Guide to Zirconia Bonding Essentials

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Disclosure: The author (JMP) is Senior Vice President of Dental Consultants, Inc., publisher of THE DENTAL ADVISOR. He is also a member of ADCAA, LLC (Apex Dental Milling), an Authorized Lava Milling Center.

Bonded Cementation of Zirconia-based Ceramic Restorations

Zirconia-based ceramics are a rapidly growing type of esthetic restoration. The high core structure strength is excellent for many restorations, such as crowns, bridges and implant abutments. This report describes the properties of zirconia-based ceramics and the cementation and bonding of zirconia-based ceramics. The descriptions will stress the achievement of esthetic restorations with a durable tooth-ceramic interface.

Zirconia-based Ceramics

Zirconia (zirconium oxide)-based ceramics have become a very popular type of all-ceramic restorations. Zirconia-based restorations can be a near ideal choice for restoring crowns, fixed partial dentures, and implants in esthetic areas. This report will describe properties of zirconia-based products, advantages, disadvantages, indications, and contraindications, and the clinical techniques involved in preparing and cementing/bonding these types of restorations.

Most zirconia-based ceramics utilize CAD/CAM technology for fabrication of crowns, bridges and implant abutments. Some copings are milled as fully sintered, hot isostatic press (HIP) blocks. Other products, due to the high-strength of zirconia (zirconium oxide), are milled in the "green" or pre-sintered state. After sintering, the material shrinks about 20% to the desired size and shape, with a high strength. After the copings are

fabricated, porcelain compatible to the properties of the zirconia coping are either pressed or stacked onto the coping, creating a uniquely strong and esthetic restoration.

Examples of zirconia-based ceramics are listed in Table 1.

TABLE 1
Examples of Zirconia-based Ceramics.

Product	Company
Lava Crowns and Bridges	3M ESPE
Cercon	DENTSPLY Ceramco
CEREC inLab	Sirona
InCeram Zirconia	Vita
IPS e.max ZirCAD	Ivoclar Vivadent
KATANA	Noritake Dental Supply
KaVo Everest	KaVo
Procera AllZirkon	Nobel Biocare
Versus System	Whip-Mix
ZENO Tec System	Wieland Dental + Technik

Composition of Zirconia-based Ceramics

Zirconia-based ceramics are divided into 3 types: pure zirconia, fully-stabilized zirconia, and partially-stabilized zirconia. Partially stabilized zirconia, especially yttria-stabilized zirconia (Y-TZP), are the most common zirconia-based ceramics in dentistry.

Case Selection

Because of the many all-ceramic alternatives available today, the dentist must choose the most favorable all-ceramic system for each clinical situation. Zirconia-based ceramics are the optimal choice for the following types of cases:

1. Endodontically-treated teeth that have become discolored and need an opaque substructure to mask the discoloration.
2. Esthetic options for patients with heavy occlusion, such as bruxism or other parafunctional habits - the high flexural strength and fracture toughness of zirconia are beneficial in these cases.
3. Cases in which bonding is not needed or desired - zirconia-based ceramic restorations do not need to be bonded to impart strength to the final restoration.
4. Esthetic implant options - zirconia implant abutments are the ideal esthetic option for the restoration of implants in the esthetic zone, and the subsequent zirconia-based ceramic crown blends in well with the zirconia implant abutment.

ADVANTAGES AND DISADVANTAGES OF ZIRCONIA-BASED CERAMICS ARE SHOWN IN THE BOX BELOW:

ADVANTAGES OF ZIRCONIA-BASED CERAMICS:

- Metal-free
- Translucent compared to ceramic-metal restorations
- Can be used for posterior bridges
- High flexural strength and fracture toughness (limit crack propagation)
- Can be used with zirconia-based implant abutments
- Block out of discolored teeth/colored core materials
- More cost-effective when high-noble metal prices are high

DISADVANTAGES OF ZIRCONIA-BASED CERAMICS:

- Limits on bridge spans depending on zirconia products
- Generally require more axial reduction than metal alloys

5. Esthetic fixed partial dentures - in fact, the connectors do not need to be as wide as other types of all-ceramic fixed partial dentures because of the strength of the material. Therfore, zirconia-based ceramics are ideal for this indication.

A summary of indications; contraindications; and limitations are shown in the box below:

INDICATIONS:

- Anterior and posterior crowns
- Anterior and posterior, maximum 14-unit full mouth bridges (span depends on product and number of abutments)
- Implant abutments
- Inlay bridges
- Maryland bridges
- Block out of darkened tooth structure or cores without the need for ceramic-metal restorations

CONTRAINDICATIONS AND LIMITATIONS:

- For long-span bridges, follow the manufacturer's guidelines
- Cantilever bridges, inlays/onlays, veneers
- Need for partial denture precision/semi-precision attachments
- Inadequate occlusal clearance or axial reduction – depends on the ceramic

Bonding of Zirconia-based Ceramics

Objectives for bonded cementation with resin cements

Zirconia-based ceramics have a high strength and, therefore, restorations can be cemented with traditional cements or bonded with resin cements. If greater retention to tooth structure with minimal marginal leakage is required, bonded cementation with resin cements is recommended. Adhesion to tooth structure and to the ceramic restoration combines good marginal sealing and strengthening of the tooth-restoration complex to minimize marginal leakage and tooth fractures. This section describes cementation techniques using three types of resin cement with a focus on durable esthetic restorations.

Definitions of terms are shown in the box on the next page. Examples of resin cements with primers or bonding agents are listed in Table 2. Examples of self-adhesive resin cements are listed in Table 3.

TABLE 2 *Examples of Resin Cements with Primers or Bonding Agents.*

Product	Company	Primer	Bonding Agent
RelyX ARC	3M ESPE	None	3M ESPE Adper Single Bond Plus
Calibra	DENTSPLY Caulk	None	Prime & Bond NT Dual Cure System
Clearfil Esthetic Cement	Kuraray America	None	Clearfil DC BOND
Multilink Automix	Ivoclar Vivadent	Primer A, B	None
NX3	Kerr Corp.	None	Optibond All-In-One
Panavia F 2.0	Kuraray America	ED Primer A, B	None

TABLE 3 *Examples of Self-adhesive Resin Cements.*

Product	Company
RelyX Unicem	3M ESPE
BisCem	Bisco
Breeze	Pentron Clinical Technologies
Clearfil SA Cement	Kuraray America
Embrace	Pulpdent
G-CEM	GC America
Maxcem Elite	Kerr Corp.
MonoCem	Shofu
SmartCem2	DENTSPLY Caulk

DEFINITIONS

Resin cements - resin-based cements include the following three types:

Esthetic resin cement - tooth-colored or translucent cement based on diacrylate resin that requires a bonding agent for adhesion to tooth structure and separate primers for bonding to ceramic substrates.

Adhesive resin cement - cement based on acrylic or diacrylate resin with adhesive monomers that bond well to metal substrates. Adhesive resin cements may require a separate primer for bonding to ceramic and tooth substrates.

Self-adhesive resin cement – cement with adhesive components that eliminate the need for separate primers for bonding to tooth structure and zirconia-based ceramics.

Bonded restoration - ceramic restoration bonded with resin cement.

Luted restoration - ceramic restoration that is mechanically retained (luted) on a standard preparation with cement that does not chemically bond to tooth structure.

Note: *Low-retentive preparations require stronger cements with adhesive properties.*

Composition of Resin Cements

Resin cements are composed of diacrylate resins and glass filler. They are usually dual-cured resins that can be light-activated and can self cure.

Esthetic resin and adhesive cements require bonding agent or primer for adhesion to tooth structure and primer for adhesion to ceramic surfaces. These resin cements should be selected when greater bond strength and stronger mechanical properties of the cement are desired. Light-cured resin cements are strictly contraindicated for zirconia-based ceramic restorations because the zirconia coping does not allow light to penetrate for proper curing.

Self-adhesive resin cements are composed of diacrylate resins with acidic and adhesive groups and glass filler. Self-adhesive resin cements have adhesive components that eliminate the need for separate etchants and primers for bonding to tooth, metal alloy or zirconia-based ceramics. Some products recommend use of ceramic primer for porcelains. They are usually dual-cured resins that can be light-activated and can self-cure. During setting, self-adhesive resin cements typically undergo a change in pH from acidic (pH 2-3) to less acidic (pH 5-6). The early acidity of the cement allows it to achieve self-etching adhesion to tooth structure.

Characteristics of Esthetic Resin Cements:

- May require refrigeration – bring to room temperature before use.
- Self-etch or total-etch bonding agent are needed for bonding to tooth substrates.
- Ceramic primer is needed for all types of ceramic restorations.
- Dual-cured – can be light- or self-cured.
- Light-cured cement is available for veneers.
- Stronger mechanical properties than self-adhesive resin cement.
- Multiple shades available.
- Most esthetic resin cements provide water soluble try-in pastes.

Characteristics of Adhesive Resin Cements:

- May require refrigeration – bring to room temperature before use.
- Primer is needed for bonding to tooth substrates.
- Silane coupling agent is needed as a ceramic primer for silica-based ceramics.
- Can bond directly to zirconia and base-metal alloys without primer.
- Dual-cured – can be light- or self-cured.
- Several shades available.
- May release fluoride.

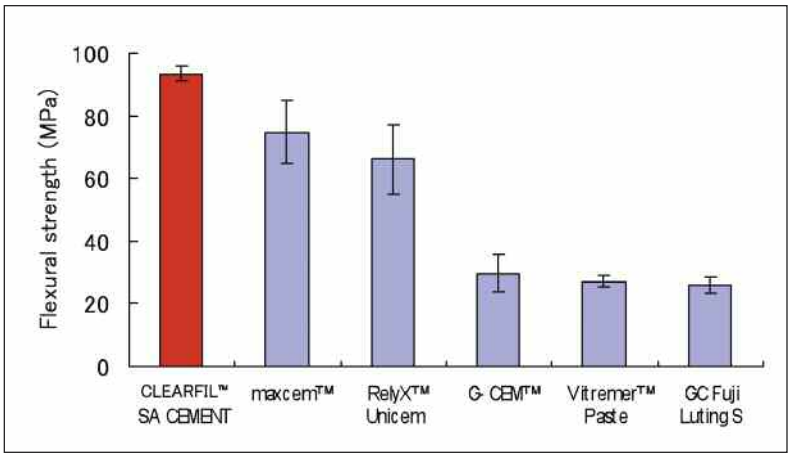


Figure 1. Flexural strength of self-adhesive resin cements. Adapted from H. Yamamoto, T. Nakamura, K. Wakabayashi, A. Okada, S. Kinuta, H. Yatani, Osaka University, 2008.

Characteristics of Self-Adhesive Resin Cements:

- May require refrigeration – bring to room temperature before use.
- Self-etching – no phosphoric acid or special primer needed for bonding to tooth substrates.
- Can bond directly to zirconia and base-metal alloys without primer.
- Dual-cured – can be light- or self-cured.
- Can release fluoride.
- Usually available in universal, translucent and opaque shades.

Manipulation of Resin Cements

Esthetic resin cements and adhesive resin cements require etching and priming steps. Ceramic primer is required with esthetic cements for zirconia bonding. Follow the manufacturer's instructions on how to apply such bonding systems to get strong bonding and enough working time. Working time of the cements may be accelerated with the primer and the bonding agents. Most of these dual-cured cements are paste-paste system with auto-mix dispensers.

Self-adhesive resin cements eliminate the etching and priming steps. Most self-adhesive resin cements are paste-paste systems with auto-mix dispensers, but encapsulated and auto-dispensed products are also available. Follow manufacturers' recommendations when bonding self-adhesive resin cements to tooth structure.

Excess cement can be removed easily after tack-cure by a curing light.

Properties of Resin Cements

Esthetic resin cements have high mechanical strength, since these cements are made of multifunctional acrylate monomers that are polymerized to a cross-linked polymer matrix without acidic monomers.

The flexural strength of several self-adhesive resin cements are compared in Figure 1. Typically, self-adhesive resin cements have higher mechanical properties when light-activated than when allowed to self-cure without light activation as shown in Table 4.

TABLE 4 *Mechanical Properties of Self-adhesive Resin Cements in Dual- and Self-cured Modes.*

	Flexural Strength, MPa		Flexural Modulus, GPa	
Cement	**Light-cured**	**Self-cured**	**Light-cured**	**Self-cured**
Maxcem Elite	86 (11)	90 (17)	5.9 (0.6)	5.2 (0.5)
RelyX Unicem (Clicker)	89 (4)	65 (15)	7.8 (0.5)	4.4 (0.2)
SmartCEM2	94 (7)	86 (7)	4.8 (0.4)	7.1 (0.9)

Yapp R, Powers JM, unpublished data.

Self-adhesive resin cements generally are not as strong as esthetic resin cements. Self-adhesive resin cements are reported to have values of linear expansion of 0.5 to 1.5% over two months. Use of these cements with zirconia-based ceramic restorations is not a concern.

TABLE 5 *Shear Bond Strength of Clearfil Esthetic Cement with Several Bonding Agents to Unground and Ground Enamel Tested at 24 Hours.*

Bonding Agent	Company	Bond Strength to Unground Enamel, MPa	Bond Strength to Ground Enamel, MPa
CLEARFIL DC BOND	Kuraray America	26 (9)	16 (8)
Xeno IV	DENTSPLY Caulk	10 (6)	15 (10)
Adper Scotchbond MP Plus	3M ESPE	20 (7)	15 (7)
Excite DSC	Ivoclar Vivadent	9 (4)	16 (5)

Krishnan G, Yapp R, Powers JM, unpublished data.

TABLE 6 *Shear Bond Strength to Self-adhesive Resin Cements in Dual- and Self-cured Modes to Tooth Structure.*

	Bond Strength, MPa			
	Enamel		Dentin	
Cement	Light-cured	Self-cured	Light-cured	Self-cured
Maxcem Elite	15 (6)	12 (2)	11 (2)	12 (4)
RelyX Unicem (Clicker)	10 (3)	4 (1)	19 (5)	3 (1)
SmartCEM2	11 (5)	12 (6)	6 (1)	4 (2)

Powers JM, unpublished data.

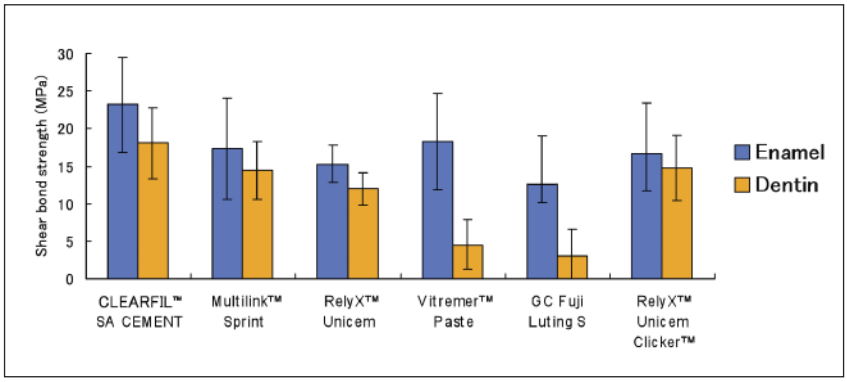


Figure 2. Shear bond strength to tooth structure. Adapted from N. Iwamoto, S. Uctasli, M. Ikeda, M. Nakajima, J. Tagami, Tokyo Medical and Dental Univeristy, 2008.

Bond Strengths of Resin Cements to Tooth Structure

Bond strengths of resin and self-adhesive resin cements to tooth structure are listed in Tables 5 and 6 and shown in Figure 2. Typically, self-adhesive resin cements have higher bond strengths when light-activated than when allowed to self-cure without light-activation. The separate use of a bonding agent is not recommended with self-adhesive resin cements. Although bonding agents may be compatible with self-adhesive resin cements, their use makes the manipulation more complicated and does not dramatically improve bond strength to tooth structure. Higher bond strengths to tooth structure can be obtained with esthetic resin cements that are bonded with separate bonding agents or primers.

Bonding Mechanisms of Zirconia-based Ceramics

Zirconia is a non-silica-based ceramic and thus doesn't etch using traditional methods. Retention of zirconia-based ceramic restorations depends on mechanical roughening of the surface and chemical bonding with adhesive monomer in special primers (see section on Ceramic Primers) or resin cements. An acidic adhesive monomer such as MDP shows chemical bonding to zirconia-based ceramics. The phosphate ester group of the acidic monomer results in chemical bonding to metal oxides (MxOy, oxidized surface of base-metal alloys), zirconia-based ceramics and other ceramics. It is effective to use self-adhesive or adhesive resin cement including an adhesive monomer for cementation. In the case of esthetic resin cement, the ceramic primer including an acidic adhesive monomer is needed as a pre-treatment.

Pretreatment Techniques for Zirconia-based Ceramics

Pretreatment techniques for promoting bonding to zirconia-based ceramics include air-particle abrasion and tribochemical silica coating. These pretreatments are utilized before chemical bonding with a silane coupling agent, ceramic primer, self-adhesive cement or adhesive cement.

If ceramic primer, self-adhesive cement or adhesive cement that contains an acidic adhesive monomer is used, air-particle abrasion is the easiest way to form a roughened surface to increase mechanical retention. Tribochemical silica coating with impact energy of blasted silicate particles produces bonding between the silicate and the targeted surface by a mechano-chemical reaction. After the mechano-chemical reaction, a silane coupling agent is applied to achieve chemical bonding to the silica-coated surface.

Bond Strength to Zirconia-based Ceramics with Tribochemical Silica Coating

Bond strengths of resin cements (***Panavia F 2.0***/*Kuraray America*, ***RelyX ARC***/*3M ESPE*, ***RelyX Unicem***/*3M ESPE*) to ***Lava***/*3M ESPE* were improved by grinding and polishing as compared to the untreated intaglio surface and by tribochemical silica coating (***Rocatec Soft***/*3M ESPE*) as compared to the sandblasting with 60-um aluminum oxide. Tribochemical silica coating resulted in improved stability of bond strength of resin cements during in-vitro thermal cycling. This result indicated that silica particles bonded to the surface of zirconia-based ceramics, and a silane coupling agent with a resin cement system bonded to the silica-coated surface.

Bond Strength to Zirconia-based Ceramics with Air-abrasion and Ceramic Primers

Another method of promoting a chemical bond to zirconia-based ceramic is the use of a ceramic primer. Ceramic primers may be based on silane and/or an acidic adhesive monomer. Silane coupling agents alone do not promote chemical bonding to zirconia-based ceramics. It is important to use a ceramic primer containing an acidic adhesive monomer, such as MDP for the priming of zirconia-based ceramics. The bonding mechanism of ***Clearfil Ceramic Primer*** (*Kuraray America*) containing MDP is shown in Figure 3. Examples of ceramic primers are listed in Table 7.

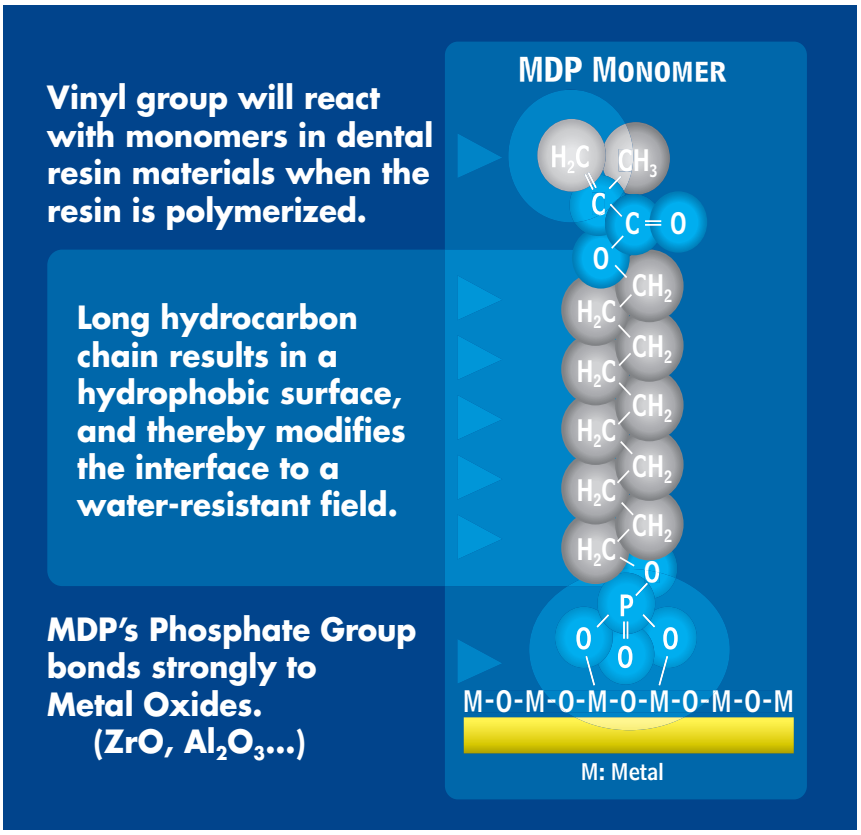


Figure 3. Chemistry of MDP monomer bonded to metal oxide.

TABLE 7 *Examples of Ceramic Primers*

Product	Company	Adhesive Components For Metal Oxide	Adhesive Components For Ceramic
Clearfil Ceramic Primer	Kuraray America	MDP	Silane coupling agent
Metal-Zirconia Primer	Ivoclar Vivadent	Phosphonic acid acrylate	
RelyX Ceramic Primer	3M ESPE		Silane coupling agent

TABLE 8
Shear Bond Strength of Resin Cement (self-cure mode) to As-sintered Zirconia-based Ceramic (IPS e.max ZirCAD) at 24 hours.

Cement	Bond Strength, MPa
Clearfil Ceramic Primer/ Clearfil Esthetic Cement	22 (5)
Metal-Zirconia Primer/ Multilink Automix	19 (6)
Clearfil Ceramic Primer/ Multilink Automix	24 (6)

Yapp R, Powers JM, unpublished data

The bond strengths of resin cements with ceramic primers to a zirconia-based ceramic are shown in Table 8. These cements have adequate bond strength to the as-sintered zirconia-based ceramic.

The effects of mechanical roughening on the bond strength of resin cement (***Clearfil Esthetic Cement & DC Bond Kit***/*Kuraray America*) with a ceramic primer to a zirconia-based ceramic are shown in Table 9. Sandblasting the as-sintered surface of the zirconia-based ceramic with 50 um alumina at 30 psi resulted in higher bond strength than abrasion with a fine diamond bur. As shown by scanning electron microscopy, sandblasting with alumina results in a roughened ceramic surface (Figure 4), whereas abrasion with a fine diamond produces a smoother smear layer on the ceramic surface (Figure 5). Both types of mechanical treatment resulted in higher bond strengths than bonding to the as-sintered surface of the zirconia-based ceramic.

TABLE 9 *Shear Bond Strength of Clearfil Esthetic Cement with Clearfil Ceramic Primer to Zirconia-based Ceramic (IPS e.max ZirCAD) with Different Surface Treatments Tested at 24 Hours and After Thermal Cycling (3000 Cycles).*

Treatment		Bond Strength, MPa 24 Hours	Thermal Cycling
Cement only	as-sintered zirconia	14 (3)	10 (2)
Primer/Cement	as-sintered zirconia	23 (6)	12 (1)
Primer/Cement	bur ground zirconia	27 (5)	19 (6)
Primer/Cement	sandblasted zirconia	36 (9)	27 (8)

Yapp R, Powers JM. Dent Advis Res Rpt 19, Aug 2008.

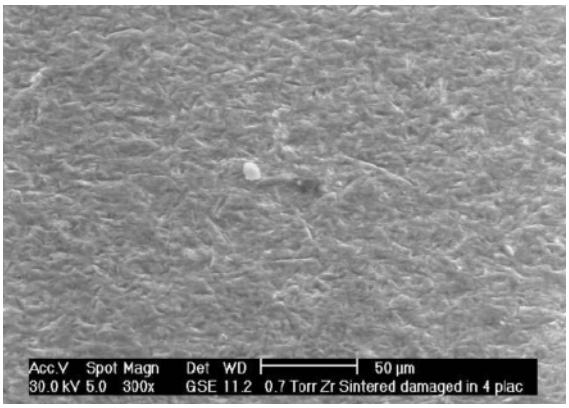


Figure 4. Scanning electron photomicrograph of zirconia-based ceramic surface prepared with 50-um alumina at 30 psi.

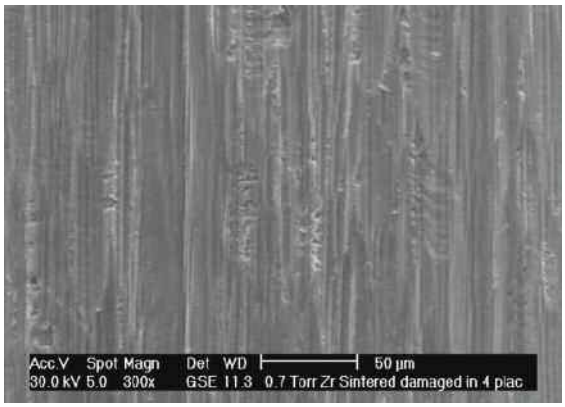


Figure 5. Scanning electron photomicrograph of zirconia-based ceramic surface prepared with a fine diamond. Note the appearance of a smear layer.

Bonding to Other Ceramic Substrates

In general, restorations prepared from lithium disilicate glass ceramic and leucite-reinforced (pressed) ceramics should be bonded with resin cements. Resin cements are recommended because of their higher mechanical properties and higher bond strength to tooth structure. Some manufacturers of self-adhesive resin cements do recommend them for cementation of selected lithium disilicate glass ceramic restorations treated with silane primer. Bond strengths of resin cement to two types of ceramic substrates are listed in Table 10.

Clearfil Esthetic Cement when used with ***Clearfil Ceramic Primer*** bonded to the intaglio surface of sintered zirconia, ***IPS e-max ZirCAD***/*Ivoclar Vivadent*. The bond strength was increased by 30% by sandblasting with 50-um aluminum oxide. The recommended technique by Ivoclar Vivadent for etching the leucite-reinforced ceramic, ***IPS Empress***/*Ivoclar Vivadent*, with 5% HF gel resulted in reduced bond strength as compared to the non-etched

control. The HF gel may selectively etch the glass phase of the ceramic causing stress concentrations that reduce bond strength.

Clinical Studies

A zirconia-based ceramic, ***Lava Crowns and Bridges***/*3M ESPE*, was studied clinically over a period of three years by THE DENTAL ADVISOR. Sixty-six units were placed in 42 patients in 2003. All restorations were cemented with a self-adhesive resin cement, ***RelyX Unicem***/*3M ESPE*. Fifty-nine units were observed at recall. Eighty percent of the restorations exhibited no signs of marginal staining, while 20% had slight graying at the margins.

Post-operative sensitivity and marginal staining in restorations with self-adhesive; adhesive; and traditional C&B cements were studied by THE DENTAL ADVISOR.

Self-adhesive resin cements and adhesive cements have a lower incidence of sensitivity than traditional crown and bridge cements as shown in Table 11. Marginal staining of self-adhesive resin cements and adhesive resin cements has been reported to be lower than that of traditional cements as shown in Table 12.

TABLE 10 *Shear Bond Strength of Clearfil Esthetic Cement and Clearfil Ceramic Primer to Treated and Untreated Zirconia and Leucite-reinforced Ceramics.*

Type of Ceramic	Product	Treatment	Bond Strength, MPa
Sintered zirconia	IPS e.max ZirCAD	Not Sandblasted	15 (6)
		Sandblasted (50 mm Al2O3)	19 (4)
Leucite-reinforced (pressed)	IPS Empress	Not Acid Etched	33 (9)
		Etched with 5% HF Gel (Ivoclar Vivadent)	19 (12)

Krishnan G, Yapp R, Powers JM. Dent Advis Res Rpt 18, Aug 2008.

TABLE 11 *Frequency of Sensitivity Reported with Different Types of Cements.*

	Adhesive Cement	Self-adhesive Cement	Traditional C&B Cement
Often/Sometimes	14%	10%	16%
Occasionally/Never	84%	84%	82%
Not applicable	2%	6%	2%

Farah JW, Powers JM, eds. Dent Advis 22 (8):5, 2005.

TABLE 12 *Frequency of Marginal Staining Reported with Different Types of Cements.*

	Adhesive Cement	Self-adhesive Cement	Traditional C&B Cement
Often/Sometimes	8%	8%	14%
Occasionally/Never	84%	84%	80%
Not applicable	8%	8%	6%

Farah JW, Powers JM, eds. Dent Advis 22 (8):5, 2005.

TABLE 13 *Survey of Clinical Consultants of THE DENTAL ADVISOR - Cements Preferred For Specific Procedures.*

	Adhesive Resin Cement	Self-adhesive Resin Cement	Traditional C&B Cement
All-ceramic inlays, onlays	**62%***	30%	6%
All-ceramic crowns, bridges	**52%**	39%	9%
Cast alloy crowns, bridges	15%	18%	**67%**
High-strength ceramic (zirconia) restorations	33%	**43%**	24%
Implant-supported crowns, bridges	13%	16%	**71%**
Laboratory composite	**66%**	29%	5%
Maryland bridges	**77%**	18%	5%
PFM crowns, bridges	14%	23%	**63%**
Metal posts	**40%**	29%	31%
Esthetic posts	**55%**	35%	10%

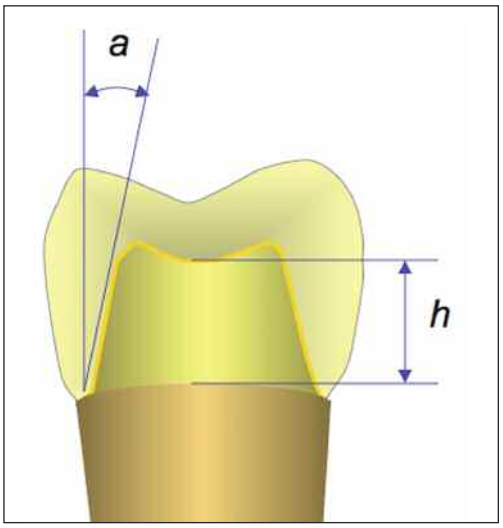
Farah JW, Powers JM, eds. Dent Advis 22 (8):5, 2005.
***Bold lettering indicates cement with majority of responses.**

A recent survey of Clinical Consultants of THE DENTAL ADVISOR has shown that self-adhesive resin cements were most commonly selected for cementation of high-strength (zirconia-based) all-ceramic restorations as shown in Table 13.

Clinical Use of Resin Cements

Self-adhesive resin cements are the best choice for zirconia-based ceramic restorations, when the restoration does not require the highest retention. They are less technique sensitive than bonding with adhesive or esthetic resin cements and offer more retention and better marginal sealing of tooth structure than the traditional glass ionomer cements. No separate bonding agent is necessary, reducing much time and effort, And cleanup is easy with self-adhesive resin cements. The cement can usually be peeled off of the marginal areas, with the advantage of leaving less cement in the area after cementation.

When more retention is needed due to a short clinical crown or an over-tapered preparation, adhesive resin cements, or dual- or self-cured esthetic resin cements may be used to bond the restoration. Both adhesive resin cements and esthetic resin cements usually include various types of compatible primers or bonding agents that are to be applied to the tooth and ceramic restoration. If the zirconia is sandblasted with aluminum oxide particles, or blasted with a tribochemical silica coating (***Rocatec Soft***/*3M ESPE*) before placing ceramic primer, the bond of resin cement to the restoration will improve. Dual- and self-cured resin cements are usually not compatible with light-cured bonding agents. All types of bonding agents contain acidic monomers that affect the self-cured chemistry of the resin cement. It is critical to follow the manufacturer's instructions for proper bonding of the restoration to tooth structure.



When Should Zirconia-Based Ceramic Restorations be Bonded?

A. Suitable for Cementation with Self-adhesive Resin Cement:

- Tooth preparation with adequate cervical-occlusal height: h > 3mm
- Tooth preparation with adequate taper: a = 2 - 5 degree

B. Bonding with Adhesive Resin Cement or Esthetic Resin Cement

Recommended:

- Tooth with short clinical crown: h < 3mm
- Tooth with over-tapered preparation: a > 5 degree

Occlusal reduction of the preparations for high strength ceramics, either A or B):

- Non-functional cusps: >2.0mm
- Functional cusps: >2.5mm

A summary of clinical tips for cementation and bonding of zirconia-based ceramics is shown in the box below;

Clinical Tips

Preparation:

- Don't over dry the tooth - moisten with water if needed.

Choice of cement:

- Never use light-cure only resin cement with zirconia-based ceramic restorations.
- Use light-activation whenever possible - dual-cured resin cements typically have increased flexural strength and bond strength when activated with a light vs. self-curing only.
- Translucent shades of resin cements may be sensitive to ambient light.
- Resin cements should not be applied directly on exposed pulp or dentin that is close to the pulp.
- Self-adhesive resin cements are contraindicated where there is not enough retention.

Ceramic Primer and Silane Primer:

- Self-adhesive and adhesive cements containing acidic monomer usually do not require ceramic primers.
- Esthetic Cements usually require ceramic primers containing acidic monomer (e.g. Clearfil Ceramic Primer/Kuraray America)
- Use a silane primer with non-zirconia-based all-ceramic restorations.
- For higher bond strength, sandblast or apply a tribochemical silica coating to the restoration before silanization.

Excess Cement:

- Excess cement is easy to remove after tack curing, but hard to clean up if you light cure too long.

Summary

Zirconia (zirconium oxide)-based ceramics are a rapidly growing type of esthetic restoration. The high strength of zirconia-based ceramic restorations increase the indications for choice. Because of their high strength, zirconia-based ceramic restorations can be cemented with traditional cements or bonded with adhesive resin cements. Self-adhesive resin cements offer less technique sensitivity than traditional cements, making them excellent choices for the cementation of appropriate zirconia-based ceramic restorations. When additional retention is required, zirconia-based restorations can be bonded with adhesive resin or dual-cured esthetic resin cements using tooth and ceramic primers.

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