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FIXING SYSTEMS FOR DENTAL CAD/CAM PROSTHETIC RESTORATIONS: A SYSTEMATIC REVIEW

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ABSTRACT. This study was conducted to review the current scientific literature regarding the fixing systems for CAD-CAM prosthetic restoration. An electronic search was conducted for relevant articles using PubMed database followed by manual search, with the following association of terms: (CAD CAM, cements) then (CAD CAM, cements, bonding) and finally (CAD CAM, cements, bonding agents). The study included articles published between 01.01.1995 and 01.09.2015. A table was designed for this review with the following information: authors, CAD-CAM system used, fixing agent/agents used, restoration type and abutment type. The most studied dental CAD-CAM system was Cerec and the most used fixing agent was RelyX. In summary, the objective of any surface treatment method is to enhance the adhesive bond strength and durability.

Keywords: CAD CAM, crowns, dental cements, bonding agents

INTRODUCTION

The development of computer-aided design/computer aided manufacturing (CAD-CAM) technology in dentistry provide more accurate prosthetic frameworks by using new biocompatible materials, especially high performance ceramics, such as zirconia and lithium disilicate [1].

Patient, tooth and treatment cost guide the selection of one or another restorative material. The selection of an all-ceramic material for tooth restoration opens a floodgate of information about emerging materials and techniques, central among these techniques is CAD-CAM [2].

CAD-CAM system is popular because of high aesthetic and short fabrication time. But, there is limited information available about the micro-tensile bonding of luting cements to CAD-CAM inlays and to dentin [3]. Unfortunately these materials are brittle and tend to fracture under heavy occlusal load [4].

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Multiple factors affect the success of fixed prosthodontic restorations with preparation design, oral hygiene/microflora, mechanical forces, and restorative materials being some of them. However, key factor to success is the choice of a proper luting agent and cementation procedure [5].

Dental luting agents provide a link between the restoration and prepared tooth, bonding them together through some form of surface attachment, which may be mechanical, micro-mechanical, chemical or combination [6]. Due to the relatively recent entry of zirconia and alumina based ceramics in dental practice, there is a lack of information about adhesive cementation technique respectively, about the special preparation of zirconia and alumina surface in order to use adhesive cement [7].

Restorative dentistry constantly evolves and the clinicians cannot indicate the ideal cement for all situations [8].

Bonded indirect restorations constitute a substantial part of contemporary dentistry [9].

Prosthetic restorations have a weak part which is the resin luting agent layer exposed at the margin [10-14].

The scientific knowledge of the materials currently available as well as the acknowledgment of their limitations and indications are key factors for durable restorations [8].

The purpose of this review was to identify the proper technique and the proper selection of luting agent for fixing CAD-CAM restoration.

RESULTS AND DISCUSSION

Relevant articles were search using PubMed database. The search was made using the following combination of keywords: (1)(CAD CAM, cements); (2)(CAD CAM, cements, bonding); (3)(CAD CAM, cements, bonding agents). The last search was conducted on September 2, 2015. Studies considered for this review were English-language articles published between 01.01.1995 and 01.09.2015, focused on the luting cements and fixing technique for CAD-CAM restoration.

The review excluded studies regarding non CAD-CAM restorations.

From each article, the following information were extracted: the type of CAD-CAM system used, fixing agent/agents used, restoration-type (veneer, inlay, coverage crown etc.), abutment type (natural tooth, implant abutment etc.) and a table was made (Table 1).

For the first search (CAD CAM, cements), a total of 326 articles were identified. Searching after the second keywords combination (CAD CAM, cements, bonding) generated a number of 116 articles and for the third search (CAD CAM, cements, bonding agents) 35 articles were found.

Table 1. Dental CAD/CAM system, fixing agent/agents, prosthetic restoration and restoration support used in the studies

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
1.	Dual cure resin cement (RelyX ARC, 3M ESPE)	**Composition:** BisGMA and TEGDMA polymer Paste A: zirconia/silica filler (68 wt.%), pigments, amine and photo initiator system. Paste B: zirconia/silica filler (67 wt.%), BPO activator (Filler= 67.5 wt.%; avg. = 1.5 µm)	Secotom-50 cutting machine	Experimental model made of CAD/CAM resin	Experimental model made of CAD/CAM resin	Gilbert S., Keul C., Ross M., Edelhoff D., Stawarczyk B. [15]
	Dual cure resin cement (Clearfil SA, Kuraray)	**Composition:** Paste A: 10-MDP, Bis-GMA, TEGDMA, Hydrophobic aromatic dimethacrylate, dl-Camphorquinone, BPO Initiator, Silanated barium glass filler and Silanated colloidal silica. Paste B: Bis-GMA, Hydrophobic aromatic dimethacrylate, Hydrophobic aliphatic dimethacrylate, Accelerators, Pigments, and Surface treated sodium fluoride, Silanated barium glass filler and Silanated colloidal silica. (Filler= 45 % vol., 66 wt.%; avg. 2.5µm)				
	Dual cure resin cement (Variolink II, Ivoclar Vivadent)	**Composition:** The monomer matrix: Bis-GMA, urethane dimethacrylate, triethylene glycol dimethacrylate. The inorganic fillers: barium glass, ytterbium trifluoride, Ba-Al-fluorosilicate glass, spheroid mixed oxide. Additional contents: catalysts, stabilizers, pigments				

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
2.	Dual cure resin cement (NX3 Nexus, Kerr)	**Composition:** glass, oxide, chemicals ytterbium trifluoride Poly(oxy-1,2-ethanediyl), α,α'-[(1-methylethylidene)di-4,1-phenylene] bis[ω-[(2-methyl-1-oxo-2-propen-1-yl)oxy]-7,7,9(or 7,9,9)-trimethyl-4,13-dioxo-3,14-dioxa-5, 12-diazahexadecane-1,16-diyl bismethacrylate 2,2'-ethylenedioxydiethyl dimethacrylate, 2-Hydroxyethyl methacrylate Silanamine, 1,1,1-trimethyl-N-(trimethylsilyl)-, hydrolysis products with silica Cumene hydroperoxide 1,1,3,3-tetramethylbutyl hydroperoxide, 2-Pyridylthiourea Oils, peppermint	Lava	Experimental model made of CAD/CAM composite	Experimental model made of CAD/CAM composite	Lührs AK, Pongprueksa P, De Munck J, Geurtsen W, Van Meerbeek B [16]
	Dual cure resin cement (RelyX Ultimate, 3M ESPE)	**Composition:** Base Paste Methacrylate monomers Radiopaque, silanated fillers Initiator components, Stabilizers, Rheological additives Catalyst Paste Methacrylate monomers, Radiopaque alkaline (basic) fillers, Initiator components, Stabilizers, Pigments, Rheological additives, Fluorescence dye, Dark cure activator				
3.	Dual cure resin cement (RelyX Ultimate, 3M ESPE)	**Composition:** Base Paste Methacrylate monomers Radiopaque, silanated fillers Initiator components, Stabilizers, Rheological additives Catalyst Paste Methacrylate monomers, Radiopaque alkaline (basic) fillers, Initiator components, Stabilizers, Pigments, Rheological additives, Fluorescence dye, Dark cure activator	Cerec	Inlay made of nano-ceramic resin	Natural tooth (intraoral)	Poticny DJ [17]

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
4.	Dual cure resin cement (RelyX Unicem Clicker, 3M ESPE)	**Composition:** Base paste (white) Methacrylate monomers containing phosphoric acid groups, Methacrylate monomers, Silanated fillers Initiator components, Stabilizers Catalyst paste (yellow) Methacrylate monomers, Alkaline (basic) fillers, Silanated fillers, Initiator components, Stabilizers, Pigments	Cerec Lava	Ceramic full crowns	Extracted human teeth (maxillary premolar)	Donnelly TJ, Burke FJ [18]
5.	Dual cure resin cement (Variolink, Ivoclar	**Composition:** See Nr. Crt. 1	Cerec	Ceramic veneers	Artificial tooth (Frasaco model)	Aboushelib MN, Elmahy WA, Ghazy MH [19]
6.	Light-curing luting composite (Variolink veneer, Ivoclar	**Composition:** Urethanedimethacrylate, inorganic fillers, ytterberiumtrifluoride, initiators, stabilizers, pigments	Cerec	Polimeric full crowns (Telio Cad)	Natural tooth (intraoral)	Edelhoff D, Beuer F, Schweiger J, Brix O, Stimmelmayr M, Guth JF [20]
7.	Self-curing non-eugenol temporary cement (Temp Bond	**Composition:** Base Mineral Oil, Zinc Oxide, Cornstarch Accelerator Ortho-Ethoxybenzoic acid, carnauba wax, octanoic acid	Cerec	Full crowns	Astra Tech abutments	Carnaggio TV, Conrad R, Engelmeier RL, Gerngross P, Paravina R, Perezous L, Powers JM [21]
	Self-curing non-eugenol temporary cement (ImProv,	**Composition:** eugenol-free acrylic urethane cement				
8.	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4	Cerec	Inlays made of glass ceramic	Extracted human molars	Frankenberge R, Hehn J, Hajtó J, Krämer N, Naumann M, Koch A,

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
	Dual cure resin cement (G-Cem, GC)	**Composition:** G-CEM powder: fluoro-alumino-silicate glass G-CEM liquid: strong frame-forming resins, UDMA and Dimethacrylate, as well as acidic resins; 4-MET and phosphoric acid ester monomer, small amount of water				Roggendorf MJ [22]
	Dual cure resin cement (Maxcem Elite, Kerr)	**Composition:** glass, oxide, chemicals, ytterbium trifluoride 1,6-hexanediyl bismethacrylate 2-hydroxy-1,3-propanediyl bismethacrylate 7,7,9(or 7,9,9)-trimethyl-4,13-dioxo-3,14-dioxa-5, 12-diazahexadecane-1,16-diyl bismethacrylate, Silanamine, 1,1,1-trimethyl-N-(trimethylsilyl)-, hydrolysis products with silica, Oils, peppermint, 1,1,3,3-tetramethylbutyl hydroperoxide, Cumene hydroperoxide, 2-Pyridylthiourea				
	Light-curing composite resin (Clearfil Majesty Posterior, Kuraray)	**Composition:** Silanated barium glass filler, Pre-polymerized organic filler, Bisphenol A diglycidylmethacrylate (Bis-GMA), Hydrophobic aromatic dimethacrylate, dl-Camphorquinone				
	Dual cure resin cement (Variolink II, Ivoclar Vivadent)	**Composition:** See Nr. Crt. 1				
9.	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4	Cerec	Polymer full crowns	Extracted human teeth	Stawarczyk B, Basler T, Ender A, Roos M, Ozcan M, Hämmerle C [23]
	Dual cure resin cement (G-Cem, GC)	**Composition:** See Nr. Crt. 8				

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
	Dual curing luting composite (artCem, Merz Dental)	**Composition:** polyacrylic acid, methacrylate, phosphoric acid ester, catalyst, stabilizers in ethanol				
	Dual cure resin cement (Variolink II, Ivoclar Vivadent)	**Composition:** See Nr. Crt. 1				
10..	Dual cure resin cement (Panavia F2.0, Kuraray)	**Composition:** **Paste A:** 10-Methacryloyloxydecyl dihydrogen phosphate (MDP), Hydrophobic aromatic dimethacrylate, Hydrophobic aliphatic dimethacrylate, Hydrophilic aliphatic dimethacrylate, Silanated silica filler, Silanated colloidal silica, dl-Camphorquinone, Catalysts, Initiators **Paste B:** Hydrophobic aromatic dimethacrylate, Hydrophobic aliphatic dimethacrylate, Hydrophilic aliphatic dimethacrylate, Silanated barium glass filler, Surface treated sodium fluoride, Catalysts, Accelerators, Pigments	Cerec	Feldspathic ceramic full crowns Composite resin full crowns	Extracted human molars	Kassem AS, Atta O, El-Mowafy O [24]
	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4				
11.	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4	Procera	Zirconia based 3 units bridge (replacing a molar or a premolar)	Human teeth (intraoral)	Sorrentino R, De Simone G, Tetè S, Russo S, Zarone F [25]

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
12.	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4	Lava	Zirconia based 3 units bridge for maxillary anterior area	Human teeth (intraoral)	Madan N, Pannu K [26]
13.	Non-lutted		Cerec	Ceramic or composite inlay	Extracted human teeth (molars and premolars)	Magne P, Paranhos MP, Schlichting LH [27]
14.	Self-cure and dual cure resin cement (SpeedCEM,Ivoclar	**Composition:** Dimethacrylates, Ytterbium trifluoride, Co-polymer, Glass filler (base only), Silicon dioxide, Adhesive monomer, Initiators, Stabilizers and Pigments	Cerec	Ceramic inlays	Extracted human molars	Flury S, Lussi A, Peutzfeldt A, Zimmerli B [28]
	Dual cure resin cement (RelyX Unicem Aplicap, 3M	**Composition:** See Nr. Crt. 4				
	Dual cure resin cement (Smart Cem2, Dentsply)	**Composition:** UDMA Resin, EBPADMA Urethane Resin, Di- and tri-functional Diluents, PENTA, Proprietary Photoinitiating system, Proprietary self-cure initiating system, 69% fillers by wt., 46% by vol.				
	Dual cure luting composite (iCEM, Heraeus	**Composition:** Composition based on methacrylates 2-component material comprising base paste and matching catalyst paste				
	Dual cure resin cement (Variolink II, Ivoclar Vivadent)	**Composition:** See Nr. Crt. 1				

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
15.	Dual cure resin cement (Calibra, Dentsply)	**Composition:** Cement Base: Dimethacrylate Resins; Camphorquinone (CQ) Photoinitiator; Stabilizers; Glass Fillers; Fumed silica; Titanium Dioxide; Pigments Cement Catalyst: Dimethacrylate Resins; Peroxide Catalyst; Stabilizers; Glass Fillers; Fumed Silica Resin Cement Try-In Paste: Glycerine; Fumed Silica; Titanium Dioxide; Pigments Silane Coupling Agent: Acetone; Ethyl Alcohol; Organo Silane	Cerec	Ceramic inlays	Human molars (intraoral)	Rechenberg DK, Göhring TN, Attin T [29]
16.	Light curing composite resin (Filtek Z100 cement, 3M ESPE)	**Composition:** Bis-GMA, TEGDMA Silica/zirconia (84.5 wt%; 0.6 µm average particle size), photoinitiator	Cerec	Composite overlays	Extracted human premolars	Magne P, Knezevic A [30]
17.	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4	Cerec	Ceramic full crowns	Extracted human molars	Mörmann W, Wolf D, Ender A, Bindl A, Göhring T, Attin T [31]
	Dual cure resin cement (Multilink Sprint, Ivocalr Vivadent)	**Composition:** Dimethacrylates; adhesive monomer; Fillers; initiators / stabilizers				
	Light cure resin cement (Variolink Ultra, Ivoclar Vivadent)	**Composition:** Base ytterbium trifluoride , Bis-GMA, urethane dimethacrylate, triethylene glycol dimethacrylate, titanium dioxide Catalyst ytterbium trifluoride, Bis-GMA, urethane dimethacrylate, triethylene glycol dimethacrylate, dibenzoyl peroxide				
	Glass ionomer cement (Ketac Cem, 3M ESPE)	**Composition:** Powder Glass powder, Polycarboxylic acid, Pigments Liquid Water, Tartaric acid, Conservation agents				

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
18.	Dual curing luting composite (Vita Cerec Duo Cement, VITA)	**Composition:** Base triethylene glycol dimethacrylate Catalyst triethylene glycol dimethacrylate, dibenzoyl peroxide	Cerec	Ceramic full crowns	Natural teeth	Zimmer S, Göhlich O, Rüttermann S, Lang H, Raab WH, Barthel CR [32]
19.	Dual cure resin cement (Variolink II, Ivoclar Vivadent)	**Composition:** See Nr. Crt. 1	Cerec	Feldspathic ceramic cylinders	Extracted human teeth	Graiff L, Piovan C, Vigolo P, Mason PN [33]
	Dual cure resin cement (RelyX ARC, 3M ESPE)	**Composition:** See Nr. Crt. 1				
20.	Dual cure composite resin (Link Max, GC)	**Composition:** 4-MET, HEMA, Ethanol, Water EP-B Ethanol Base paste UDMA, HEMA, Fluoroalminosilicate glass filler, Silica filler Catalyst paste UDMA, HEMA, Fluoroalminosilicate glass filler, Silica filler	MicroSpecimen Former	Ceramic block GN-I (GC)	Ceramic block GN-I (GC)	Peumans M, Hikita K, De Munck J, Van Landuyt K, Poitevin A, Lambrechts P, Van Meerbeek B [34]
	Dual cure resin cement (Panavia F2.0, Kuraray)	**Composition:** See Nr. Crt. 10				
	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4				
	Dual cure resin cement (Variolink II, Ivoclar Vivadent)	**Composition:** See Nr. Crt. 1				
21.	Dual cure resin cement (Panavia F2.0, Kuraray)	**Composition:** See Nr. Crt. 10	Cerec	Ceramic inlays	Extracted human molars	Oztürk AN, Inan O, Inan E, Oztürk B [35]

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
	Dual cure resin cement (Variolink II, Ivoclar Vivadent)	**Composition:** See Nr. Crt. 1				
22.	Dual cure resin cement (Panavia F2.0, Kuraray)	**Composition:** See Nr. Crt. 10	Procera	Zirconia copyings	Extracted human molars	Palacios RP, Johnson GH, Phillips KM, Raigrodski AJ [36]
	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4				
	Dual cure resin cement (RelyX Unicem, 3M ESPE)	**Composition:** See Nr. Crt. 4				
23.	Light curing microhybrid composite (Tetric, Ivoclar Vivadent)	**Composition:** Bis-GMA, Triethylenglycole Dimethacrylate, Urethane dimethacrylate Barium glassfiller, Ytterbiumtrifluoride, High dispersed silica, Mixed oxide Catalysts and Stabilizers Pigments	Cerec	Ceramic inlays	Extracted i maxillary premolars	Hannig C, Westphal C, Becker K, Attin [37]
24.	Light curing microhybrid composite (Tetric Flow, Ivoclar Vivadent)	**Composition:** Urethane dimethacrylate, Bis-GMA Ethoxylated Bis-EMA, Triethyleneglycol dimethacrylate, Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide, Prepolymers, Additives, tabilizers, catalysts, pigment	Cerec	Ceramic block	Ceramic surface	El Zohairy AA, De Gee AJ, Hassan FM, Feilzer AJ [38]
	Dual cure resin cement (NX2 Nexus, Kerr)	**Composition:** 2-hydroxyethyl methacrylate, Ytterbium trifluoride ,Methacrylated poly(acrylic acid) copolymer 2-hydroxy-1,3-propanediyl bismethacrylate				

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
25.	Dual curing luting composite (Vita Cerec Duo Cement, VITA)	**Composition:** See Nr. Crt. 18	Cerec	Conuri trunchiate din Dicor MGC sau blocuri Cerec Vita Mark II	Extracted anterior teeth	Chang JC, Hart DA, Estey AW, Chan JT [39]
	Dual cure resin cement (EnForce, Dentsply)	**Composition:** Bis-GMA: 2,2-bis[p-(2 -hydroxy-3 -methacryloxypropoxy)phenyl]propane. TEGDMA: triethylene glycol dimethacrylate				
	Self-cure resin cement (Panavia 21, Kuraray)	**Composition:** Catalyst Paste 10-Methacryloyloxydecyl dihydrogen phosphate, Hydrophobic aromatic dimethacrylate, Hydrophobic aliphatic dimethacrylate, Silanated silica filler, Colloidal silica, Catalysts Universal Paste Hydrophobic aromatic dimethacrylate, Hydrophobic aliphatic dimethacrylate, Hydrophilic aliphatic dimethacrylate, Silanated titanium oxide, Silanated barium glass filler, Catalysts, Accelerators, Pigments				
	Self-cure resin cement (C&B Metabond cement, Parkell)	**Composition:** Base Methyl Methacrylate Monomer Powders Polymethylmethacrylate (PMMA), Metal Oxide				
	Glass ionomer cement (Fuji Duet, GC)	**Composition:** Powder aluminosilicate glass Liquid aqueous solution of polyacrylic acid, 2-hydroxyethyl, methacrylate (2-HEMA), tartaric acid				
26.	Light curing microhybrid composite (Tetric, Ivoclar Vivadent)	**Composition:** See Nr. Crt. 23	Cerec	Ceramic partial crowns	Extracted human molars	Bindl A, Mörmann WH [40]

Nr. Crt	Material		CAD CAM	Restoration type	Abutment type	Authors
27.	Dual cure resin cement (Variolink II, Ivoclar Vivadent)	**Composition:** See Nr. Crt. 1	Celay milling machine	Ceramic onlays	Human molars (intraoral)	Sevük C, Gür H, Akkayan B [41]
28.	Dual curing luting compo site (Vita Cerec Duo Cement, VITA)	**Composition:** See Nr. Crt. 18	Cerec	Inlays	Human tooth (intraoral)	Molin MK, Karlsson SL [42]
	Dual cure composite resin (Mirage FLC, Chameleon Dental)	**Composition:** Bisphenol a diglycidyl methacrylate, 1,6-hexanediol dimethacrylate, dimethylaminoethyl methacrylate				
	Dual cure resin cement (IPS Empress dual cement, Ivoclar Vivadent)	**Composition:** urethane dimethacrylate, ytterbium trifluoride, tricyclodocane dimethanol dimethacrylate, Bis-GMA				
29.	Dual cure composite resin (Link Max, GC)	**Composition:** 4-MET, HEMA, Ethanol, Water EP-B Ethanol Base paste UDMA, HEMA, Fluoroalminosilicate glass filler, Silica filler Catalyst paste UDMA, HEMA, Fluoroalminosilicate glass filler, Silica filler	Isomet 11-1180-170 low-speed cutting saw	Experimental model made of CAD/ CAM composite	Experimental model made of CAD/CAM composite	Yoshida K, Kamada K, Atsuta M [43]
	Dual curing luting composite (Vita Cerec Duo Cement, VITA)	**Composition:** See Nr. Crt. 18				
30.	*N		Cerec	Ceramic inlays	Extracted human molars	LoPresti JT, David S, Calamia JR [44]

*N-unidentified fixing agent

Five studies were excluded because they were considered ineligible for this review, so a number of 30 studies were analyzed. Cerec dental CAD/CAM system was used in 73.3% of these studies.

Twenty-four fixing agents were tested and the most used were RelyX, Variolink and Panavia (Table 2).

Table 2. Fixing agents most used.

30 studies		
Fixing agent	**No. Articles**	**Percentage**
Rely X	14	58.33%
Variolink II	11	45.83%
Panavia	5	20.83%

Self-adhesive cements do not require any tooth surface pre-treatment, and their application is easy, similar to the more conventional zinc-phosphate and polycarboxylate cements [45].

Our results were compared with literature data and they are in good agreement with Monticelli et al. [46] "RelyX Unicem is the most investigated self-adhesive cement in the current literature published in Medline cited journals".

In order to choose the proper luting agent suitable for different clinical indications technical data sheet should be consulted (Table 3).

Table 3. Technical data summary for the most used fixing agents.

Fixing Agent	Technical Data Summary
RelyX Luting Cement (3M ESPE)	Compressive Strength (MPa) 111.7±26.0 Flexural Strength (MPa) 27.6±4.3 Film thickness (microns) 17.0±2.6 Radiopacity (mm) 1.53±0.02
Variolink II (Ivoclar Vivadent)	Compressive Strength (MPa)278.8±30.9 Flexural Strength (MPa) 148.5±22.4 Film thickness (microns) 9.4±2.4 Radiopacity (mm) 4.07±0.5
Panavia F 2.0 (Kuraray)	Compressive Strength (MPa) 290 Flexural Strength (MPa) 77 Film thickness (microns) 19.2±2.2 Radiopacity (mm) 1.44±0.7

The most studied type of prosthetic restorations were inlays (nine articles) and coverage crowns (eight articles), on the third place were experimental models (seven articles).

The evolution of materials and adhesive systems permits the clinician to choose a technique that is more aesthetic and less invasive and this explain why the inlays were the most studied.

Regarding prosthetic restoration support the most used were extracted human teeth (53.33%) and experimental models were used in a percentage of 16.66% (five studies of thirty).

Extracted teeth are routinely used in dentistry to learn technical and preclinical skills before entering clinics and treating patients. It is necessary to use freshly extracted teeth to simulate in vivo conditions [47].

A requirement for the successful function of a ceramic restoration is adequate adhesion between ceramic and tooth substance, however, the literature is unclear on which cement, ceramic, conditioning treatment and dentine bonding agent produce the highest bond strength [48].

The prosthetic restoration success depends of a number of steps and some of the factors involved in the process derive from the particularities of dental CAD-CAM systems, pretreatment of the surfaces that come into contact, cement type, material selection and, of course, the role of human intervention.

Dental CAD-CAM system

Donnelly et al [18] consider that ceramic crown constructed with the same characteristics but with different dental CAD-CAM systems show significant statistically differences. His study showed that the fracture resistance of teeth restored with Lava crown is significantly greater than a similar group of teeth restored with Cerec crowns.

Pretreatment of the surfaces

Gilbert et al [15] showed that for a clinical use of XHIPC-CAD/CAM-resin (Xplus 3, Echzell, Germany), the bond surface should be additionally pretreated with visio.link as bonding agent.

Lührs et al [16] revealed a significant influence of the factors “curing mode” and “composite cement” and a less significant effect of the factor “restoration-surface pre-treatment”. The curing mode is decisive for the bonding effectiveness of adhesively luted composite CAD-CAM restoration to dentin.

Stawarczyk et al [23] concluded that airborne particle abrasion before cementation of polymeric CAD-CAM crowns minimally improved the tensile strength. This study showed that although the tensile strength results were low, crowns cemented with RelyX Unicem showed, after aging, the highest tensile strength. Non-treated CAD-CAM resin crowns showed no bonding for all cements. Pre-treatment with alumina improved the results. The tensile strength of pre-treated resin crowns cemented with all tested cements presented significantly lower values than those of the adhesively luted glass ceramic crowns [23].

The study of Graiff et al [33] demonstrated that the application of a silane-coupling agent to the ceramic surface after etching with hydrofluoric acid increased the adhesion strength with both adhesive materials used (Variolink II, Rely X ARC).

Some clinicians have suggested the use of surface abrasion with alumina and the subsequent placement of a tribochemical silica coating to allow the creation of chemical bonds between silane and a resin cement [49].

Another technique is the application of molecular vapor deposition of gas-phase chlorosilane ($SiCl_4$) pretreatment to place an ultra-thin silica seed layer. This is achieved by combining chlorosilane with water vapor to form a more reactive surface. This 2nm to 3nm layer allows the creation of bond strength statistically equivalent to traditional bonded porcelain materials [50].

It was developed a surface treatment called selective infiltration etching which use the heat-induced maturation concept and grain boundary diffusion to form a highly retentive surface on Y-TZP. Because selective infiltration etching is only a surface treatment, the mechanical properties of yttria stabilized zirconia (Y-TZP) are not affected [51-52].

Laser treatment has also been shown to create acid-etch type effects. Hydrophobicity of the substrate surface can be improved during laser texturing. Laser texturing of yttria stabilized zirconia is carried out at high pressure nitrogen assisting gas environment (Figure 1) [53].

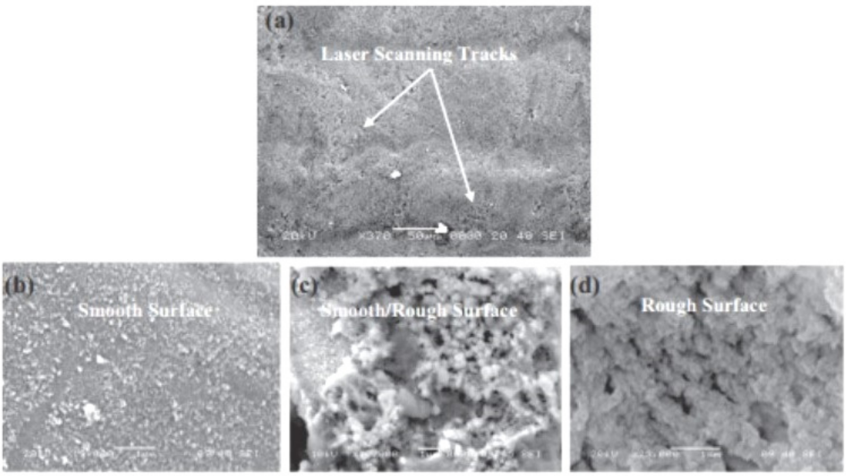

Figure 1. Surface texture of laser treated Y-TZP surface, SEM images [53].

Cement type and material selection

The study of Kassem et al [24] demonstrated that micro-leakage scores of ceramic crowns cemented with Panavia F 2.0 were significantly lower than those of ceramic crowns cemented with RelyX Unicem Clicker and those of composite crowns.

Magne et al [27] concluded that the material selection has a significant effect on the risk of CAD/CAM inlay fracture during pre-cementation functional occlusal tapping.

El Zohairy et al [38] showed in their study that strong and durable bonds to ceramics can be achieved with resin cements and in particular those of hydrophobic nature, when these are applied directly to hydrofluoric acid etched and silanized surfaces.

Study of Felizer et al [54] found that the stress relaxation by water sorption of the composites based on BisGMA/TEGDMA and urethane dimethacrylate resins differed from composite based on tricyclodecane diacrylate which allow to occure very little hygroscopic relaxation.

Monomer-based primers can also be used with zirconia that have not been treated or sandblasted [55].

According to El Zohairy AA application of an intermediate layer of Visio Bond showed a substantial increase in bond strength for both resin cements only to H3PO4 treated surfaces and not to HF-treated surfaces The results also showed that the 1 d bond strength values for Visio Bond as an intermediate resin was consistently lower than with Syntac Single Component or OptiBond Solo Plus regardless the surface treatment (HF or H3PO4) or resin cement used (Tetric Flow or Nexus 2). The most probable explanation for this interesting finding is a decreased possibility for the Visio Bond monomer Tricyclodecane diacrylate to react with the silane-C=C-bonds by severe steric hindrance. The reactive C=C-bonds are too closely positioned to this bulky monomer (Figure 2), that they cannot easily reach the silane-C=C-bonds to react with. Synthesis of a similar monomer with longer chains carrying the C=C-groups may significantly improve coupling to the silane layer [56].

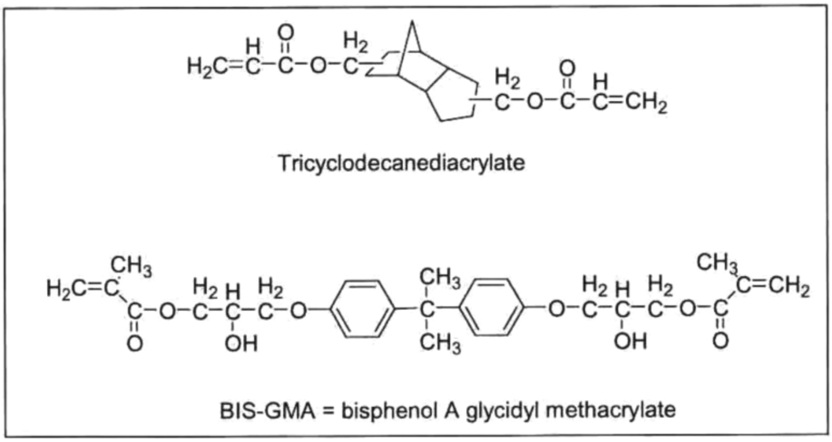

Figure 2. Chemical structure of Tricyclodecane diacrylate and BIS-GMA. The reactive C=C-bonds of Tricyclodecanee diacrylate are more closely positioned to the central core of the monomer molecule in comparison to BIS-GMA [56]

CONCLUSIONS

Adhesion has two aspects and for durable prosthetic restoration not only the conditioning of restoration material but also the dentin is crucial for good attachment of the resin cement to both substrates. Etching and rinse bonding systems are still considered the gold standard for conditioning of dentin. However due to their technique sensitivity, some of the conventional resin cement systems involve self-etch adhesives. On the other hand, self-adhesive cements do not require any conditioning of the dentin, which eliminates technique sensitivity [57]. Light curing after inlay insertion showed improved marginal adaptation. Using dual-curing adhesive and Luting Cements, advantages in marginal adaptation between Luting Cements and dentin were observed [58].

The authors of this paper tried to provide an overview of currently available luting agents, the chemical composition and properties intending to help the clinician to choose the suitable luting agent for a particular clinical situation.

In summary, the objective of any surface treatment method is to enhance the adhesive bond strength and durability. The basic requirements for a good adhesive bond are following: proper choice of adhesive, good joint design, cleanliness of surfaces, wetting of adherends (surfaces that are to be bonded together by the adhesive), proper adhesive bonding process (solidification and cure) [59-60].

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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