Evaluation of Contemporary Ceramic Materials

Author
SUMITHA N. AHMED, BDS, MS*,
TERRY E. DONOVAN, DDS†
Associate Editor
EDWARD J. SWIFT, JR., DMD, MS

The last 25 years have witnessed the introduction of a bewildering number of ceramic systems to the dental profession. Most of these systems have been introduced with little or no clinical testing. Laboratory studies of physical and mechanical properties of ceramics provide little predictive information regarding likely clinical survival rates. Early adopters of many of these new systems learned quickly that most of the systems had poor survival rates. Meaningful clinical trials must be of 5 years' duration, which means it will be several years after the introduction of a product to the market before clinicians will have an evidence base on which to make educated clinical decisions.

The gold standard for ceramic restorations is clearly porcelain-fused-to-metal (PFM). With PFM, it is reasonable to expect a 10- to 15-year survival rate of 95%, with the incidence of porcelain chipping around 4 to 10%. With the use of porcelain facial margins and proper tooth preparations, good to excellent esthetic results can be anticipated. PFM restorations have been popular for decades because they provide a combination of reasonable esthetics coupled with maximum longevity.

However, recent years have seen dramatic increases in the basic price of gold and other noble metals used with porcelain bonding alloys, which has resulted in a significant increase in laboratory costs. This increase in cost, coupled with society's obsession with esthetics, has resulted in increased interest in ceramic restorations. There are four groups of ceramic materials that have a sufficient level of clinical testing and/or anecdotal evidence that clinicians should investigate and consider for use with their patients. Table 1 lists the groups of ceramic materials and their approximate laboratory costs. These costs were determined by contacting five different commercial laboratories to obtain estimates and then calculating the average cost.

Leucite-reinforced glass-ceramics (IPS Empress, Ivoclar Vivadent, Amherst, NY, USA) were introduced in the late 1980s. IPS Empress was the first system to employ pressing technology that can be used to fabricate both monolithic and layered restorations, the later involving a pressed core with veneering ceramic. Layered IPS Empress anterior crowns are likely the most esthetic ceramic restoration available, and clinical trials have demonstrated 95% survival at 5 years *on anterior teeth*. On posterior teeth, the survival rate drops to 80% or less, dictating that they only be used on anterior teeth.

To attain this high survival rate, it is imperative that IPS Empress crowns be internally etched and bonded in place. Bonding can be accomplished using the immediate dentin sealing technique and a dual-cure resin cement (e.g., Variolink II, Ivoclar Vivadent) or use of a self-adhesive dual-cure resin cement (e.g., RelyX Unicem, 3M ESPE, St. Paul, MN, USA). The primary indication for these restorations is single crowns on the anterior teeth in patients with high esthetic expectations. The laboratory cost of these restorations is less than that of a PFM crown. In a survey of commercial dental laboratories, it was determined that

*Assistant professor, Department of Operative Dentistry, UNC School of Dentistry at Chapel Hill, Chapel Hill, NC, USA
†Professor and section head for biomaterials, Department of Operative Dentistry, UNC School of Dentistry at Chapel Hill, Chapel Hill, NC, USA

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TABLE 1. Type of crown and average cost (based on survey of five commercial laboratories)

PFM (high noble)	$273
PFM (noble)	$248
Cast Gold	$314
IPS Empress (layered)	$219
IPS e.max (layered)	$212
IPS e.max (monolithic)	$196
Zirconia (layered)	$242
Zirconia (monolithic)	$171

the average price of a PFM crown using high noble metal alloy was $273, whereas the average price of an IPS Empress crown was $219 (Table 1).

Lithium disilicate glass ceramic restorations (IPS e.max, Ivoclar Vivadent) have been available for several years, and based on short-term clinical trials and anecdotal evidence single-unit crowns seem to have high (>95%) short-term survival rates on both anterior and posterior teeth. These materials have high flexural strength compared with leucite-reinforced materials (400 MPa versus 160 MPa). They are used both in the monolithic form and the layered form. Monolithic e.max crowns are indicated primarily on posterior teeth, and layered crowns are indicated for anterior teeth. Layered e.max crowns are more esthetic, but seem to fracture at twice the rate of monolithic crowns. Available data indicate that the failure rate of three-unit fixed partial dentures is unacceptably high.

Lithium-disilicate glass-ceramic crowns can be either cemented or bonded, but at this time it is recommended that they be etched and bonded using a self-adhesive dual-cure resin cement. Laboratory costs for these crowns are considerably less than for PFM crowns ($196–212 for e.max versus $273 for PFM) (Table 1).

Layered zirconia crowns have been commercially available for more than 10 years. Table 2 lists the brand names and manufacturers of some of the more popular

TABLE 2. Brand names and manufacturers of zirconia crowns

Brand names	Manufacturer
Lava	3M ESPE, St. Paul, MN, USA
BruxZir	Glidewell Laboratories, Newport Beach, CA, USA
Zenostar	Ivoclar Vivadent, Inc., Amherst, NY, USA
KATANA Zirconia HT (high translucency) and ML (multilayered)	Kuraray Noritake, Tokyo, Japan
Prettau Zirconia	Zirkonzahn USA, Norcross, GA, USA
NexxZr	Sagemax Bioceramics, Inc
Cercon ht	Dentsply Prosthetics, York, PA, USA
Vita IN-Ceram YZ	Vident, Brea, CA, USA
GC Initial	GC America Inc., Alsip, IL, USA
Zirlux	Zahn Dental Laboratories, a division of Henry Schein, Melville, NY, USA
CAP Multi FZ	Advanced Dental Technologies, Stoneham, MA, USA

zirconia-based products available to dentists. Core fracture of layered zirconia crowns is very rare due to the property of transformation toughening, which intrinsically stops crack propagation when a defect begins to propagate. The esthetic results with layered zirconia crowns are satisfactory and the marginal fits acceptable.

One problem with layered zirconia crowns, which has been seen in almost all clinical trials, is the cohesive chipping of the veneering ceramic. This chipping, which occurs approximately five times more frequently than with PFM restorations, does not always necessitate replacement of the crown, but it has been a persistent problem. Causes of the chipping may be lack of support of the veneering ceramic by the core and the low thermal conductivity of the core material. The latter problem may have been resolved by utilization of slower cooling cycles, and the former issue has been resolved with improved software programs to insure optimum support by the core. Clinical trials with the new protocols are essential to confirm the belief that

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the incidence of chipping can be reduced to acceptable levels, but cautious use of layered zirconia crowns can be recommended for use when cost-containment is important. The average cost for a layered zirconia crown is $242 (Table 1).

Monolithic zirconia restorations have only been in use for a few years, so no long-term clinical trials are available. Most authorities are optimistic regarding survival rates based on the fact that so few zirconia cores have fractured in clinical trials, and a monolithic or full-contour zirconia crown is essentially an un-veneered zirconia core. They have very high flexural strength (1200–1400 MPa) and have been used experimentally with large multi-unit restorations. Because of these excellent properties, more conservative tooth preparations are possible compared with those used with PFM, lithium disilicate, or layered zirconia crowns. Another advantage of monolithic zirconia crowns is that when polished well, they are very kind to opposing tooth structure, and multiple in vitro studies have shown much less wear of enamel than with other types of ceramic.

These restorations are relatively opaque, resulting in reduced esthetics compared with layered restorations. They are also relatively inexpensive with an average cost of $171. The major indication for monolithic zirconia crowns is for posterior teeth where esthetics is not critical, especially for second molars when patients decline cast gold restorations. Because zirconia crowns can be fabricated with significantly less tooth reduction, another indication is for crowns on mandibular anterior teeth.

Zirconia cannot be etched with hydrofluoric acid because their molecular structure is different from glass ceramics. Protocols involving airborne particle abrasion bonding with MDP primers and resin cements have been tested in vitro, but they generally form relatively weak bonds that deteriorate with aging and run the risk of transformation of the entire crown or core as a result of particle abrasion. In the opinion of the authors, zirconia crowns are best used with retentive preparations and cemented. It should be noted that the internal surface of zirconia crowns is usually contaminated with saliva and possibly blood during try-in, and has a strong affinity to salivary proteins that are not easily removed. If these are not removed, crowns can be prematurely dislodged. The best protocol for cleaning the internal surface is to use a solution of sodium hydroxide (Ivoclean, Ivoclar Vivadent) for 20 seconds followed by rinsing with water.

SUMMARY AND CONCLUSIONS

Clearly PFM is the gold standard for esthetic crowns restorations, but the price of noble metals has driven laboratory costs to unprecedented levels. Advances in materials and technology have resulted in the development of four ceramic systems that can be considered as economic alternatives to PFM, which provide good to excellent esthetic results and have demonstrated adequate clinical longevity.

Layered leucite-reinforced crowns provide excellent esthetic results on maxillary anterior teeth when etched and bonded in place. Monolithic lithium disilicate crowns are indicated for premolars and first molars, whereas layered lithium disilicate crowns can be used with maxillary incisors. Layered zirconia cored crowns can be predictably used on anterior teeth and premolars. Monolithic zirconia crowns are best used for molars and mandibular anterior teeth.

SUGGESTED READING

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Terry E. Donovan
Department of Operative Dentistry
UNC School of Dentistry at Chapel Hill
Chapel Hill, NC, USA
Telephone: 919-537-3985
Fax: 919-537-3990
E-mail: Terry_Donovan@unc.edu

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