85% after 15 years.

7. The frameworks are available in how many shades?
   a. 3
   b. 5
   c. 8
   d. 9

8. Veneering ceramic is available in how many Vita® shades?
   a. 16
   b. 24
   c. 28
   d. 32

9. The ideal preparation for the Lava three-unit FPD is a shoulder or chamfer preparation with a circumferential step or chamfer placed at more than what degree angle horizontally?
   a. 4 degrees
   b. 5 degrees
   c. 6 degrees
   d. 7 degrees

10. The use of which cement is contraindicated for Lava restorations because of esthetic considerations?
    a. glass ionomer
    b. phosphate
    c. self-etching
    d. self-curing

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