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SELF-ADHESIVE CEMENTS AND ALL CERAMIC CROWNS: A REVIEW

Foudda Homsy * | Elie Daou ** | Maha Ghotmi *** | Mireille Rahi ***

Abstract

Adhesive bonding techniques and modern all-ceramic systems offer a wide range of highly esthetic treatment options. The inherent brittleness of some ceramic materials and certain clinical situations require resin bonding of the restoration to the tooth for long-term clinical success. A surface pretreatment of the ceramic and the tooth is necessary to obtain a good adhesion. The clinician faces many problems when luting restorations such as the choice of the appropriate agent depending on the restoration material, the technique sensitivity and the necessity of applying different luting materials. To overcome some of the disadvantages of the conventional and resin cements, self-adhesive cements were introduced to the market. They do not require any pretreatment of the tooth surface and their application is accomplished in a single clinical step. A wide literature review was conducted, through a MEDLINE search. Articles that treat self-adhesives properties were selected. According to *in vitro* studies, self-adhesive cement adhesion to dentin and to all-ceramic materials is satisfactory and comparable to other multistep resin cements. Randomized clinical trials and long-term *in vitro* studies are necessary prior to any recommendation regarding their use.

Keywords: Self-adhesive cement - bonding all-ceramic restoration - resin cement.

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CIMENTS AUTO-ADHÉSIFS ET COURONNES « ALL-CERAMIC »: UNE REVUE DE LA LITERATURE

Résumé

Les techniques de collage et les systèmes d'adhésifs modernes offrent un large éventail d'options de traitements esthétiques. Dans certaines situations cliniques, la fragilité inhérente à certains matériaux en céramique exige le collage de la restauration à la dent à l'aide d'un ciment à base de résine pour une meilleure pérennité. Un traitement préalable de la surface de la céramique et de celle de la dent est nécessaire pour obtenir une bonne adhérence.

Le clinicien est confronté à de nombreux problèmes lors du collage des restaurations tels que le choix de l'agent approprié en fonction du matériau de restauration et la nécessité de procéder souvent par étapes.

Pour pallier à certains inconvénients des ciments conventionnels, des ciments auto-adhésifs ont été introduits sur le marché. Ces derniers ne nécessitent pas un traitement préalable de la surface dentaire et ils sont appliqués en une seule étape.

Une revue de la littérature a été réalisée par une recherche sur MEDLINE. Les articles qui traitent des ciments auto-adhésifs ont été sélectionnés. Selon les études obtenues, l'adhésion du ciment auto-adhésif à la dentine et aux restaurations en céramique est satisfaisante et comparable aux autres ciments en résine conventionnels. Des essais cliniques randomisés et de long-terme sont nécessaires avant toute recommandation concernant l'utilisation des ciments auto-adhésifs.

Mots-clés: ciment auto-adhésif - ciment à base de résine.

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Introduction

To fulfill patients' expectations, dental biomaterials must have a highly aesthetic appearance comparable to that of natural teeth as well as good mechanical properties [1]. This explains the professionals' growing interest for all-ceramic restorations [1, 2].

On the other hand, successful bonding of the luting material to both the restorative material and the tooth structure is imperative for the retention and longevity of the restoration [3].

Obtaining adhesion between a luting agent and a ceramic surface requires surface pretreatment [4, 5] such as etching, priming and bonding [6-9].

Until recently, resin cements were divided into two subgroups according to the adhesive system used to prepare the tooth prior to cementation. One group utilizes etch-and-rinse adhesive systems (example: RelyX™ ARC, 3M ESPE, St. Paul, Minn). The second group uses self-etch primer (example: Panavia™ F, Kuraray Medical Inc, Tokyo, Japan) [10, 11]. Multistep luting materials make the procedure technique-sensitive [11]. *In-vitro* studies on the shear bond, the microtensile bond and the long-term durability of the resin cement on the tooth substrate and the ceramic restoration demonstrated that the bond strength was impaired when the surface treatment was insufficient [12-50].

Bonding to traditional silica-based ceramics is a predictable procedure yielding durable results when fabricants' guidelines are respected [51-63]. However, the composition and physical properties of high-strength ceramic materials, such as aluminum oxide (Al₂O₃) [64-72] and zirconium oxide (ZrO₂) ceramics [73-76] differ substantially from silica-based ceramics and require alternative bonding techniques to achieve a strong and durable resin bond [28, 29, 54, 61].

An ideal dental adhesive must be biocompatible and resistant to microleakage [2, 12]. The cement should also provide a durable bond between

dissimilar materials, possess favorable compressive and tensile strengths, have sufficient fracture toughness to prevent dislodgment as a result of interfacial or cohesive failures [13, 14], be able to wet the tooth and the restoration surfaces, exhibit adequate film thickness and viscosity to ensure complete seating [12-15], exhibit minimal solubility in the oral cavity [13, 14, 16] and demonstrate adequate working and setting times [12-15]. The dental adhesive should also enhance the fracture resistance of the full-ceramic crowns [2, 13, 17] and ensure adequate marginal adaptation [18].

Resin cements are composites that consist of a resin matrix, eg bis-GMA or urethane dimethacrylate, and a filler of fine inorganic particles.

Bonding of resin-based composite materials to tooth hard tissues has been simplified recently [11]. Even though enamel and dentin bonding has progressed from the first to the current seventh-generation adhesives, bonding to dentin remains less predictable than bonding to enamel [19-21].

All luting agents required the application of one of these adhesive systems to prepare the tooth prior to cementation [6, 19, 22, 23]. This multistep procedure and the performance of the etch-and-rinse or self-etch adhesive itself can influence the bonding effectiveness [11, 24].

To overcome some of the shortcomings of both conventional and resin cements, resin-based self-adhesive cements were introduced in 2002 as a new subgroup of resin cements. The goal was to present the favorable characteristics of different classes (total etch, self-etch) in a single product [10]. This new category of cements does not require any surface treatment of the teeth or restorations and provides effective bond strength [3, 8, 13, 26, 27].

Self-adhesive cements aim to combine the favorable properties of conventional (zinc phosphate, glass ionomers and polycarboxylate cements) and resin luting agents [10, 16]. In fact, it is reported that self-adhesive resin cements provide the

equivalent bond strength of conventional resin cements to dentin [19, 23], gold alloy and glass ceramics [34] and zirconia [35, 36]. Attar et al. [38] demonstrated that resin-based cements that rely on the application of etch-and-rinse adhesive systems have greater flexural strength than conventional resin cements; different studies found lower bond strengths [11, 23].

Due to its simplified application technique, the first self-adhesive cement introduced to the market (RelyX™ Unicem; 3M ESPE, St. Paul, Minn) rapidly gained popularity among clinicians [11]. Thus, several brands developed self-adhesive cements (RelyX™ Unicem; RelyX™ U100; 3M ESPE, St. Paul, Minn; SmartCem® 2 Dentsply Caulk, Milford; G-Cem™, GC America, Inc, Alsip, Ill; Maxcem Elite™ (Kerr Corp, Orange, Calif) ; SeT (SDI Ltd, Bayswater, Australia); SAC-H, SAC-A (Kuraray Medical, Tokyo,...) (Table 1).

Regarding their composition, self-adhesive cements are based on phosphoric-acid methacrylates that demineralize and infiltrate the tooth substrate, resulting in micromechanical retention. Secondary reactions have been suggested to provide chemical adhesion to hydroxyapatite [10, 32].

The basic inorganic fillers are able to undergo a cement reaction with the phosphoric-acid methacrylates. The dominant setting reaction starts with free radical polymerization, which can be initiated either by light or by a redox system (dual-curing composite materials) [3, 32].

The purpose of this literature review is to evaluate the reliability of self-adhesive luting agents when used with all-ceramic crowns and compare them to the conventional etch-and-rinse and self-etching luting agents.

Materials and Methods

A broad systematic search of English dental literature was initiated. Keywords or phrases included: silica-based ceramics, aluminum oxide ceramics, zirconium oxide cera-

mics, dental cements, composite resin cements, adhesives, total-etch adhesives, self-etch adhesives, self-adhesives, RelyX™ Unicem, BisCem®, Breeze™, G-Cem®, Maxcem Elite™, Monocem®, Clearfil, Embrace, Multilink® Sprint, SmartCem®, SeT and iCEM®.

Peer-reviewed articles published in English between 1976 and 2010 were identified through a MEDLINE search (Pubmed and Elsevier) as well as a hand search of relevant textbooks and annual publications.

Results

Of the retrieved articles, articles on the bonding to silica-based ceramics [22, 44, 76], on the bonding to aluminium oxide ceramics [34, 58, 76] and on the bonding to zirconium oxide ceramics [30, 34-36, 72] were selected. Additional references were included to accompany statements of facts [1, 21, 23-71, 73-76].

RelyX™ Unicem was the most thoroughly investigated self-adhesive while one article investigated other currently marketed self-adhesive cements.

Two main subjects were treated: bonding to tooth structure and bonding to ceramics.

Bonding to tooth structure

Dental cement acts as a barrier against microbial leakage, sealing the interface between the tooth and the restoration [16, 33]. This attachment may be mechanical, chemical, or a combination of both [15, 34]. Research has also shown that leakage may occur even with successful bonding, or that shrinkage may cause cohesive fracture of tooth structure although the bond is preserved [36]. However, it is well established that the cementing agent used for bonding influence microleakage [35].

Enamel and dentin are dissimilar in composition and structure. The resin tags mainly determine the adhesive performance of the enamel bond [37] and the penetration of the resin

cement in the microporosities forms a well-accepted micromechanical bond [20, 38].

The bond between the cementing agent and the dentinal hard tissue is compromised by the tubular microstructure, the higher content of organic material, and the intrinsic humidity of the dentinal substrate [28].

Finish lines placed below the cemento-enamel junction result in a significant loss of adhesion [40], since cementum cannot be infiltrated by resin to the same extent as the dentin [41].

The favorable bond strength observed for RelyX™ Unicem has been attributed to the micromechanical retention and chemical interaction between monomer acidic phosphate groups and dentin/enamel hydroxyapatite [9, 19, 31, 35, 42, 43]. The smear layer is partially removed or incorporated by acidic monomers that promote micromechanical retention to the tooth structure [19].

The quality of the dentin-adhesive-cement interface is closely related to the extension of monomers infiltration into the demineralized collagen network [46] and to their ability to chemically interact with dentin hydroxyapatite [24, 31]. Despite the low initial pH of RelyX™ Unicem (pH<2 in the first minute, according to the manufacturer), almost no demineralization and no true hybrid layer formation was observed on the dentin surface [19, 27, 31]. It was found that RelyX™ Unicem applied to fractured dentin only interacts very superficially without any evidence of a smear layer or resin tags (irregular interaction zone ranging from nearly 0 to 2µm [21]). This may explain the low bond strengths recorded [19, 47] and the high number of adhesive failures for the self-adhesive materials [24, 31]. This finding might be attributed to the high cement viscosity, which hinders the wetting and infiltrating of the dentin surface by the luting agent [19].

The multifunctional monomers having acidic phosphate groups are supposedly capable of demineralizing

and infiltrating the substrate simultaneously [10]. According to the manufacturers, the self-etching capacity is attributed to the presence of different monomers in the luting agent formulation, such as the hydrophilic monomer 4-MET in SmartCem® and methacrylated phosphoric esters in SeT [11]. An increase in pH from 1 to 7 is observed as a consequence of the reaction between phosphate groups and both alkaline filler particles and hydroxyapatite from enamel and dentin, to neutralize resin acidity [13, 22]. Han et al. [13] reported low pH values for G-Cem™, Maxcem Elite™, SmartCem® and RelyX™ Unicem a few seconds after manipulation. However, after 48 hours, only RelyX™ Unicem presented a neutral pH (pH=7.0).

Unlike conventional cements, resin materials designed for adhesive use are anhydrous and have silanized, unreactive fillers [32]. The pH neutralization results in water formation and a more hydrophilic cement, which enhances the cement's wetting ability on the dentin surface and the cement tolerance to water. Water is crucial for self-adhesive luting agents to release hydrogen ions required for smear layer demineralization [20] and is also reused in the reaction between multifunctional acidic phosphate monomers and alkaline filler particles.

Shear bond strength of RelyX™ Unicem to enamel was evaluated prior to and after thermocycling [3]. Before thermocycling, this cement produced bond strength of 14.5 MPa, which was significantly lower than the bond strengths of other resin luting systems investigated, which range between 17 and 32 MPa. Moreover, its shear bond strength to enamel was significantly lower after thermocycling, in contrast to other resin cements that were not influenced by the same aging condition [3]. The author concluded that RelyX™ Unicem might not be the ideal material for luting if a considerable enamel surface area is present [3] and is contraindicated for veneers.

Similar results in terms of enamel bond strengths were reported in

Product	Delivery system	Working/setting time	Shades	Composition
BisCem® (Bisco; Schaumburg, IL, USA)	Paste/paste dual syringe; direct dispensing through a mixing tip	1min/6min at 22°C	Translucent Opaque	Bis (hydroxyethyl methacrylate) phosphate (base), tetraethylene glycol dimethacrylate, dental glass
Breeze™ (Pentron Clinical Technologies, Wallingford, CT, USA)	Paste/paste dual syringe; direct dispensing through a mixing tip	1min/4min at 22°C	A2 Translucent Opaceous White	Mixture of Bis-GMA, UDMA, TEGDMA, HEMA, and 4-MET resins, silane-treated barium borosilicate glasses, silica with initiators, stabilizers and UV absorber, organic and/or inorganic pigments, opacifiers
Clearfil SA (Kuraray, Tokyo, Japan; SL)	Dual-barrel syringe	1min/5min	A2 White	Bis-GMA, TEGDMA, MDP, barium glass, silica, sodium fluoride
Embrace WetBond resin cement (Puldent; Watertown, MA, USA)	Automix or standard syringe packaging	Completely autocures in 7min	One shade	Di-, tri-, and multi-functional acrylate monomers into a hydrophilic, resin acid-integrating network (RAIN).
G-Cem™ (GC; Tokyo, Japan)	Capsules	2min/4min	A2, AO3, Translucent, BO1	Powder: fluoroaluminosilicate glass, initiator, pigment. Liquid: 4-Met, phosphoric acid ester monomer, water, UDMA, dimethacrylate, silica powder, initiator, stabilizer
iCEM® (Heraeus Kulzer)	Double syringe			No information available
Maxcem Elite™ (Kerr; Orange, CA, USA)	Paste/paste dual syringe; direct dispensing through a mixing tip	2min/3min	Clear White White opaque Yellow Brown	GPDM (glycerol dimethacrylate dihydrogen phosphate), comonomers (mono, di, and tri-functional methacrylate monomers), proprietary self-curing redox activator, photo-initiator (camphorquinone), stabilizer, barium glass fillers, fluoroaluminosilicate glass filler, fumed silica (filler load 67%wt, particle size 3.6µm)
MonoCem™ (Shofu Dental; San Marcos, CA, USA)	Paste/paste dual syringe; direct dispensing through a mixing tip	Unlimited working time (7min in anaerobic conditions)	Translucent Bleach white	No information available
RelyX™ Unicem (3M ESPE; St Paul, MN, USA)	Capsules (Aplicap: 0.001ml; Maxicap: 0.36ml)	2min/5min at 22°C	A1 A2 Universal Translucent White opaque A3 Opaque	Powder: glass fillers, silica, calcium hydroxide, self-curing initiators, pigments, lighth-curing initiators. Liquid: methacrylated phosphoric esters, dimethacrylates, acetate, stabilizers, self-curing initiators, lighth-curing initiators
SeT (SDI, Australia; SE)	Capsules	5min	Translucent, A1, A2, OA3 White opaque	UDMA, phosphate, fluoroaluminosilicate glass, silica
SmartCem® (Dentsply-Caulk- Germany)	Dual-barreled syringe	2min/6min	Translucent Light Medium Dark Opaque	Urethane dimethacrylate; di- and tri-methacrylate resins; phosphoric acid modified acrylate resin; barium boron fluoroaluminosilicate glass; organic peroxide initiator; camphorquinone photoinitiator; phosphene oxide photoinitiator; accelerators; butylated hydroxy toluene; UV stabilizer; titanium dioxide; iron oxide; hydrophobic amorphous silicon dioxide
SpeedCEM™ (Ivoclar, Vivadent)	Double syringe	Working time: self 100 – 140s, dual 100 – 140s Setting time: (37 °C) self 150 – 220s, dual 150 – 220s	Transparent Opaque Yellow	Dimethacrylates, ytterbium trifluoride, co-polymer, glass filler, silicon dioxide, adhesive monomer initiators, stabilizers and pigments

Table 1: Characteristics of self-adhesive cements of different brands.

microtensile bond strength investigations. Enamel microtensile bond strengths of RelyX™ Unicem ranged between 10.7 MPa [27] and 19.6 MPa [19] and were significantly lower than the bond strengths of the self-etching cement Panavia™ F 2.0 and other resin cements which ranged between 25 and 49 MPa [19, 27].

The majority of the results obtained are consistent and demonstrate that in contrast to enamel adhesion, RelyX™ Unicem performs comparably to other multistep systems on coronal dentin. Comparable bond strength with Panavia™ F was obtained [3, 19, 27].

In contrast to the positive effect observed on enamel, de Munck Jan [19] found that acid etching was detrimental to RelyX™ Unicem dentin adhesion. However, in a recent study, Pavan et al. [16] proposed, as for glass ionomer materials, that the use of polyacrylic acid (Ketac Conditioner; 3M ESPE, Seefeld, Germany) might have enhanced the dentin bond strength of self-adhesive cement [16].

In terms of marginal adaptation, Frankenberger and al. [49] reported that RelyX™ Unicem offers a tight seal at dentin margins, while self-adhesive cements cannot compete with cements which utilize etch-and-rinse adhesives in terms of bonding performance [49].

On the other hand, it should be noted that with the latest generation of dental adhesives, in pull and shear testing adhesion, values are so high that fracturing no longer occurs at the interface (adhesive failure), but directly in dentin (cohesive failure) [32].

Bonding to ceramics

Ceramics fall into three main categories that differ by their composition and their physical properties: silica-based ceramics, aluminium oxide-based ceramics and zirconium oxide-based ceramics. The ability of the combination of resin cement/adhesive system to adhere to dental ceramics depends on the microstructure of the esthetic restoration and the applied surface treatment [9].

Silica-based ceramics

Silica-based ceramics, such as feldspathic porcelain (Vita Mark II, VITA Zahnfabrik, Bad Sackingen, Germany) and glass ceramic Empress, Empress II and Emax (Ivoclar, Vivadent, Schaan, Liechtenstein) [50] are used to veneer metal frameworks or high-strength ceramic copings for all-ceramic restorations. In spite of the inherent brittleness and limited flexural strength of silica-based ceramics, final adhesive cementation with composite increases the fracture resistance of the ceramic restoration and the abutment tooth [50].

Surface preparation of ceramic material is important for a strong resin bond [51]. To achieve this bond, the porcelain surface may be chemically or mechanically modified to promote surface roughness and/or reactivity of the porcelain to the luting agent [52]. Several authors have described various surface treatment procedures to allow adhesion of all-ceramic restorations [22, 28, 52-56]. Bonding to silicate-based ceramics is usually obtained by two simultaneous mechanisms: 1) micromechanical retention provided by acid-etching of the ceramic surface, and 2) chemical coupling by the application of a silane coupling agent [50, 53, 54, 57-59].

The hydrofluoric (HF) acid reacts with the glassy matrix that contains silica, dissolving the surface to the depth of a few micrometers [53]. This glassy matrix is selectively removed and the crystalline structure is exposed [54]. The silane coupling agent presents bifunctional characteristics, promoting a chemical interaction between the silica in the glass phase of ceramics and the methacrylate groups of the resin through siloxane bonds [53, 60, 61]. It has been demonstrated that silane primers may confer a resistance to the degradation of the ceramic-resin bond exposed to moisture and intraoral thermal changes [62]. Etching and silanization increase the surface energy and the wettability of the ceramic substrate, which decrease

the contact angle between the ceramic surface and the resin cement [53, 54].

Several studies have demonstrated that RelyX™ Unicem can achieve high or comparable bond strength to other investigated cements without any pretreatment steps such as etching, priming or bonding [53, 63]. However, other studies observed higher shear bond strength values after etching with HF acid and silanized [22, 28, 50, 53]. In a study of Kumbuloglu et al. [55], RelyX™ Unicem showed lower shear bond strengths than the other resin cements investigated, but no pretreatment of the ceramic surface was performed. In the study of Reich et al., only the RelyX™ Unicem, in contrast to Variolink (Ivoclar, Vivadent) and Calibra (DeTrey Dentsply, Konstanz, Germany), was able to survive the whole thermocycling procedure in the case of no pretreatment. This indicates that besides mechanical interlocking, additional bonding mechanisms with RelyX™ Unicem to the ceramic surface are possible.

The specific phosphoric acid methacrylates have the ability to provide physical interactions with the ceramic surface and are able to provide strong hydrogen bonding with hydroxyl groups present on the ceramic surface [22]. An increase in the bond strength after pretreatment with hydrofluoric acid and silane was also observed [22]. This is in agreement with the study of Piwowarczyk [28] who reported that, in comparison with 10 cements from different classes, only RelyX™ Unicem exhibited high shear bond strength after 14 days of water storage followed by thermal cycling. In the same study, it was reported that the light polymerization of the self-adhesive resin cements enhances shear-bond strength in comparison to autopolymerization [28].

Aluminium oxide ceramics

The aluminium oxide serves as reinforcement of the glassy matrix [50]. In general, ceramics containing less than 15% silica are not regarded as silica-based or silicate ceramics [50]. Glass-infiltrated aluminium oxide

ceramic (In-Ceram, Vita Zahnfabrik, Bad Sackingen, Germany) and densely-sintered high-purity aluminium oxide ceramic (Procera® All-Ceram, Nobel Biocare, Goteborg, Sweden) are widely used representatives of this group.

Glass-infiltrated aluminium oxide ceramic

In-Ceram is made of a high-content aluminium oxide opaque core that is glass-infiltrated to achieve its final strength [50, 66]. Because of its low silica content, neither acid etching nor adding a silane resulted in an adequate resin bond to the alumina-based In-Ceram ceramic [58, 62]. However, other authors recommended a surface treatment of etching and/or sandblasting followed by silanization [68, 69]. Silanization of glass-infiltrated aluminium oxide ceramic does not provide a chemical bond but may have a rewetting effect on air-particle-abraded alumina surfaces [50].

Air abrasion with Al₂O₃ abrasive particles is effective and practical for creating a roughened surface for aluminium oxide ceramics [58]. Silica coating with silanization can increase the bond strength significantly compared to that of airborne-particle abrasion alone [67]. The adhesive functional phosphate monomer 10-methacryloyloxydecyl dihydrogen phosphate (MDP) chemically bonds to metal oxides such as aluminium and zirconium oxides [50, 70]. These results are confirmed by Baldissara who revealed that MDP-based resin cement with sandblasting with Al₂O₃ particles and bis-GMA-based resin cement with tribochemical silica coating were the best luting protocols for the alumina ceramic [71].

Procera All-Ceram

Procera uses a high-purity aluminium oxide ceramic with an aluminium oxide content of 99.9%. Borges et al. [70] showed that the ceramic surface of densely sintered alumina was not etched by hydrofluoric acid because it does not contain a silica phase [70].

Other authors confirmed this result [50, 59].

Airborne particle abrasion with a micro-etcher (50µm Al₂O₃) is necessary to create porosities which improve microretention of the luting agents by interlocking [58, 70, 72]. Borges et al. [70] found in his study that airborne-particle abrasion of the material with 50µm aluminium oxide caused flattening of the alumina rather than creating microretentive features. SEM revealed only an irregular surface texture [70]. Hummel [72] reported that the phosphate monomer containing composite resin Panavia™21 showed the highest bond strength to sandblasted Procera which did not decrease significantly over storage time. The same study revealed that the use of Variolink II after priming the sandblasted ceramic showed high bond strength.

The silane might increase the wettability, which allows flow of the bonding resins into the undercuts and porosities [72]. Blixt et al. [50] found tribochemical surface treatment with the Rocatec™ system (to bis-GMA based resin cement) to be superior to other treatments; however, this study was limited to short-term observations [50].

Piwowarczyk et al. [28] demonstrated that among 12 cementing agents, only RelyX™ Unicem and Panavia™ F exhibited strong bond strengths to airborne particle-abraded pure aluminum oxide ceramic after 14 days of water storage followed by thermal cycling.

Zirconium oxide ceramics

Polycrystalline ZrO₂ is typically used in a tetragonal crystalline phase [73]. A number of zirconia-oxide ceramic systems have been recently introduced, such as Cercon® (Dentsply, Amherst, N.Y.), DCS® system (DCS® Dental AG, Allschwil, Switzerland), Lava™ (3M ESPE) and Procera all-Zirkon (NobelBiocare, Goteborg, Sweden). Each of the commercial zirconia systems has unique material properties due to the specific fabrication process, creating a unique intaglio surface that influences bonding beha-

viour [73]. Full coverage zirconium oxide may not require adhesive cementation [73]; however, some authors concluded that adhesive cementation is preferable for ensuring better retention, marginal adaptation and fracture resistance of the restoration and the abutment tooth [75].

Neither the application of HF acid nor the silanization resulted in a satisfactory resin bond to zirconia [63] because of the high crystalline content and the limited vitreous phase (below 1%) of this high strength core ceramic [73, 75]. Conventional silanes are not as effective on zirconia as on silica-based ceramics. Airborne particle abrasion with Al₂O₃ abrasive particles has proven to be effective [50, 56]. It increases surface energy and, therefore, wettability [56].

It has been reported that the 10-MDP (10-methacryloyloxydecyl dihydrogen phosphate) containing luting system (Clearfil™ Esthetic cement) seems to be the most suitable to bond zirconia ceramic surfaces and it does not require any pretreatment of the ceramic surface before luting [75]. The adhesive potential of MDP to zirconia may depend on the presence of a passive coating of zirconium oxide on the ceramic surface. Chemical reactions involving the hydroxyl groups of the layer and the phosphate ester monomers of the MDP may occur at the interfacial level [76]. Therefore, the MDP containing self-adhesive resin cement Clearfil SA luting (Kuraray, Tokyo, Japan) is more suitable to bond the zirconia surface than other self-adhesive resin cements when no pretreatment of the ceramic was done [76]. Blatz [74] found that the application of a MDP-containing bonding/silane coupling agent is the key factor for a reliable resin bond to airborne particle-abraded Procera AllZirkon (NobelBiocare, Goteborg, Sweden) and is not influenced by the resin luting agent used. Jie Lin [76] found that silica coating and tribochemical treatment improved the bond strength of the self-adhesive cements (RelyX™ Unicem, Maxcem Elite™, Smartcem®,

Breeze™, Biscem™, Clearfil SA) to zirconia compared to untreated ceramic.

Furthermore, De Oyague [75] found that RelyX™ Unicem bonded to zirconia, regardless of the ceramic surface treatment and without additional coupling agent application. According to Kumbuloglu [56], RelyX™ Unicem showed higher bond strength than the Panavia™ F in both water-storage and thermocycling when used with a zirconium oxide (DCS Dental AG) [56]. Panavia™ F and RelyX™ Unicem contain phosphoric-acid methacrylates that provide a strong physical interaction, such as hydrogen bonding, with the air abraded ceramic surface [28].

Conclusion

Based on the published articles, RelyX™ Unicem - the most investigated self-adhesive cement- proved to be satisfactory and comparable to other multistep resin cements. However, RelyX™ Unicem bonding performance was found to be better on dentin than on enamel. On the other hand, this product can bond to the silica-based ceramics, aluminium oxide ceramics, zirconium oxide ceramics regardless of the ceramic treatment.

Self-adhesive cements seem to be promising in indirect restorative procedures because they offer a simplified technique, reduce the occurrence of postoperative sensitivity and are suitable for a wide range of applications.

Prospective, long-term studies are necessary to evaluate self-adhesives introduced in the market prior to making any general recommendation regarding their use.

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