1-2022

# The Resin Bond to High-Translucent Zirconia—A Systematic Review

Amirah Alammar

Markus Blatz
*University of Pennsylvania*

## Recommended Citation

Alammar, A., & Blatz, M. (2022). The Resin Bond to High-Translucent Zirconia—A Systematic Review. *Journal of Esthetic and Restorative Dentistry, 34* (1), 117-135. http://dx.doi.org/10.1111/jerd.12876

# The Resin Bond to High-Translucent Zirconia—A Systematic Review

## Abstract

Objectives: Several systematic literature reviews have assessed the scientific evidence on resin bonding protocols to conventional 3 mol% ytrria-stabilized zirconia (3Y-TZP) ceramics. It has been widely discussed, however, that the differing composition and physical properties of new high-translucent zirconia generations (4Y-TZP and 5Y-TZP) may require alternative bonding materials and procedures. This paper reviewed in vitro studies on the success and durability of bonding protocols to high-translucent zirconia. Material and methods: A systematic search of PubMed and Cochrane Library for in vitro studies on bonding to new zirconia generations published until November 2020 was conducted and complemented by a manual search. Studies selected for review fulfilled the applied inclusion and exclusion criteria. The quality of the included studies was assessed with the Cochrane risk-of-bias tool for randomized trials. Results: Of 629 screened articles, 18 were included in this review. They investigated different surface pretreatment methods, primers, resin cements, aging procedures, and bond strength test protocols. The limited number of the identified studies and the heterogeneity of the extracted data did not allow to conduct a meta-analysis. Conclusions: The available evidence suggests that resin bonding protocols successfully applied to conventional zirconia are also the most successful for high-translucent zirconia. Airborne particle abrasion and special phosphate monomer-containing primers or composite resin cements provide long-term durable resin bonds. Clinical significance: Durable bonds can be established between high-translucent zirconia and resin cements. The bonding materials and procedures applied do not compromise their physical properties. © 2022 Wiley Periodicals LLC.

## Disciplines

Dentistry

Received: 2 November 2021 | Revised: 20 December 2021 | Accepted: 31 December 2021
DOI: 10.1111/jerd.12876

REVIEW ARTICLE

WILEY

# The resin bond to high-translucent zirconia—A systematic review

**Amirah Alammar BDS**[1] | **Markus B. Blatz DMD, PhD**[2]

[1]Sijam Medical Center, Private Practice, Riyadh, Saudi Arabia

[2]School of Dental Medicine, Department of Preventive and Restorative Sciences, University of Pennsylvania, Philadelphia, Pennsylvania, USA

**Correspondence**
Amirah Alammar, Sijam Medical Center, Private Practice, Northern Ring Road, AlGadeer district, Riyadh-13311, Saudi Arabia.
Email: dr.a-alammar@sijam-mc.com

## Abstract

**Objectives:** Several systematic literature reviews have assessed the scientific evidence on resin bonding protocols to conventional 3 mol% ytrria-stabilized zirconia (3Y-TZP) ceramics. It has been widely discussed, however, that the differing composition and physical properties of new high-translucent zirconia generations (4Y-TZP and 5Y-TZP) may require alternative bonding materials and procedures. This paper reviewed in vitro studies on the success and durability of bonding protocols to high-translucent zirconia.

**Material and methods:** A systematic search of PubMed and Cochrane Library for in vitro studies on bonding to new zirconia generations published until November 2020 was conducted and complemented by a manual search. Studies selected for review fulfilled the applied inclusion and exclusion criteria. The quality of the included studies was assessed with the Cochrane risk-of-bias tool for randomized trials.

**Results:** Of 629 screened articles, 18 were included in this review. They investigated different surface pretreatment methods, primers, resin cements, aging procedures, and bond strength test protocols. The limited number of the identified studies and the heterogeneity of the extracted data did not allow to conduct a meta-analysis.

**Conclusions:** The available evidence suggests that resin bonding protocols successfully applied to conventional zirconia are also the most successful for high-translucent zirconia. Airborne particle abrasion and special phosphate monomer-containing primers or composite resin cements provide long-term durable resin bonds.

**Clinical significance:** Durable bonds can be established between high-translucent zirconia and resin cements. The bonding materials and procedures applied do not compromise their physical properties.

KEYWORDS
bonding, bonding protocols, in vitro, resin cements, translucent zirconia

## 1 | INTRODUCTION

Yttria-stabilized zirconium dioxide ceramics (Y-TZP or zirconia) have been increasingly used as an alternative to porcelain-fused-to-metal (PFM) restorations in daily dental practice, first as coping and framework materials to be veneered with layering porcelain and later to fabricate full-contour monolithic restorations.[1,2] The rapid shift to zirconia for all-ceramic restorations was due to their superior mechanical and biological properties,[3,4] high-clinical success,[5,6] accurate milling process,[7,8] low-wear behavior of the antagonist dentition,[9,10] and low material as well as fabrication costs.[2,11] Zirconia is a polymorphic material that exists in several phases depending on the applied temperature.[12] The monoclinic phase is stable from room temperature to 1170°C, tetragonal at 1170–2370°C, and cubic over 2370°C.[13,14]

Phase transformation from tetragonal to monoclinic goes along with a volumetric particle increase of approximately 4–5%.[15] This phenomenon proves advantageous to limit crack propagation, also referred to as "transformation toughening." Spontaneous transformation can be prevented by stabilizing the tetragonal phase at room temperature by adding certain oxides such as yttria, leading to high-fracture toughness.[16–18]

The yttria content in zirconia largely defines its mechanical and optical properties. Different generations of zirconia can be classified according to their yttria content (mol%). The first generation contains 3 mol% yttria, known as 3Y-TZP or conventional zirconia. 3Y-TZP is partially stabilized in the tetragonal phase and has the highest fracture toughness and flexural strength among other generations.[19,20] It is preferred for long-span fixed dental prostheses and in posterior areas with high-occlusal loads.[21,22] However, due to its high opacity and compromised esthetic appearance, 3Y-TZP is predominantly used as a supporting coping and framework structure for bilayer all-ceramic restorations.[23–25]

New generations of zirconia were developed to enhance esthetics appearance by increasing the yttria content to 4 and 5 mol% and apply them for full-contour monolithic restorations.[26] These generations contain approximately 30% to 50% cubic phase particles, which makes them more translucent and less susceptible to low-temperature degradation compared to conventional 3Y-TZP.[27,28] Transformation toughening, key factor for the superior flexural strength, does not occur with these compositions. The reduced fracture toughness and flexural strength limits their clinical indication to single unit, partial coverage, and short-span fixed dental restorations in areas of limited occlusal load.[26,29,30]

As with all brittle ceramic materials, resin bonding does not only provide adhesion of indirect ceramic restorations to teeth but also increases their flexural strength. This is especially true for silica-based ceramics and lower strength zirconia compositions with limited thickness. Conventional bonding protocols (i.e., hydrofluoric acid etching and silane coupling agents) applied to glass ceramics do not provide a durable chemical and micromechanical resin bonds to zirconia.[31,32] Different mechanical, chemical, and combined chemical–mechanical surface pretreatment methods have been found to improve the zirconia-resin bonding.[33] These include airborne-particle abrasion (APA), tribochemical silica airborne-particle abrasion (TBS), low-fusion porcelain application, hot chemical etching solutions, selective infiltration etching (SIE), laser irradiation, plasma spraying, and zirconia ceramic powder coating.[31,33–35]

Surface pretreatment methods aim to improve mechanical and chemical bonds.[36,37] A combination of such surface pretreatment followed by 10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer or phosphate ester monomer-based primers and resin cements have resulted in superior and long-term durable zirconia-resin bonds.[38–40] These functional monomers have proven to provide durable chemical bonds to the metal oxides in zirconia.[41,42] Resin bonds to zirconia have been investigated for more than two decades now. Classic articles by Kern and coworkers have first demonstrated the effectiveness of APA and MDP-containing resin luting agents for long-term durable zirconia resin bonds.[37,43] Other studies stressed the importance of an MDP-containing primer, which provides better wettability, especially to the slightly rough computer-aided design/computer-aided manufacture (CAD/CAM) milled surfaces and can be used with conventional composite resin luting agents. This bonding protocol to 3Y-TZP consists of three main steps: air-particle abrasion with alumina or silica-coated alumina particles (step A), priming the air-abraded surfaces with an MDP or phosphate-monomer-based primer (step P), and cementation with dual or self-cure composite resin cement (step C), known as the "APC Zirconia Bonding Concept".[44]

Systematic reviews have also assessed both in vitro and clinical durability of different bonding protocols of 3Y-TZP to enamel, dentin, composite cores, titanium abutments and bases, zirconia abutments, and lithium disilicate crowns.[45,46] They also concluded that 3Y-TZP surface pretreatment and chemically activating these surfaces with functional monomer-based primers and resin cements provide superior bond strengths.

Limited information is available about bonding to 4Y-TZP and 5Y-TZP zirconia. Concerns were expressed about surface pretreatment methods to new zirconia generations and the possibility of decreasing their flexural strength.[47,48] It is unclear whether these treatments in combination with functional monomers would be also feasible. Therefore, the aim of this article is to systematically review in vitro studies on bonding protocols to new zirconia generations. The focused question was: Is the application of different surface pretreatment methods combined with an MDP monomer or phosphate monomer-based primer or resin cement a durable bonding protocol for new zirconia generations?

## 2 | MATERIAL AND METHODS

### 2.1 | Study selection criteria

This systematic review followed the PRISMA statement for reporting systematic reviews and meta-analysis.[49] The focused question was formulated according to the PICO strategy to develop the search strategy: ***P*:** 4Y and 5Y-TZP zirconia, ***I*:** MDP monomer or phosphate monomer-based primers/resin cements, ***C*:** Surface pretreatment methods, **O:** Durable bonding protocol.

One reviewer (A.A) conducted a search for English-language articles published in dental journals until 16 November 2020 of the following electronic data bases: PubMed and Cochrane Library. A manual search was also conducted. Searches used a combination of MeSH terms and free text words, as follows: 'Zirconia', 'translucent zirconia','4Y-TZP', '5Y-TZP', '4Y-PSZ', '5Y-PSZ', '4Y','5Y', '4Y-ZP', '5Y-ZP', 'Primer', 'functional monomers',' MDP', 'resin cement', 'adhesion', 'bonding', 'surface pretreatment methods', 'surface roughening', 'test', 'bond strength', 'in vitro', and 'laboratory'. References from different studies were included to identify relevant eligible studies. For the selection of studies, titles and abstracts of the studies were first reviewed independently by the two authors (A.A and M.B) according to the inclusion criteria. Second, final inclusion of studies was based on screening and assessing full texts and with consensus of the authors. Table 1 gives a summary of all articles excluded in the second phase of the review along with reasons for exclusion.

## 2.2 | Inclusion criteria

1. In vitro studies reporting on the bond strength to new translucent zirconia generations.
2. Surface pretreatment methods applied to new translucent zirconia generations must be reported.
3. In vitro studies investigating the effect of surface pretreatment methods and adhesive bonding protocols on the bond strength outcomes.
4. In vitro studies including one of the artificial aging procedures: water storage, artificial saliva storage, thermocycling or mechanical load cycling.
5. Publications in the English-language dental literature.

## 2.3 | Exclusion criteria

1. In vitro studies reporting on the bond strength outcomes to conventional 3Y-TZP.
2. In vitro studies with a sample size of less than five test specimens in each subgroup.
3. Finite element analysis studies.
4. Clinical trials, case reports or animal studies.

Risk of bias assessment followed the Cochrane risk-of-bias tool for randomized trials (RoB 2).[94] The assessment of the quality of the studies was conducted according to a fixed set of domains of bias (selection bias, performance bias, attrition bias, reporting bias, and other bias). Within each domain, signaling questions were raised to extract information about features of the trial that are relevant to risk of bias, as follows: (1) random sequence generation, (2) allocation concealment, (3) blinding participants and personal, (4) blinding outcome assessment, (5) incomplete outcome data, (6) selective reporting, and (7) other resources of bias. The assessment of RoB was performed by categorizing each of the study features as 'low risk of bias', 'high-risk of bias', or 'unclear' (not possible to find the information). Both reviewers (A.A and M.B) conducted the assessment independently, and any uncertainty or disagreements were then resolved by discussion.

## 3 | RESULTS

Figure 1 depicts the study selection process according to the PRISMA checklist. The initial search revealed 629 papers, out of which 62 were selected for full-text assessment. Finally, 18 studies meet the inclusion criteria and were included in this systematic review. The studies identified were published between 2017 and 2020. Data from the

**TABLE 1** In vitro studies excluded from the second phase of the review

| Author (year) | Reasons for exclusion |
|---|---|
| Aung et.al 2019[50] | Tested specimens were not subjected to an aging procedure |
| Cadore-Rodrigues et.al 2020[51] | Bond strength values was not evaluated |
| Elsayed et.al 2019[52] | |
| Aboushelib et.al 2018[53] | 3Y-TZP zirconia were tested |
| Ali et.al 2019[54] | |
| Asadzadeh et.al 2019[55] | |
| Bhavana et.al 2019[56] | |
| Cakirbay Tanis et.al 2019[57] | |
| Carvalho et.al 2019[58] | |
| Colombo et.al 2020[59] | |
| Dantas et.al 2019[60] | |
| Dantas et.al 2019[61] | |
| Ebeid et.al 2018[62] | |
| Elsaka et.al 2016[63] | |
| Flores-Ferreyra et.al 2019[64] | |
| Hou et.al 2020[65] | |
| Koko et.al 2020[66] | |
| Kvam et.al 2019[67] | |
| Lee et.al 2017[68] | |
| Lee et.al 2019[69] | |
| Le et.al 2019[70] | |
| Li et.al 2020[71] | |
| Maciel et.al 2020[72] | |
| Mendes et.al 2019[73] | |
| Nagaoka et.al 2019[74] | |
| Okada et.al 2017[75] | |
| Okutan et.al 2020[76] | |
| Omidi et.al 2018[77] | |
| Özdemir et.al 2019[78] | |
| Petrauskas et.al 2018[79] | |
| Ruyter et.al 2017[80] | |
| Saade et.al 2019[81] | |
| Saade et.al 2020[82] | |
| Saleh et.al 2019[83] | |
| Salem et.al 2016[84] | |
| Sathish et.al 2019[85] | |
| Sharafeddin et.al 2018[86] | |
| Skienhe et.al 2018[87] | |
| Smielak et.al 2019[88] | |
| Soltaninejad et.al 2018[89] | |
| Tabatabaei et.al 2018[90] | |
| Thammajaruk et.al 2020[91] | |
| Lümkemann et.al 2019[92] | |
| Zahoui et.al 2020[93] | |

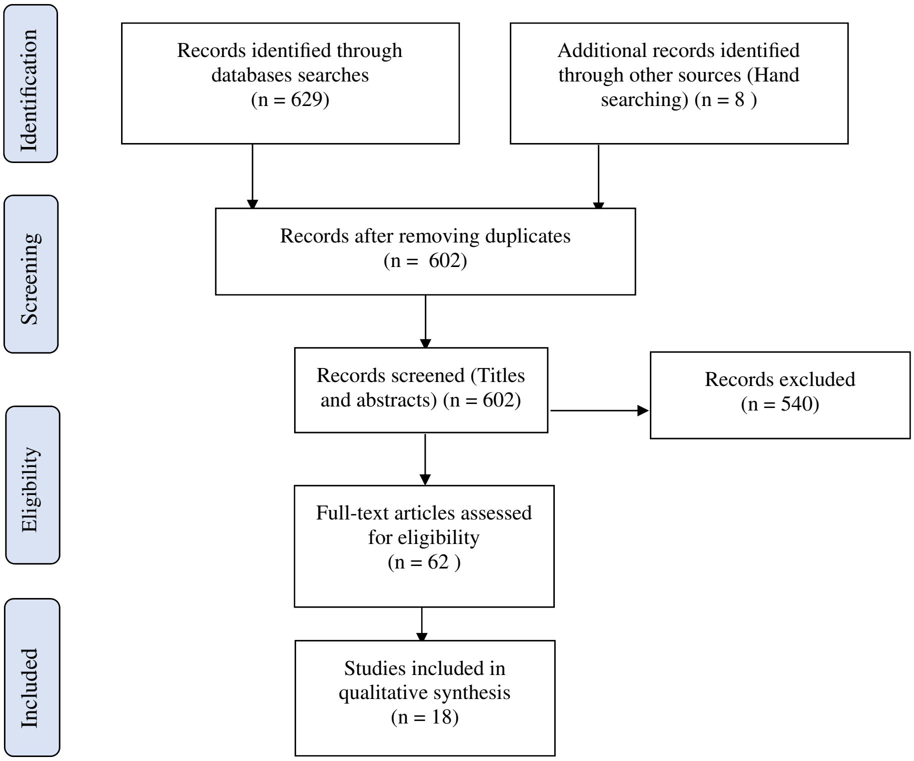

**FIGURE 1** Flow chart of the study selection process

included studies were chronologically extracted in Table 2. Data extraction was performed using a predefined data extraction form as follows: author name, year of publication, zirconia generation, surface pretreatment method, primer, resin cement, aging procedure, bond strength values, and bonding failure mode analysis. Bonding failure modes were categorized as adhesive (failure along the interface between the resin cement and zirconia), cohesive (failure in the resin cement), or mixed (adhesive and cohesive).

### 3.1 | Bonding to 4Y-TZP

Three studies on bonding to 4Y-TZP zirconia were identified.[95–97] The applied surface pretreatment methods in these studies were mechanical: alumina and glass-bead APA (Table 2). Alumina particles (50 μm) were applied at either 1 or 2 bar pressures. Glass-bead particles were 80 μm in size. Only one study included an MDP-based primer,[96] and two studies used MDP-based resin cements.[95,97] All studies applied simulated aging in terms of water storage,[97] thermocycling,[95] and thermocycling combined with water storage.[96] Bond strength was tested with a shear test in all studies. Only one study provided results of failure mode analyses,[96] which were mainly adhesive with only a few categorized as mixed.

### 3.2 | Bonding to 5Y-TZP

The search revealed 18 studies on bonding to 5Y-TZP zirconia.[86,95,96,98–111] The three types of surface pretreatment methods were applied: mechanical, through alumina and glass-bead APA; chemical–mechanical, through TBS, lithium disilicate glass–ceramic coat, and plasma treatment; and chemical, through piranha acid etch solution and hot chemical etching (Table 2). Alumina APA particle sizes ranged between 40–110 μm at 1–6 bar pressure. Glass-bead particles were 80 μm in size. Most of the studies applied functional monomer-based primers and resin cements. All specimens in the identified studies underwent simulated aging, in terms of water storage,[86,95,103,105,107,110] thermocycling,[97,111] thermocycling combined with water storage,[96,98,99,101,102,104,106,108,109] or thermocycling combined with water storage and mechanical load cycling.[100] Tensile, micro-tensile, shear, and pull-out tests were applied to test and measure bond strength. Most of the identified studies performed failure mode analyses, indicating adhesive, mixed or cohesive failure.

The risk of bias assessment of the 18 studies is shown in Table 3. The most common risk of bias was the absence of blinding the outcome assessment. Most of the identified studies did not provide any information about division of the tested specimens in a random manner (random sequence generation).

## 4 | DISCUSSION

Patient demand for dental restorations with a natural esthetic appearance has increased considerably over the past few decades. Translucency is considered as one of the primary parameters in controlling esthetics,[112,113] which is a crucial step in the selection of restoration material. New zirconia generations have intermediate translucency to those of conventional zirconia and lithium disilicate glass-

**TABLE 2** Identified in vitro studies

| Author (year) | Zirconia generation | Surface pretreat-ment method | Primer | Functional monomers | Resin cement | Functional monomers | Pretest storage | Aging procedure | Bond strength test | Bond strength values | Failure mode analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Krifka et.al 2017[111] | 5Y-TZP | Alumina APA 40 μm at 2 bar pressure | - Scotchbond Universal (3 M ESPE, Sefeld, Germany)<br>- Monobond Plus (Ivoclar Vivadent, Shaan, Liechtenstein) | MDP<br>MDP | RelyX Unicem 2 (3 M ESPE, Sefeld, Germany)<br>RelyX Ultimate (3 M ESPE, Sefeld, Germany)<br>Multilink Automix (Ivoclar Vivadent, Shaan, Liechtenstein) | Phosphoric acid<br>-<br>- | — | 12,000 TC (5°C/55°C) | Shear | 67.6 ± 24 MPa (alumina APA 40 μm at 2 bar pressure + Monobond Plus +Multilink Automix)<br>57.6 ± 11 MPa (alumina APA 40 μm at 2 bar pressure + Scotchbond Universal +RelyX Ultimate)<br>54 ± 17.4 MPa (alumina APA 40 μm at 2 bar pressure + RelyX Unicem 2) | All test specimens experienced mainly adhesive failure modes |
| Kwon et.al 2018[103] | 5Y-TZP | Alumina APA 50 μm at 2 bar pressure | Clearfil Ceramic Primer (Kuraray, Tokyo, Japan) | MDP | Panavia SA (Kuraray, Tokyo, Japan) | MDP | 150-day WS | — | Shear | 25.03 ± 6.44 MPa | NP |
| Yagawa et. al 2018[104] | 5Y-TZP | Without surface pretreat-ment | - Alloy Primer (Kuraray, Tokyo, Japan)<br>- Clearfil Ceramic Primer (Kuraray, Tokyo, Japan)<br>- Meta Fast Bonding Liner (Sun Medical Co., Moriyama, Japan)<br>- MR. bond (Tokuyama Dental Corp., Tokyo, Japan)<br>Super-Bond PZ Primer (Sun Medical Co., Moriyama, Japan)<br>V-Primer (Sun Medical Co., Moriyama, Japan) | MDP<br>MDP<br>—<br>—<br>—<br>— | - Panavia V5 Universal (Kuraray, Tokyo, Japan)<br>- Panavia V5 Opaque (Kuraray, Tokyo, Japan) | —<br>— | 1-day WS | 5000 TC (5°C/55°C) | Shear | 42.3 ± 4.1 MPa (without surface pretreatment + Clearfil Ceramic Primer Plus +Panavia V5 Universal)<br>41.5 ± 3.7 MPa (without surface pretreatment + Alloy Primer + Panavia V5 Universal)<br>36.5 ± 2.7 MPa (without surface pretreatment +Clearfil Ceramic Primer Plus +Panavia V5 Opaque)<br>32.4 ± 2.2 MPa (without surface pretreatment + Alloy Primer + Panavia V5 Opaque)<br>14.9 ± 3.9 MPa (without surface pretreatment Meta Fast Bonding Liner + Panavia V5 Universal)<br>10.9 ± 3.4 MPa (without surface pretreatment + Meta Fast Bonding Liner + Panavia V5 Opaque)<br>0.6 ± 0.3 MPa (without surface pretreatment+MR. bond+Panavia V5 Opaque)<br>0.6 ± 0.2 MPa (without surface pretreatment+ Super-Bond PZ Primer+Panavia V5 Universal)<br>0.5 ± 0.2 MPa (without surface pretreatment+MR. bond+Panavia V5 Universal)<br>0.4 ± 0.2 MPa (without surface pretreatment +Super-Bond PZ Primer+Panavia V5 Opaque)<br>0.2 ± 0.1 MPa (without surface pretreatment+V-Primer+Panavia V5 Opaque) | *Without surface pretreatment + Clearfil Ceramic Primer Plus + Panavia V5 Universal*<br>- Mainly adhesive<br>- Few mixed<br>*Without surface pretreatment+Alloy Primer+Panavia V5 Universal*<br>- Mainly adhesive<br>- Few mixed<br>*Without surface pretreatment+Clearfil Ceramic Primer Plus + Panavia V5 Opaque*<br>- Mainly adhesive<br>- Few mixed<br>*Without surface pretreatment + Alloy Primer + Panavia V5 Opaque*<br>- Mainly adhesive<br>- Few mixed<br>*Without surface pretreatment + Meta Fast Bonding Liner + Panavia V5 Universal*<br>Adhesive<br>*Without surface pretreatment + Meta Fast Bonding Liner+ Panavia V5 Opaque*<br>Adhesive<br>*Without surface pretreatment+MR. bond + Panavia V5 Opaque*<br>Adhesive<br>*Without surface pretreatment + Super-Bond PZ Primer + Panavia V5 Universal*<br>Adhesive<br>*Without surface pretreatment + MR. bond + Panavia V5 Universal*<br>Adhesive<br>*Without surface pretreatment + Super-Bond PZ Primer + Panavia V5 Opaque*<br>Adhesive |

(Continues)

**TABLE 2** (Continued)

| Author (year) | Zirconia generation | Surface pretreat-ment method | Primer | Functional monomers | Resin cement | Functional monomers | Pretest storage | Aging procedure | Bond strength test | Bond strength values | Failure mode analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 0.2 ± 0.1 MPa<br>(without surface pretreatment+V-Primer+Panavia V5 Universal)<br>0.2 ± 0.1 MPa<br>(without surface pretreatment +Panavia V5 Universal)<br>0.1 ± 0.1 MPa<br>(without surface pretreatment +Panavia V5 Opaque) | *Without surface pretreatment + V-Primer + Panavia V5 Opaque*<br>Adhesive<br>*Without surface pretreatment + V-Primer + Panavia V5 Universal*<br>Adhesive<br>*Without surface pretreatment + Panavia V5 Universal*<br>Adhesive<br>*Without surface pretreatment + Panavia V5 Opaque*<br>Adhesive |
| Sharafeddin et.al 2018[86] | 5Y-TZP | Alumina APA 50 μm at 2 bar pressure | - All Bond Universal (Bisco, Schaumburg, USA)<br>- Z-Prime Plus (Bisco, Schaumburg, USA) | MDP<br>MDP | Variolink N (Ivoclar Vivadent, Shaan, Liechtenstein) | — | 1-day WS | — | Shear | 22.45 ± 3.60 MPa<br>(alumina APA 50 μm at 2 bar pressure + Z-Prime Plus + Variolink N)<br>17.51 ± 1.34 MPa<br>(alumina APA 50 μm at 2 bar pressure + All Bond Universal + Variolink N)<br>7.57 ± 1.62 MPa<br>(alumina APA 50 μm at 2 bar pressure + Variolink N) | *Alumina APA 50 μm at 2 bar pressure ± Z-Prime Plus + Variolink N*<br>- Mostly adhesive<br>- Some mixed<br>*Alumina APA 50 μm at 2 bar pressure ± All Bond Universal + Variolink N*<br>- Half of the specimens adhesive<br>- Half of the specimens mixed<br>*Alumina APA 50 μm at 2 bar pressure ± Variolink N*<br>Adhesive |
| Shimizu et. al 2018[98] | 5Y-TZP | - Without surface pretreatment<br>- Alumina APA 50 μm at 2 bar pressure<br>- Plasma treatment | Super-Bond PZ Primer (Sun Medical Co., Moriyama, Japan) | MDP | Super-Bond (Sun Medical Co., Moriyama, Japan) | 4-META | 1-day WS | 10,000 TC (5°C/55°C) | Tensile | 36.7 MPa<br>(without surface pretreatment + Super-Bond PZ Primer + Super-Bond)<br>35.5 MPa<br>(alumina APA 50 μm at 2 bar pressure + Super-Bond)<br>32.6 MPa<br>(Plasma treatment + Super-Bond PZ Primer + Super-Bond)<br>28.4 MPa<br>(alumina APA 50 μm at 2 bar pressure + Super-Bond PZ Primer + Super-Bond)<br>11.1 MPa<br>(without surface pretreatment + Super-Bond)<br>4.3 MPa<br>(Plasma treatment + Super-Bond) | *Without surface pretreatment + Super-Bond PZ Primer + Super-Bond*<br>- Mainly cohesive and mixed<br>- Few adhesive<br>*Alumina APA 50 μm at 2 bar pressure ± Super-Bond*<br>- Mainly cohesive and mixed<br>- Few adhesive<br>*Plasma treatment + Super-Bond PZ Primer + Super-Bond*<br>- Mainly cohesive and mixed<br>*Alumina APA 50 μm at 2 bar pressure ± Super-Bond PZ Primer + Super-Bond*<br>- Mainly cohesive and mixed<br>- Few adhesive<br>*Without surface pretreatment + Super-Bond*<br>- Mainly adhesive<br>- Few cohesive and mixed<br>*Plasma treatment + Super-Bond*<br>- Mainly adhesive<br>- Few cohesive and mixed |
| Agren et.al 2019[105] | 5Y-TZP | Alumina APA 110 μm at 3.5 bar pressure<br>Lithium disilicate glass–ceramic coat | Monobond Plus (Ivoclar Vivadent, Shaan, Liechtenstein) | MDP | Variolink Esthetic (Ivoclar Vivadent, Shaan, Liechtenstein) | — | 1-day WS | — | Shear | 21.60 ± 7.32 MPa<br>(alumina APA 110 μm at 3.5 bar pressure + Variolink Esthetic)<br>16.56 ± 11.09 MPa<br>(Lithium disilicate glass–ceramic coat + Variolink Esthetic) | *Alumina APA 110 μm at 3.5 bar pressure ± Variolink Esthetic*<br>Adhesive<br>*Lithium disilicate glass–ceramic coat + Variolink Esthetic*<br>Adhesive |

**TABLE 2** (Continued)

| Author (year) | Zirconia generation | Surface pretreatment method | Primer | Functional monomers | Resin cement | Functional monomers | Pretest storage | Aging procedure | Bond strength test | Bond strength values | Failure mode analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Franco-Tabares et.al 2019[97] | 4Y-TZP<br>5Y-TZP | Alumina APA 50 μm at 1 bar pressure | — | — | Panavia F 2.0 (Kuraray, Tokyo, Japan) | MDP | — | TC | Shear | 5.99 ± 1.20 MPa (4Y-TZP)<br>5.13 ± 1.21 MPa (5Y-TZP) | NP |
| Ruales-Carrera et.al 2019[106] | 5Y-TZP | Without surface pretreatment<br>Alumina APA 50 μm at 2.5 bar pressure<br>TBS | Single Bond Universal (3 M ESPE, Sefeld, Germany) | MDP | RelyX Ultimate (3 M ESPE, Sefeld, Germany) | — | 1-day WS | 10,000 TC (5°C/55°C) | Micro-tensile | 15.18 ± 4.04 MPa (alumina APA 50 μm at 2.5 bar pressure + Single Bond Universal + RelyX Ultimate)<br>11.35 ± 3.88 MPa (TBS + Single Bond Universal + RelyX Ultimate)<br>3.38 ± 2.10 MPa (Without surface pretreatment + Single Bond Universal + RelyX Ultimate) | *Alumina APA 50 μm at 2.5 bar pressure ± Single Bond Universal + RelyX Ultimate*<br>Mixed<br>*TBS + Single Bond Universal + RelyX Ultimate*<br>- Mainly mixed<br>- Few adhesive<br>*Without surface pretreatment + Single Bond Universal + RelyX Ultimate*<br>- Mainly adhesive<br>- Few mixed |
| Zhao et.al 2019[107] | 5Y-TZP | Without surface pretreatment<br>Alumina APA 50 μm at 1 bar pressure for 10 s<br>Alumina APA 50 μm at 1 bar pressure for 20<br>Alumina APA 50 μm at 3 bar pressure for 10 s<br>Alumina APA 50 μm at 3 bar pressure for 20 s<br>- Alumina APA 50 μm at 6 bar pressure for 10 s<br>- Alumina APA 50 μm at 6 bar pressure for 20 s<br>- Alumina APA 110 μm at 1 bar pressure for 10 s<br>- Alumina APA 110 μm at 1 bar pressure for 20 s<br>- Alumina APA 110 μm at 3 bar pressure for 10 s<br>- Alumina APA 110 μm at 3 bar pressure for 20 s<br>- Alumina APA 110 μm at 6 bar pressure for 10 s<br>- Alumina APA 110 μm at 6 bar pressure for 20 s | — | — | RelyX U200 (3 M ESPE, Sefeld, Germany) | Phosphoric acid | 1-day WS | — | Shear | 18.27 ± 3.50 MPa (alumina APA 110 μm at 3 bar pressure for 20 s + RelyX U200)<br>12.42 ± 3.32 MPa (alumina APA 110 μm at 6 bar pressure for 20 s + RelyX U200)<br>11.24 ± 1.99 MPa (alumina APA 110 μm at 3 bar pressure for 10 s + RelyX U200)<br>10.96 ± 3.26 MPa (alumina APA 50 μm at 1 bar pressure for 20 s + RelyX U200)<br>9.88 ± 2.36 MPa (alumina APA 50 μm at 3 bar pressure for 10 s + RelyX U200)<br>9.80 ± 3.13 MPa (alumina APA 110 μm at 1 bar pressure for 10 s + RelyX U200)<br>9.53 ± 2.97 MPa (alumina APA 110 μm at 1 bar pressure for 20 s + RelyX U200)<br>8.70 ± 3.42 MPa (alumina APA 50 μm at 6 bar pressure for 20 s + RelyX U200)<br>8.41 ± 1.98 MPa (alumina APA 50 μm at 1 bar pressure for 10 s + RelyX U200)<br>7.34 ± 2.64 MPa (alumina APA 50 μm at 3 bar pressure for 10 s + RelyX U200)<br>6.86 ± 2.46 MPa (alumina APA 110 μm at 6 bar pressure for 10 s + RelyX U200)<br>5.98 ± 2.95 MPa (alumina APA 50 μm at 3 bar pressure for 20 s + RelyX U200)<br>0.97 ± 0.92 MPa (without surface pretreatment + RelyX U200) | *Alumina APA 110 μm at 3 bar pressure for 20 s ± RelyX U200*<br>- Mainly adhesive<br>- Some mixed<br>*Alumina APA 110 μm at 6 bar pressure for 20 s ± RelyX U200*<br>- Mainly adhesive<br>- Few mixed<br>*Alumina APA 110 μm at 3 bar pressure for 10 s ± RelyX U200*<br>- Mainly mixed<br>- Few adhesive<br>*Alumina APA 50 μm at 1 bar pressure for 20 s ± RelyX U200*<br>- Mainly mixed<br>- Few adhesive<br>- Few cohesive<br>*Alumina APA 50 μm at 3 bar pressure for 10 s ± RelyX U200*<br>- Mainly mixed<br>- Few adhesive<br>- Few cohesive<br>*Alumina APA 110 μm at 1 bar pressure for 10 s ± RelyX U200*<br>- Half mixed<br>- Half adhesive<br>*Alumina APA 110 μm at 1 bar pressure for 20 s ± RelyX U200*<br>- Mainly mixed<br>- Few adhesive<br>*Alumina APA 50 μm at 6 bar pressure for 20 s ± RelyX U200*<br>- Mainly mixed<br>- Some adhesive<br>*Alumina APA 50 μm at 1 bar pressure for 10 s ± RelyX U200*<br>Mainly adhesive<br>*Alumina APA 50 μm at 3 bar pressure for 10 s ± RelyX U200* |

(Continues)

**TABLE 2** (Continued)

| Author (year) | Zirconia generation | Surface pretreatment method | Primer | Functional monomers | Resin cement | Functional monomers | Pretest storage | Aging procedure | Bond strength test | Bond strength values | Failure mode analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | - Mainly mixed<br>- Few adhesive<br>- Few cohesive<br>*Alumina APA 110 μm at 6 bar pressure for 10 s ± RelyX U200*<br>- Mainly adhesive<br>- Few mixed<br>*Alumina APA 50 μm at 3 bar pressure for 20 sec ± RelyX U200*<br>- Half mixed<br>- Half adhesive<br>*Without surface pretreatment + RelyX U200*<br>Mainly Adhesive |
| Chen et.al 2020[99] | 5Y-TZP | Alumina APA 50 μm at 2.5 bar pressure<br>TBS | Monobond N (Ivoclar Vivadent, Shaan, Liechtenstein) | Phosphoric acid | Variolink N (Ivoclar Vivadent, Shaan, Liechtenstein)<br>Multilink Speed (Ivoclar Vivadent, Shaan, Liechtenstein) | -<br>MDP | 60-day WS | 10,000 TC (5°C/55°C) | Shear | 14.4 ± 1.5 MPa<br>(TBS + Monobond N + Variolink N)<br>13.2 ± 1.5 MPa<br>(alumina APA 50 μm at 2 bar pressure + Multilink Speed) | All tested specimens experienced mainly mixed and few adhesive failure modes |
| De Angelis et.al 2020[108] | 5Y-TZP | Alumina APA 50 μm at 2 bar pressure | Clearfil Ceramic Primer Plus (Kuraray, Tokyo, Japan) | MDP | Panavia V5 (Kuraray, Tokyo, Japan)<br>Panavia SA (Kuraray, Tokyo, Japan)<br>RelyX Unicem 2 Clicker (3 M ESPE, Sefeld, Germany) | -<br>MDP<br>Phosphoric acid | 1-day WS | 5000 TC (5°C/55°C) | Shear | 21.1 ± 3 MPa<br>(alumina APA 50 μm at 2 bar pressure + Clearfil Ceramic Primer Plus+Panavia V5)<br>20.3 ± 1.7 MPa<br>(alumina APA 50 μm at 2 bar pressure + Panavia SA)<br>6.1 ± 2.4 MPa<br>(alumina APA 50 μm at 2 bar pressure + RelyX Unicem 2 Clicker) | *Alumina APA 50 μm at 2 bar pressure ± Clearfil Ceramic Primer Plus + Panavia V5*<br>- Mainly mixed<br>- Few adhesive<br>*Alumina APA 50 μm at 2 bar pressure ± Panavia SA*<br>- Mainly mixed<br>- Some adhesive<br>*Alumina APA 50 μm at 2 bar pressure ± RelyX Unicem 2 Clicker*<br>- Mainly adhesive<br>- Few mixed |
| Franco-Tabares et.al 2020[95] | 4 Y-TZP<br>5Y-TZP | Without surface pretreatment | - | - | Panavia F 2.0 (Kuraray, Tokyo, Japan) | MDP | 1-day WS | - | Shear | 6.01 ± 1.2 MPa<br>(5Y-TZP)<br>4.81 ± 1.2 MPa<br>(4Y-TZP) | NP |
| Mehari et.al 2020[96] | 4Y-TZP<br>5Y-TZP | Without surface pretreatment<br>Alumina APA 50 μm at 2 bar pressure<br>80 μm glass-bead APA | Z-Prime Plus (Bisco, Schaumburg, USA) | MDP | NX3 (Kerr, Rastatt, Germany) | — | 1-day WS | 2500 TC (5° C/55° C) | Shear | 12.9 ± 3.4 MPa<br>(5Y-TZP + alumina APA 50 μm at 2 bar pressure + Z-Prime Plus +NX3)<br>11.8 ± 4.1 MPa<br>(4Y-TZP + alumina APA 50 μm at 2 bar pressure + Z-Prime Plus +NX3)<br>6.4 ± 1.4 MPa<br>(5Y-TZP + without surface pretreatment + Z-Prime Plus + NX3)<br>5.6 ± 1.1 MPa<br>(5Y-TZP + 80 μm glass-bead APA + Z-Prime Plus + NX3)<br>5.1 ± 1.3 MPa | All tested specimens experienced mainly adhesive and some mixed failure modes |

**TABLE 2** (Continued)

| Author (year) | Zirconia generation | Surface pretreat-ment method | Primer | Functional monomers | Resin cement | Functional monomers | Pretest storage | Aging procedure | Bond strength test | Bond strength values | Failure mode analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (4Y-TZP + without surface pretreatment + Z-Prime Plus + NX3)<br>4.8 ± 1 MPa<br>(4Y-TZP + 80 μm glass-bead APA + Z-Prime Plus + NX3) | |
| Monteiro et. al 2020[100] | 5Y-TZP | Without surface pretreatment<br>Alumina APA 50 μm at 2 bar pressure<br>TBS | Scotchbond Universal (3 M ESPE, Sefeld, Germany) | MDP | RelyX Ultimate (3 M ESPE, Sefeld, Germany) | — | 1-day WS | 10,000 TC (5° C/55° C) + 240,000 MC (50 N) | Pull-out | 4 ± 1.2 MPa<br>(alumina APA 50 μm at 2 bar pressure + Schotchbond Universal+RelyX Ultimate)<br>4 ± 1.2 MPa<br>(TBS+ Scotchbond Universal+RelyX Ultimate)<br>0.8 ± 0.3 MPa<br>(Without surface pretreatment+ Scotchbond Universal+ RelyX Ultimate) | *Alumina APA 50 μm at 2 bar pressure ± Schotchbond Universal+RelyX Ultimate*<br>- Some adhesive<br>- Few mixed<br>- Few cohesive<br>*TBS+ Scotchbond Universal + RelyX Ultimate*<br>- Mainly adhesive<br>- Some mixed<br>*Without surface pretreatment + Scotchbond Universal + RelyX Ultimate*<br>Mainly adhesive |
| Sakrana et. al 2020[101] | 5Y-TZP | Alumina APA 50 μm at 2 bar pressure<br>Alumina APA 50 μm at 2 bar pressure + Silane flame treatment<br>Alumina APA 50 μm at 2 bar pressure + Piranha acid etch<br>Alumina APA 50 μm at 2 bar pressure + Piranha acid etch + Silane flame treatment<br>- Alumina APA 50 μm at 2 bar pressure + hot etching<br>- Alumina APA 50 μm at 2 bar pressure + hot etching + Silane flame treatment | — | — | - Panavia SA Plus (Kuraray, Tokyo, Japan)<br>- TheraCem (Bisco, Schaumburg, USA)<br>- Panavia F2.0 (Kuraray, Tokyo, Japan) | MDP<br>MDP<br>MDP | 1-day WS | 10,000 TC (5° C/55° C) | Micro-tensile | 25.1 ± 4.6 MPa<br>(alumina APA 50 μm at 2 bar pressure + hot etching + Panavia SA)<br>23.2 ± 4.6 MPa<br>(alumina APA 50 μm at 2 bar pressure + hot etching + Silane flame treatment + Panavia F2.0)<br>23.1 ± 5.1 MPa<br>(alumina APA 50 μm at 2 bar pressure + Piranha acid etch + Panavia SA)<br>23 ± 3 MPa<br>(alumina APA 50 μm at 2 bar pressure hot etching + Silane flame treatment + Panavia SA)<br>22.2 ± 6.9 MPa<br>(alumina APA 50 μm at 2 bar pressure + hot etching + Panavia F2.0)<br>21.5 ± 7.3 MPa<br>(alumina APA 50 μm at 2 bar pressure + Panavia SA)<br>20.8 ± 5.5 MPa<br>(alumina APA 50 μm at 2 bar pressure + hot etching + Silane flame treatment + TheraCem)<br>20.6 ± 2.5 MPa<br>(alumina APA 50 μm at 2 bar pressure + Panavia F2.0)<br>20.2 ± 4.2 MPa<br>(alumina APA 50 μm at 2 bar pressure + Silane flame treatment + Panavia SA)<br>19.7 ± 7.1 MPa | All test specimens experienced predominately adhesive and few cohesive failure modes |

(Continues)

**TABLE 2** (Continued)

| Author (year) | Zirconia generation | Surface pretreat-ment method | Primer | Functional monomers | Resin cement | Functional monomers | Pretest storage | Aging procedure | Bond strength test | Bond strength values | Failure mode analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (alumina APA 50 μm at 2 bar pressure + Piranha acid etch + Silane flame treatment + TheraCem)<br>17.5 ± 8.8 MPa<br>(alumina APA 50 μm at 2 bar pressure + hot etching + TheraCem)<br>17.4 ± 3.4 MPa<br>(alumina APA 50 μm at 2 bar pressure + Piranha acid etch + Silane flame treatment + Panavia F2.0)<br>15.4 ± 1.8 MPa<br>(alumina APA 50 μm at 2 bar pressure + TheraCem)<br>13 ± 4.3 MPa<br>(alumina APA 50 μm at 2 bar pressure + Piranha acid etch + Silane flame treatment + Panavia SA)<br>11.4 ± 3.8 MPa<br>(alumina APA 50 μm at 2 bar pressure + Piranha acid etch + TheraCem)<br>10.6 ± 4.1 MPa<br>(alumina APA 50 μm at 2 bar pressure + Silane flame treatment + TheraCem)<br>10.1 ± 4.3 MPa<br>(alumina APA 50 μm at 2 bar pressure + Silane flame treatment + Panavia F2.0)<br>5.7 ± 0.8 MPa<br>(alumina APA 50 μm at 2 bar pressure + Panavia F2.0) | |
| Yoshida et. al 2020[102] | 5Y-TZP | Without surface pretreatment<br>Alumina APA 50 μm at 2 bar pressure<br>Alumina APA 50 μm at 2 bar pressure + HT1h | — | — | G-CEM ONE (GC Corp, Tokyo, Japan) | MDP | 1-day WS | 20,000 TC (4°C/60°C) | Tensile | 29.2 ± 2.5 MPa<br>(alumina APA 50 μm at 2 bar pressure + G-CEM ONE)<br>9.1 ± 1.8 MPa<br>(without surface pretreatment + G-CEM ONE)<br>8.1 ± 0.8 MPa<br>(alumina APA 50 μm at 2 bar pressure + HT1h + G-CEM ONE) | *Alumina APA 50 μm at 2 bar pressure ± G-CEM ONE*<br>Cohesive<br>*Without surface pretreatment + G-CEM ONE*<br>Adhesive<br>*Alumina APA 50 μm at 2 bar pressure ± HT1h ± G-CEM ONE*<br>Adhesive |
| Zhang et.al 2020[109] | 5Y-TZP | Without surface pretreatment<br>Alumina APA 50 μm at 1 bar pressure<br>Alumina APA 50 μm at 2 bar pressure<br>Alumina APA 50 μm at 3 bar pressure<br>Alumina APA 50 μm at 4 bar pressure<br>Alumina APA 50 μm at 5 bar pressure | Z-Prime Plus (Bisco, Schaumburg, USA) | MDP | Duolink (Bisco, Schaumburg, USA) | — | 1-day WS | 5000 TC (5°C/55°C) | Shear | 14.5 MPa<br>(alumina APA 50 μm at 2 bar pressure + Z-Prime Plus+Duolink)<br>14 MPa<br>(alumina APA 50 μm at 3 bar pressure + Z-Prime Plus+Duolink)<br>10.9 MPa<br>(alumina APA 50 μm at 4 bar pressure + Z-Prime Plus + Duolink)<br>10,1 MPa | *Alumina APA 50 μm at 2 bar pressure ± Z-Prime Plus + Duolink*<br>- Mainly adhesive<br>- Few mixed<br>*Alumina APA 50 μm at 3 bar pressure ± Z-Prime Plus + Duolink*<br>- Mainly adhesive<br>- Few mixed<br>*Alumina APA 50 μm at 4 bar pressure ± Z-Prime Plus + Duolink*<br>- Mainly adhesive |

**TABLE 2** (Continued)

| Author (year) | Zirconia generation | Surface pretreatment method | Primer | Functional monomers | Resin cement | Functional monomers | Pretest storage | Aging procedure | Bond strength test | Bond strength values | Failure mode analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (alumina APA 50 µm at 1 bar pressure + Z-Prime Plus + Duolink)<br>9 MPa<br>(alumina APA 50 µm at 5 bar pressure + Z-Prime Plus + Duolink)<br>3.4 MPa<br>(without surface pretreatment + Z-Prime Plus + Duolink) | - Few mixed<br>*Alumina APA 50 µm at 1 bar pressure ± Z-Prime Plus + Duolink*<br>- Mainly adhesive<br>- Few mixed<br>*Alumina APA 50 µm at 5 bar pressure ± Z-Prime Plus + Duolink*<br>Adhesive<br>*Without surface pretreatment + Z-Prime Plus + Duolink*<br>Adhesive |
| Khanlar et.al 2020[110] | 5Y-TZP | Alumina APA 50 µm at 2 bar pressure | - Super-Bond PZ Primer (Sun Medical Co., Moriyama, Japan)<br>- Super-Bond PZ Primer + MMA (Sun Medical Co., Moriyama, Japan)<br>- Super-Bond monomer (Sun Medical Co., Moriyama, Japan)<br>- 4-MET experimental Primer (Sun Medical Co., Moriyama, Japan) | MDP<br>MDP<br>4-META<br>4-META | Super-Bond powder and Catalyst (Sun Medical Co., Moriyama, Japan) | — | 150-day WS | — | Tensile | 14.6 MPa<br>(alumina APA 50 µm at 2 bar pressure + experimental 4-MET Primer + Super-Bond powder and Catalyst)<br>14.4 MPa<br>(alumina APA 50 µm at 2 bar pressure + Super-Bond PZ Primer + MMA + Super-Bond powder and Catalyst)<br>10.8 MPa<br>(alumina APA 50 µm at 2 bar pressure + Super-Bond monomer + Super-Bond powder and Catalyst)<br>10 MPa<br>(alumina APA 50 µm at 2 bar pressure + PZ Primer + Super-Bond powder and Catalyst)<br>6.8 MPa<br>(alumina APA 50 µm at 2 bar pressure + Super-Bond powder and Catalyst) | *Alumina APA 50 µm at 2 bar pressure ± experimental 4-MET Primer + Super-Bond powder and Catalyst*<br>- Mainly cohesive<br>- Few adhesive<br>*Alumina APA 50 µm at 2 bar pressure ± Super-Bond PZ Primer + MMA ± Super-Bond powder and Catalyst*<br>Cohesive<br>*Alumina APA 50 µm at 2 bar pressure ± Super-Bond Monomer + Super-Bond powder and Catalyst*<br>- Mainly cohesive<br>- Few mixed<br>*Alumina APA 50 µm at 2 bar pressure ± Super-Bond PZ Primer + Super-Bond powder and Catalyst*<br>Cohesive<br>*Alumina APA 50 µm at 2 bar pressure ± Super-Bond powder and Catalyst*<br>- Mainly cohesive<br>- Few mixed<br>- Few adhesive |

TABLE 3 Risk of bias assessment

| Domain<br>Study | Selection bias<br>Random sequence generation | <br>Allocation concealment | Performance bias<br>Blinding participants and personal | <br>Blinding outcome assessment | Attrition bias<br>Incomplete outcome data | Reporting bias<br>Selective reporting | Other bias<br>Other resources of bias |
|---|---|---|---|---|---|---|---|
| Krifka et.al 2017[111] | Unclear | NA | NA | High | Low | Low | Low |
| Kwon et.al 2018[103] | High | NA | NA | High | High | Low | Low |
| Yagawa et.al 2018[104] | Low | NA | NA | High | Low | Low | Low |
| Sharafeddin et.al 2018[86] | Unclear | NA | NA | High | Low | Low | Low |
| Shimizu et.al 2018[98] | Unclear | NA | NA | High | Low | Unclear | Low |
| Agren et.al 2019[105] | Unclear | NA | NA | High | Low | Low | Low |
| Franco-Tabares et.al 2019[97] | High | NA | NA | High | High | Low | Low |
| Ruales-Carrera et.al 2019[106] | Low | NA | NA | High | Low | Low | Low |
| Zhao et.al 2019[107] | Low | NA | NA | High | Low | Low | Low |
| Chen et.al 2020[99] | Unclear | NA | NA | High | Low | Low | High |
| De Angelis et.al 2020[108] | Low | NA | NA | High | Low | Low | Low |
| Franco-Tabares et.al 2020[95] | High | NA | NA | High | High | Low | Low |
| Mehari et.al 2020[96] | Unclear | NA | NA | High | Low | Low | Low |
| Monteiro et.al 2020[100] | Unclear | NA | NA | High | Low | Low | Unclear |
| Sakrana et.al 2020[101] | Unclear | NA | NA | High | Low | Low | Low |
| Yoshida et.al 2020[102] | Low | NA | NA | High | Low | Low | Low |
| Zhang et.al 2020[109] | Low | NA | NA | High | Low | Low | Low |
| Khanlar et.al 2020[110] | Unclear | NA | NA | High | Low | Low | High |

Abbreviations: 4-META, 4-methacryloyloxyethyl trimellitic acid; 4Y-TZP, 4 mol% yttria-stabilized tetragonal zirconia; 5Y-TZP, 5 mol% yttria-stabilized tetragonal zirconia; APA, airborne-particle abrasion; HT, hot treatment; MC, mechanical loading; MDP, methacryloyloxydecyl dihydrogen phosphate; MMA, methyl methacrylate; NP, not performed; TBS, tribochemical silica air-borne-particle abrasion; TC, thermocycling; WS, water storage.

ceramics,[103,114] thereby increasing their potential use as esthetic monolithic restorations.[115] Establishing a durable resin-bond to these new zirconia generations is crucial for their long-term clinical success. This systematic review aimed to review all in vitro studies investigated the durability of different bonding protocols applied in new zirconia generations. A meta-analysis was not performed due to the heterogeneity of the extracted data in terms of study design, surface pretreatment methods, resin cements, aging procedures utilized, laboratory tests, and the size of the sample. Therefore, a summary of the identified studies was made.

## 4.1 | Bonding to 4Y-TZP

APA surface pretreatment was tested in two of the identified studies.[96,97] It cleans the zirconia surface, removes impurities, increases surface roughness, and modifies the surface energy and wettability.[116] The effect of APA on the flexural strength of 3Y-TZP seems inconclusive as some studies report strengthening while others find a weakening effect.[117–120] These conflicting results may be due to the diverse testing protocols and variations in particle type, size, and pressure. However, results from a meta-analysis showed that APA does actually strengthen 3Y-TZP, independent of particle size and air pressure.[121] Included studies showed that APA in combination with an MDP monomer-based primer or resin cement resulted in durable resin-zirconia bonds. Bond strength values achieved with alumina APA were over twice as high than with other treatment methods (glass-bead APA) or no surface pretreatment (Table 2). Glass beads are typically used for APA of enamel, dentin, nickel-chromium alloys, and CAD/CAM composite materials.[122–124] The particles are softer and may have less adverse effects on the mechanical properties of zirconia than alumina APA. However, bond strengths were similar to glass-bead-APA and nontreated zirconia surfaces. Additionally, failure mode analyses showed more mixed failures associated with alumina than glass-bead APA.[96]

Nontreated zirconia surfaces showed reduced bond strength values and more adhesive failure modes compared to other surface pretreatment methods (Table 2).[96] Therefore, APA with alumina particles is essential for durable resin bonds to 4Y-TZP, even when functional monomer-based primers and resin cements are used.[125,126]

Further in vitro investigations are required to test the effects of various sizes of alumina and glass-bead particles, different levels of air pressure, other surface pretreatment methods, primers, and resin cements when bonding to 4Y-TZP.

## 4.2 | Bonding to 5Y-TZP

APA with alumina was the most widely tested surface treatment in the identified studies (Table 2). Most of these focused on the effects of APA[96–100,103,105,106,111] and found them to improve resin bonds to 5Y-TZP zirconia. Failure modes were either mixed or cohesive (Table 2), indicating strong resin bonds. Focused ion beam (FIB) microscopy showed that alumina APA, followed by MDP monomer-based primers, is necessary to optimize the adhesive bond interface between resin cements and zirconia.[32] Resin cements and primers containing functional monomers such as MDP, other phosphate monomers, mixture of organophosphate and carboxylic monomers, and 4-methacryloxyethyl tri-mellitic anhydride (4-META) provide chemical bonds to pretreated 3Y-TZP surfaces.[127,128] Outcomes of different types of functional monomer-based primers and resin cements to APA 5Y-TZP are inconsistent (Table 2). De Angelis and coworkers[108] found that MDP monomer-based primers and resin cements performed significantly better than phosphate monomer-based resin cements. Failure modes obtained with a phosphate monomer-based resin cement (RelyX Unicem 2 Clicker, 3 M ESPE, Seefeld, Germany) were mainly adhesive (Table 2). Conversely, Khanlar and coworkers[110] and Shimizu and coworkers[98] found no significant difference between MDP and 4-META. Both types of functional monomers achieved comparable bond strengths to 5Y-TZP, and failure modes were mainly cohesive (Table 2).

Several alumina APA parameters influence the resin bond to zirconia, including particle size, air pressure, timing of abrasion, angle of abrasion, and the distance.[116,129,130] The effect of particle size and air pressure on the 5Y-TZP zirconia-resin bond was investigated in two of the identified studies.[107,109] Zhang and coworkers stated that APA with 50 μm alumina particles at 2 bar pressure is recommended for establishing durable resin bonds. This protocol did not achieve sufficient surface roughness in another study.[107] The authors found that an increase in particle size up to 110 μm and air pressure up to 3 bar provided a significant increase in bond strength (Table 2). Furthermore, the increase in particle size and air pressure did not induce tetragonal-monoclinic phase transformation. No decrease in flexural strength of the tested 5Y-TZP zirconia was observed.

Conventional 3Y-TZP zirconia undergoes transformation toughening, a tetragonal-monoclinic phase transformation that limits crack propagation.[48,70,131] New zirconia generations with higher yttria content do not undergo transformation toughening, one of the reasons that limit their mechanical strength.[132] However, the cited study did not include sufficient aging protocols, a clear limitation that negates any comment on bond durability over time (Table 2).[107]

Additional heat treatment of air-abraded 5Y-TZP zirconia surfaces was investigated in one study (Table 2). This additional treatment could recover any possible flexural strength reduction of the tested zirconia specimens after APA.[102] However, a significant reduction in bond strength compared to the APA-only group was observed. Failure modes were mainly adhesive (Table 2). More specifically, APA created a conducive surface for durable bond strengths with an MDP-based resin cement. The significant reduction in bond strength after heat treatment suggests a decrease in surface roughness.[102] Therefore, alumina APA and MDP-based resin cements provide superior and durable resin bonds to 5Y-TZP.[101] Piranha and hot chemical etching solutions were applied after APA (Table 2). Piranha acid etching solution is a strong oxidizing corrosive agent.[133] It is a combination of hydrogen peroxide and sulfuric acid to remove organic impurities and hydroxylate surfaces.[134,135] Hot chemical etching increases surface roughness and removes the superficial ceramic layer, creating a porous zirconia texture.[136] APA combined with hot etching solution resulted in greater bond strength values than piranha acid etching solution (Table 2). The additional heat treatment after hot acid etching improved the bond between MDP-based resin cements and zirconia. The authors reported that piranha solution hydroxylated and cleaned the zirconia surfaces, but failed to create a sufficiently rough surface.[101] In addition, this method cannot be recommended for use in clinics.[134,137] Furthermore, glass-bead surface pretreatment resulted in a smooth and less retentive zirconia surface than alumina APA.[96]

Plasma surface treatment has been proposed as a chemical–mechanical surface treatment for zirconia bonding.[33] The goal is to increase the surface energy, improve wettability, and remove organic impurities.[138] Specimens that were plasma treated but not chemically activated with an MDP-based primer had significantly lower bond strength, while failure modes were mainly adhesive.[98] Besides plasma surface treatment, TBS has also been proposed for chemical–mechanical surface treatment.[33] It exerts dual functionality by increasing the silica content on the zirconia surface and roughening it, thereby creating a conducive surface for silanization that promotes chemical affinity to resin cements.[50,139–141] Application of an MDP-based primer on TBS-treated zirconia resulted in durable bond strengths[99,100,106] and failure modes were predominantly mixed (Table 2). All MDP primers in the identified studies incorporate silane molecules in their chemical composition (Table 2). Some studies have shown that utilizing a primer that contains both MDP and silane improved the resin-bond to TBS treated zirconia surfaces,[142–144] while others suggested that these primers might reduce bonding to silica-enriched surfaces, due to silanol condensation.[145,146] Moreover, SEM results showed that surface roughness generated by TBS was lower than after alumina APA.[99,100,106] This is due to the inability of the silica-coated particles to be firmly embedded into the zirconia surface.[42,147] Glass–ceramic lithium silicate coating has been also suggested in one of the studies (Table 2). It applies an etchable glass–ceramic coat on the zirconia surface,[105] which had varying results on 3Y-TZP.[139,148–151] Concerns were raised regarding thickness control of that additional layer and its possible implications on restoration fit.[148,152] SEM analyses revealed that the applied primer did not provide micromechanical interlocking to the HF-etched layer, either due its specific composition or the glass–ceramic coating method.[105]

Some studies stated that adhesive system selection is more important than surface treatment.[153,154] However, the latter were found to be essential for durable resin-zirconia bonds in a recent systematic review.[45] The applied surface pretreatment methods changed the morphology of 5Y-TZP zirconia surfaces, created different levels of surface roughness, and improved the bond strength of resin cements to zirconia. Therefore, combined micromechanical and chemical surface treatment is key for strong and durable resin-zirconia bonds.

Further in vitro studies to test various bonding protocols to 5Y-TZP are necessary.

### 4.3 | Laboratory studies

Experimental designs and testing set ups varied greatly between studies. Several testing methods (i.e., shear, tensile, micro-tensile, and pull-out test) were applied to measure and compare bond strength of resin cements to new zirconia generations (Table 2), with the shear-bond strength test being the most common. This might be because its user-friendliness, simple specimen preparation, clear test protocol, and fast results.[155,156] However, shear test has been criticized for the development of nonhomogenous stress distributions along the ceramic interface. Its fracture pattern may cause cohesive failures, leading to inaccurate interpretations of the results[38,157,158] while failing to simulate clinical conditions.[159,160] Tensile tests, on the other hand, provide more homogenous stress distribution. Fracture patterns occur within the adhesive interface, which seems more appropriate for evaluating bond strength values.[158,161] Microtensile tests are claimed to be most suitable method.[162] They offer better distribution of stresses and a more sensitive analysis. However, a major limitation is the demanding and technique sensitive specimen preparation.[127,162–164] Pull-out tests may be the most adequate in terms of stress distribution, but their clinical relevance is not superior to the other tests mentioned.[160,165] They are also technique sensitive and susceptible to additional influencing parameters.[160]

Despite the variety of laboratory tests, their results are limited to the tested bonding protocols.[166] A microscopic analysis of the failure mode type is necessary to understand and properly interpret the obtained bond strength values.[166–168] Another critical aspect is the inclusion of simulated aging parameters to evaluate the effects intraoral conditions in terms of temperature changes in a wet environment. It has long been demonstrated that long-term water storage and especially thermocycling considerably stress bonding interfaces and influence resin-zirconia bond strengths in a significant manner.[169,170] Aging parameters such as water storage duration, temperature, number of thermal cycles, and their dwell times differed among almost all identified studies. To date, there is little consensus about the specific aging parameters. However, a combination of thermal and mechanical load cycling may best simulate intra-oral conditions.[171] The mechanical loading mimics chewing forces while thermocycling subjects the test specimens to sudden changes in temperature, which causes repetitive contraction-expansion stresses to resin cements.[172,173] And lastly, exposure in a wet environment subjects the applied materials to hydrolysis. Table 4 gives a summary of all abbreviated terms.

**TABLE 4** List of abbreviations

| APA | Airborne-particle abrasion |
|---|---|
| CAD/CAM | Computer-aided design/ Computer-aided manufacturing |
| FIB | Focused ion beam |
| HF-etched | Hydrofluoric etched |
| MDP | Methacryloyloxydecyl dihydrogen phosphate |
| PFM | Porcelain-fused-to-metal |
| Rob | Risk of bias |
| SEM | Scanning electron microscope |
| SIE | Selective infiltration etching |
| TBS | Tribochemical silica airborne-particle abrasion |
| Y-TZP | Yttria-stabilized tetragonal zirconia polycrystal |
| 4-META | 4-methacryloxyethyl tri-mellitic anhydride |

The reviewed studies suggest that mechanical surface pretreatment in combination with an MDP monomer or phosphate monomer-based primer or resin cement are recommended for new zirconia generations. However, most of the studies did not use clinically relevant specimen geometries and flat discs or cylinders fail to reproduce actual stresses that occur at the zirconia-tooth interface.[174] There is also little information on the influence of the tested bonding protocols on the flexural strength and other physical properties of new zirconia generations.

Therefore, further studies that include clinically relevant test conditions, new and emerging bonding protocols, and their effect on various material properties are needed. And ultimately, their results must be confirmed in controlled clinical trials.

## 5 | CONCLUSIONS

Within the limitations of this review, the available evidence suggests that:

1. Resin bonding protocols successfully applied to conventional zirconia are also the most successful for high-translucent zirconia.
2. Airborne particle abrasion and special phosphate monomer-containing primers and/or composite resin cements provide long-term durable resin bonds.
3. Further in vitro studies applying clinically relevant geometry test specimens and aging procedures as well as clinical trials are necessary to further support these findings.

### DATA AVAILABILITY STATEMENT

Data sharing is not applicable- the systematic review describes entirely theoretical research

### DISCLOSURE

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

## ORCID

*Markus B. Blatz* https://orcid.org/0000-0001-6341-7047

## REFERENCES

1. Mühlemann S, Lakha T, Jung RE, Hämmerle CH, Benic GI. Prosthetic outcomes and clinical performance of CAD-CAM monolithic zirconia versus porcelain-fused-to-metal implant crowns in the molar region: 1-year results of a RCT. *Clin Oral Implants Res*. 2020;31(9):856-864.
2. Zarone F, Russo S, Sorrentino R. From porcelain-fused-to-metal to zirconia: clinical and experimental considerations. *Dent Mater*. 2011; 27(1):83-96.
3. Nistor L, Gradinaru M, Rica R, et al. Zirconia use in dentistry-manufacturing and properties. *Curr Health Sc J*. 2019;45(1):28.
4. Gautam C, Joyner J, Gautam A, Rao J, Vajtai R. Zirconia based dental ceramics: structure, mechanical properties, biocompatibility and applications. *Dalton Trans*. 2016;45(48):19194-19215.
5. Özkurt Z, Kazazoglu E. Clinical success of zirconia in dental applications. *J Prosthodont*. 2010;19(1):64-68.
6. Larsson C, Wennerberg A. The clinical success of zirconia-based crowns: a systematic review. *Int J Prosthodont*. 2014;27(1):33-43.
7. Kohorst P, Junghanns J, Dittmer MP, Borchers L, Stiesch M. Different CAD/CAM-processing routes for zirconia restorations: influence on fitting accuracy. *Clin Oral Investig*. 2011;15(4):527-536.
8. Hamza TA, Sherif RM. In vitro evaluation of marginal discrepancy of monolithic zirconia restorations fabricated with different CAD-CAM systems. *J Prosthet Dent*. 2017;117(6):762-766.
9. Lohbauer U, Reich S. Antagonist wear of monolithic zirconia crowns after 2 years. *Clin Oral Investig*. 2017;21(4):1165-1172.
10. Passos SP, Torrealba Y, Major P, Linke B, Flores-Mir C, Nychka JA. In vitro wear behavior of zirconia opposing enamel: a systematic review. *J Prosthodont*. 2014;23(8):593-601.
11. Burgess JO. Zirconia: the material, its evolution, and composition. *Compend Contin Educ Dent*. 2018;39(4):4-8.
12. Stawarczyk B, Keul C, Eichberger M, Figge D, Edelhoff D, Lümkemann N. Three generations of zirconia: from veneered to monolithic. Part I. *Quintessence Int*. 2017;48(5):369-380.
13. Chen Y-W, Moussi J, Drury JL, Wataha JC. Zirconia in biomedical applications. *Expert Rev Med Devices*. 2016;13(10):945-963.
14. Denry I, Kelly J. Emerging ceramic-based materials for dentistry. *J Dent Res*. 2014;93(12):1235-1242.
15. Kelly JR, Denry I. Stabilized zirconia as a structural ceramic: an overview. *Dent Mater*. 2008;24(3):289-298.
16. Heuer AH, Lange FF, Swain MV, Evans AG. Transformation toughening: an overview. *J Am Ceram Soc*. 1986;69(3):1-5.
17. Hannink RH, Kelly PM, Muddle BC. Transformation toughening in zirconia-containing ceramics. *J Am Ceram Soc*. 2000;83(3):461-487.
18. Garvie RC, Hannink R, Pascoe R. Ceramic steel? *Springer*. 1990;258: 253-257.
19. Jansen JU, Lümkemann N, Letz I, Pfefferle R, Sener B, Stawarczyk B. Impact of high-speed sintering on translucency, phase content, grain sizes, and flexural strength of 3Y-TZP and 4Y-TZP zirconia materials. *J Prosthet Dent*. 2019;122(4):396-403.
20. Lawson NC, Maharishi A. Strength and translucency of zirconia after high-speed sintering. *J Esthet Dent*. 2020;32(2):219-225.
21. Miyazaki T, Nakamura T, Matsumura H, Ban S, Kobayashi T. Current status of zirconia restoration. *J Prosthodont Res*. 2013;57(4): 236-261.
22. Studart AR, Filser F, Kocher P, Gauckler LJ. In vitro lifetime of dental ceramics under cyclic loading in water. *Biomaterials*. 2007;28(17): 2695-2705.
23. Agustin-Panadero R, Roman-Rodriguez JL, Ferreiroa A, Sola-Ruiz MF, Fons-Font A. Zirconia in fixed prosthesis. A literature review. *J Clin Exp Dent*. 2014;6(1):e66-e73.
24. Sailer I, Balmer M, Jürg H, et al. Comparison of fixed dental prostheses with zirconia and metal frameworks: five-year results of a randomized controlled clinical trial. *Int J Prosthodont*. 2017;30(5): 426-428.
25. Schley JS, Heussen N, Reich S, Fischer J, Haselhuhn K, Wolfart S. Survival probability of zirconia-based fixed dental prostheses up to 5 yr: a systematic review of the literature. *Eur J Oral Sci*. 2010; 118(5):443-450.
26. Güth J-F, Stawarczyk B, Edelhoff D, Liebermann A. Zirconia and its novel compositions: what do clinicians need to know? *Quintessence Int*. 2019;50(7):512-520.
27. Spies BC, Zhang F, Wesemann C, Li M, Rosentritt M. Reliability and aging behavior of three different zirconia grades used for monolithic four-unit fixed dental prostheses. *Dental Mater*. 2020;36(11):e329-e339.
28. Jerman E, Lümkemann N, Eichberger M, et al. Evaluation of translucency, Marten's hardness, biaxial flexural strength and fracture toughness of 3Y-TZP, 4Y-TZP and 5Y-TZP materials. *Dent Mater*. 2021;37(2):212-222.
29. Zhang Y, Lawn B. Novel zirconia materials in dentistry. *J Dent Res*. 2018;97(2):140-147.
30. Souza ROBF, de Araujo GM, Miyashita E, Bottino MA, de Melo RM, Zhang Y. Ultra-thin monolithic zirconia veneers: reality or future? Report of a clinical case and one-year follow-up. *Oper*. 2018;43: 3-11.
31. Komine F, Blatz MB, Matsumura H. Current status of zirconia-based fixed restorations. *J Oral Sci*. 2010;52(4):531-539.
32. Blatz M, Vonderheide M, Conejo J. The effect of resin bonding on long-term success of high-strength ceramics. *J Dent Res*. 2018;97(2): 132-139.
33. Papia E, Larsson C, du Toit M, von Steyern PV. Bonding between oxide ceramics and adhesive cement systems: a systematic review. *J Biomed Mater Res*. 2014;102(2):395-413.
34. Bielen V, Inokoshi M, Munck J, et al. Bonding effectiveness to differently sandblasted dental zirconia. *J Adhes Dent*. 2015;17(3):235-242.
35. Scaminaci Russo D, Cinelli F, Sarti C, Giachetti L. Adhesion to zirconia: a systematic review of current conditioning methods and bonding materials. *J Dent*. 2019;7(3):74.
36. Senyilmaz D, Palin WM, Shortall A, Burke F. The effect of surface preparation and luting agent on bond strength to a zirconium-based ceramic. *Oper*. 2007;32(6):623-630.
37. Kern M, Wegner SM. Bonding to zirconia ceramic: adhesion methods and their durability. *Dent Mater*. 1998;14(1):64-71.
38. Inokoshi M, De Munck J, Minakuchi S, Van Meerbeek B. Meta-analysis of bonding effectiveness to zirconia ceramics. *J Dent Res*. 2014;93(4):329-334.
39. Yang L, Xie H, Meng H, et al. Effects of luting cements and surface conditioning on composite bonding performance to zirconia. *J Adhes Dent*. 2018;20(6):549-558.
40. Aboushelib MN, Matinlinna JP, Salameh Z, Ounsi H. Innovations in bonding to zirconia-based materials: part I. *Dent Mater*. 2008;24(9): 1268-1272.
41. Lehmann F, Kern M. Durability of resin bonding to zirconia ceramic using different primers. *J Adhes Dent*. 2009;11(6):479-483.
42. Kern M. Bonding to oxide ceramics—laboratory testing versus clinical outcome. *Dent Mater*. 2015;31(1):8-14.
43. Wegner SM, Kern M. Long-term resin bond strength to zirconia ceramic. *J Ades Dent*. 2000;2(2):139-146.
44. Blatz MB, Alvarez M, Sawyer K, Brindis M. How to bond zirconia: the APC concept. *Compend Contin Educ Dent*. 2016;37(9):611-618.
45. Alammar A, Att W. Bonding durability between zirconia and different types of tooth or implant abutments-a systematic review. Part I: outcomes of in vitro studies. *Int J Prosthodont*. 2021;34(5): 650-669.

46. Alammar A, Att W. Bonding durability between zirconia and different types of tooth or implant abutments-a systematic review. Part II: outcomes of clinical studies. *Int J Prosthodont*. 2021;
47. McLaren EA, Lawson N, Choi J, Kang J, Trujillo C. New high translucent cubic phase containing zirconia: clinical and laboratory considerations and the effect of air abrasion on strength. *Compend Contin Educ Dent*. 2017;34(6):1-9.
48. Inokoshi M, Shimizu H, Nozaki K, et al. Crystallographic and morphological analysis of sandblasted highly translucent dental zirconia. *Dent Mater*. 2018;34(3):508-518.
49. McInnes MD, Moher D, Thombs BD, et al. Preferred reporting items for a systematic review and meta-analysis of diagnostic test accuracy studies: the PRISMA-DTA statement. *JAMA*. 2018;319(4): 388-396.
50. Aung S, Takagaki T, Lyann SK, et al. Effects of alumina-blasting pressure on the bonding to super/ultra-translucent zirconia. *Dent Mater*. 2019;35(5):730-739.
51. Cadore-Rodrigues AC, Prochnow C, Burgo TAL, et al. Stable resin bonding to Y-TZP ceramic with air abrasion by alumina particles containing 7% silica. *J Adhes Dent*. 2020;22(2):149-159.
52. Elsayed A, Meyer G, Wille S, Kern M. Influence of the yttrium content on the fracture strength of monolithic zirconia crowns after artificial aging. *Quintessence Int*. 2019;50(5):344-348.
53. Aboushelib MN, Ragab H, Arnaot M. Ultrastructural analysis and long-term evaluation of composite zirconia bond strength. *J Adhes Dent*. 2018;20(1):33-39.
54. Ali N, Safwat A, Aboushelib M. The effect of fusion sputtering surface treatment on microshear bond strength of zirconia and MDP-containing resin cement. *Dent Mater*. 2019;35(6):e107-e112.
55. Asadzadeh N, Ghorbanian F, Ahrary F, et al. Bond strength of resin cement and glass ionomer to Nd:YAG laser treated zirconia ceramics. *J Prosthodont*. 2019;28(4):e881-e885.
56. Bhavana BL, Rupesh PL, Kataraki B. An in vitro comparison of the effect of various surface treatments on the tensile bond strength of three different luting cement to zirconia copings. *J Indian Prosthodont Soc*. 2019;19(1):26-32.
57. Tanıs M, Akcaboy C. Effects of different surface treatment methods and MDP monomer on resin cementation of zirconia ceramics an in vitro study. *J Lasers Med Sci*. 2015;6(4):174-181.
58. Carvalho RF, Rippe MP, Melo RM, Bottino MA, Souza ROA. Resin bond strength to zirconia: effects of surface treatments and resin cements. *Gen Dent*. 2019;67(1):71-77.
59. Colombo M, Gallo S, Padovan S, Chiesa M, Poggio C, Scribante A. Influence of different surface pretreatments on shear bond strength of an adhesive resin cement to various zirconia ceramics. *Mater*. 2020;13(3):625.
60. Dantas TS, Silveira Rodrigues RC, Naves LZ, Lapria Faria AC, Palma-Dibb RG, Ribeiro RF. Effects of surface treatments on mechanical behavior of sintered and pre-sintered yttria-stabilized zirconia and reliability of crowns and abutments processed by CAD/CAM. *Int J Oral Maxillofac Implants*. 2019;34(4):907-919.
61. Dantas AM, Campos F, Pereira SM, et al. The effect of air-particle abrasion and a zirconia primer application on resin cement bonding strength to zirconia. *Minerva Stomatol*. 2019;68(2):89-94.
62. Ebeid K, Wille S, Salah T, Wahsh M, Zohdy M, Kern M. Bond strength of resin cement to zirconia treated in pre-sintered stage. *J Mech Behav Biomed Mater*. 2018;86:84-88.
63. Elsaka SE. Influence of surface treatments on the bond strength of resin cements to monolithic zirconia. *J Adhes Dent*. 2016;18(5): 387-395.
64. Flores-Ferreyra BI, Scougall-Vilchis RJ, Velazquez-Enriquez U, Garcia-Contreras R, Aguillon-Sol L, Olea-Mejia OF. Effect of airborne-particle abrasion and, acid and alkaline treatments on shear bond strength of dental zirconia. *Dent Mater J*. 2019;38(2):182-188.
65. Hou Y, Yi J, Huang Y, Gao J, Chen Y, Wang C. Effect of Er:YAG laser etching on the shear bond strength and microleakage of self-glazed zirconia ceramics. *Photobiomodul Photomed Laser Surg*. 2020;38(5): 289-294.
66. Koko M, Takagaki T, Abdou A, et al. Effects of the ratio of silane to 10-methacryloyloxydecyl dihydrogenphosphate (MDP) in primer on bonding performance of silica-based and zirconia ceramics. *J Mech Behav Biomed Mater*. 2020;112:104026.
67. Kvam K, Irkayek A, Vangaeva E, El-Homsi F. Comparison of sandblasted, ground and melt-etched zirconia crowns regarding adhesion strength to resin cement. *Biomater Investig Dent*. 2019;6(1):1-5.
68. Lee JJ, Choi JY, Seo JM. Influence of nano-structured alumina coating on shear bond strength between Y-TZP ceramic and various dual-cured resin cements. *J Adv Prosthodont*. 2017;9(2):130-137.
69. Lee Y, Oh KC, Kim NH, Moon HS. Evaluation of zirconia surfaces after strong-acid etching and its effects on the shear bond strength of dental resin cement. *Int J Dent*. 2019;2019:1-10.
70. Le M, Larsson C, Papia E. Bond strength between MDP-based cement and translucent zirconia. *Dent Mater J*. 2019;38(3):480-489.
71. Li R, Wang C, Ma SQ, et al. High bonding strength between zirconia and composite resin based on combined surface treatment for dental restorations. *J Appl Biomater Funct Mater*. 2020;18:1-9.
72. Maciel LC, Amaral M, Queiroz DA, Baroudi K, Silva-Concílio LR. The effect of repeated surface treatment of zirconia on its bond strength to resin cement. *J Adv Prosthodont*. 2020;12(5):291-298.
73. Mendes F, Zanini MM, Favarao J, et al. Bonding strength of luting cement to zirconia-based ceramic under different surface treatments. *Eur J Dent*. 2019;13(2):222-228.
74. Nagaoka N, Yoshihara K, Tamada Y, Yoshida Y, Meerbeek BV. Ultrastructure and bonding properties of tribochemical silica-coated zirconia. *Dent Mater J*. 2019;38(1):107-113.
75. Okada M, Inoue K, Irie M, Taketa H, Torii Y, Matsumoto T. Resin adhesion strengths to zirconia ceramics after primer treatment with silane coupling monomer or oligomer. *Dent Mater J*. 2017;36(5): 600-605.
76. Okutan Y, Kandemir B, Gundogdu Y, Kilic HS, Yucel MT. Combined application of femtosecond laser and air-abrasion protocols to monolithic zirconia at different sintering stages: effects on surface roughness and resin bond strength. *J Biomed Mater Res B Appl Biomater*. 2020;109(4):596-605.
77. Ranjbar Omidi B, Karimi Yeganeh P, Oveisi S, Farahmandpour N, Nouri F. Comparison of micro-shear bond strength of resin cement to zirconia with different surface treatments using universal adhesive and zirconia primer. *J Lasers Med Sci*. 2018;9(3):200-206.
78. Özdemir H, Yanikoglu N, Sagsoz N. Effect of MDP-based silane and different surface conditioner methods on bonding of resin cements to zirconium framework. *J Prosthodont*. 2019;28(1):79-84.
79. Petrauskas A, Novaes Olivieri KA, Pupo YM, Berger G, Gonçalves BE. Influence of different resin cements and surface treatments on microshear bond strength of zirconia-based ceramics. *J Conserv Dent*. 2018;21(2):198-204.
80. Ruyter EI, Vajeeston N, Knarvang T, Kvam K. A novel etching technique for surface treatment of zirconia ceramics to improve adhesion of resin-based luting cements. *Acta Biomater Odontol Scand*. 2017;3(1):36-46.
81. Saade J, Skienhe H, Ounsi H, Matinlinna JP, Salameh Z. Effect of different combinations of surface treatment on adhesion of resin composite to zirconia. *Clin Cosmet Investig Dent*. 2019;11:119-129.
82. Saade J, Skienhe H, Ounsi HF, Matinlinna JP, Salameh Z. Evaluation of the effect of different surface treatments, aging and enzymatic degradation on zirconia-resin micro-shear bond strength. *Clin Cosmet Investig Dent*. 2020;12:1-8.
83. Saleh NE, Guven MC, Yildirim G, Erol F. Effect of different surface treatments and ceramic primers on shear bond strength of self-

adhesive resin cement to zirconia ceramic. *Niger J Clin Pract*. 2019; 22(3):335-341.

84. Salem R, Naggar GE, Aboushelib M, Selim D. Microtensile bond strength of resin-bonded hightranslucency zirconia using different surface treatments. *J Adhes Dent*. 2016;18(3):191-196.
85. Sathish S, Lakshmi S, Patel P, Annapoorni H. Effect of thermocycling on the micro-tensile bond strength between self-adhesive resin cement and nonphosphate monomer cements on zirconium-oxide ceramics. *Indian J Dent Res*. 2019;30(1):73-79.
86. Sharafeddin F, Shoale S. Effects of universal and conventional MDP primers on the shear bond strength of zirconia ceramic and nanofilled composite resin. *J Dent*. 2018;19(1):48-56.
87. Skienhe H, Habchi R, Ounsi H, Ferrari M, Salameh Z. Evaluation of the effect of different types of abrasive surface treatment before and after zirconia sintering on its structural composition and bond strength with resin cement. *Biomed Res Int*. 2018;2018:1-18.
88. Smielak B, Klimek L, Wojciechowski R, Bąkała M. Effect of zirconia surface treatment on its wettability by liquid ceramics. *J Prosthet Dent*. 2019;122(4):410.e410.
89. Soltaninejad F, Valian A, Moezizadeh M, Khatiri M, Razaghi H, Nojehdehian H. Nd:YAG laser treatment of bioglass-coated zirconia surface and its effect on bond strength and phase transformation. *J Adhes Dent*. 2018;20(5):379-387.
90. Tabatabaei MH, Chiniforush N, Namdar SF. Effects of different ceramic primers and surface treatments on the shear bond strength of restorative composite resin to zirconium. *Laser Ther*. 2018;27(2): 111-117.
91. Thammajaruk P, Blatz MB, Buranadham S, Guazzato M, Wang Y. Shear bond strength of composite cement to alumina-coated versus tribochemical silica-treated zirconia. *J Mech Behav Biomed Mater*. 2020;105:103710.
92. Lümkemann N, Eichberger M, Stawarczyk B. Different surface modifications combined with universal adhesives: the impact on the bonding properties of zirconia to composite resin cement. *Clin Oral Investig*. 2019;23(11):3941-3950.
93. Zahoui A, Bergamo ET, Marun MM, Silva KP, Coelho PG, Bonfante EA. Cementation protocol for bonding zirconia crowns to titanium base CAD/CAM abutments. *Int J Prosthodont*. 2020;33(5):527-535.
94. Sterne JA, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019;366:14898.
95. Franco-Tabares S, Wardecki D, Nakamura K, et al. Effect of airborne-particle abrasion and polishing on novel translucent zirconias: surface morphology, phase transformation and insights into bonding. *J Prosthodont Res*. 2021;65(1):97-105.
96. Mehari K, Parke AS, Gallardo FF, Vandewalle KS. Assessing the effects of air abrasion with aluminum oxide or glass beads to zirconia on the bond strength of cement. *J Contemp Dent Pract*. 2020;21(7): 713-717.
97. Franco-Tabares S, Stenport VF, Hjalmarsson L, Tam PL, Johansson CB. Chemical bonding to novel translucent zirconias: a mechanical and molecular investigation. *J Adhes Dent*. 2019;21(2): 107-116.
98. Shimizu H, Inokoshi M, Takagaki T, Uo M, Minakuchi S. Bonding efficacy of 4-META/MMA-TBB resin to surface-treated highly translucent dental zirconia. *J Adhes Dent*. 2018;20(5):453-459.
99. Chen B, Yan Y, Xie H, Meng H, Zhang H, Chen C. Effects of tribochemical silica coating and alumina-particle air abrasion on 3Y-TZP and 5Y-TZP: evaluation of surface hardness, roughness, bonding, and phase transformation. *J Adhes Dent*. 2020;22(4):373-382.
100. Monteiro RV, Dos Santos DM, Bernardon JK, De Souza GM. Effect of surface treatment on the retention of zirconia crowns to tooth structure after aging. *J Esthet Restor Dent*. 2020;32(7):699-706.
101. Sakrana AA, Al-Zordk W, Shoukry H, Özcan M. Bond strength durability of adhesive cements to translucent zirconia: effect of surface conditioning. *Eur J Prosthodont Restor Dent*. 2020;28(7):161-171.
102. Yoshida K. Influence of alumina air-abrasion for highly translucent partially stabilized zirconia on flexural strength, surface properties, and bond strength of resin cement. *J Appl Oral Sci*. 2020;28:e20190371.
103. Kwon SJ, Lawson NC, McLaren EE, Nejat AH, Burgess JO. Comparison of the mechanical properties of translucent zirconia and lithium disilicate. *J Prosthet Dent*. 2018;120(1):132-137.
104. Yagawa S, Komine F, Fushiki R, Kubochi K, Kimura F, Matsumura H. Effect of priming agents on shear bond strengths of resin-based luting agents to a translucent zirconia material. *J Prosthodont Res*. 2018;62(2):204-209.
105. Agren M, Kou W, Molin TM. Bond strength of surface-treated novel high translucent zirconia to enamel. *Biomater Investig Dent*. 2019; 6(1):35-42.
106. Ruales-Carrera E, Cesar PF, Henriques B, Fredel MC, Özcan M, Volpato CAM. Adhesion behavior of conventional and high-translucent zirconia: effect of surface conditioning methods and aging using an experimental methodology. *J Esthet Restor Dent*. 2019;31(4):388-397.
107. Zhao P, Yu P, Xiong Y, Yue L, Arola D, Gao S. Does the bond strength of highly translucent zirconia show a different dependence on the airborne-particle abrasion parameters in comparison to conventional zirconia? *J Prosthodont Res*. 2019;64(1):60-70.
108. De Angelis F, D'Arcangelo C, Buonvivere M, Rondoni GD, Vadini M. Shear bond strength of glass ionomer and resin-based cements to different types of zirconia. *J Esthet Dent*. 2020;32(8):806-814.
109. Zhang X, Liang W, Jiang F, et al. Effects of air-abrasion pressure on mechanical and bonding properties of translucent zirconia. *Clin Oral Investig*. 2021;25(4):1979-1988.
110. Khanlar LN, Takagaki T, Inokoshi M, Ikeda M, Nikaido T, Tagami J. The effect of carboxyl-based monomers on resin bonding to highly translucent zirconia ceramics. *Dent Mater J*. 2020;39(6):956-962.
111. Krifka S, Preis V, Rosentritt M. Effect of decontamination and cleaning on the shear bond strength of high translucency zirconia. *Dent J*. 2017;32(5):1-8.
112. Kelly JRNI, Campell SD. Ceramics in dentistry: historical roots and current prespectives. *J Prosthet Dent*. 1996;75:18-32.
113. Fehmer VMS, Hämmerle CH, Sailer I. Criteria for the selection of restoration materials. *Quintessence Int*. 2014;45:723-730.
114. Carrabba MKA, Aziz A, Vichi A, Fonzar RF, Wood D, Ferrari M. Translucent zirconia in the ceramic scenario for monolitic restorations: a flexural strength and translucency comparasion test. *J Dent*. 2017;60(5):70-76.
115. Rabel KLU, Polydorou O, Flügge T, Spies BC. Prosthetic rehabilitation with fixed monolithic trancelucent zirconia restorations: a case history report. *Int J Prosthodont*. 2019;32(6):544-548.
116. Moon JEKS, Lee JB, Hans JS, Yeo IS, Ha SR. Effects of airborne-particle abrasion protocol choice on the surface characteristics of monolithic zirconia materials and the shear bond strength of resin cements. *Ceram*. 2016;42(1):1552-1562.
117. Ozer FNA, Turp V, Mante F, Sen D, Blatz MB. Effect of thickness and surface modifications on flexural strength of monolithic zirconia. *J Prosthet Dent*. 2018;119(6):987-993.
118. Fonseca RG, dOA-RF, Reis JM, Rambaldi E, Baldissara P. Effect of particle size on the flexural strength and phase transformation of an airborne-particle abraded yttria-stabilized tetragonal zirconia polycrystal ceramic. *J Prosthet Dent*. 2013;110(6):510-514.
119. Özcan MMR, Souza RO, Machado JP, Valandro LF, Botttino MA. Effect of air-particle abrasion protocols on the biaxial flexural strength, surface characteristics and phase transformation of zirconia after cyclic loading. *J Mech Behav Biomed Mater*. 2013;20:19-28.
120. Souza ROVL, Melo RM, Mechado JP, Bottino MA, Özcan M. Air-particle abrasion on zirconia ceramic using different protocols: effects on biaxial flexural stregth after cyclic loading, phase transformation and surface topography. *J Mech Behav Biomed Mater*. 2013; 26:155-163.

121. Aurelio ILMA, Montagner AF, May LG, Soares FZ. Does air particle abrasion affect the flexural strength and phase transformation of Y-TZP? A systematic review and meta-analysis. *Dent Mater*. 2016;32(6):827-845.
122. Nobauki ARKY, Takashi SA. Effects of air abrasion with alumina or glass beads on surface characteristics of CAD/CAM composite materials and the bond strength of resin cements. *J App Oral Sci*. 2015;23(6):629-639.
123. Coelho CMRJ, Pegoraro LF. Tensile bond strength of a resinous cement to a nickel-chromium alloy modified with five surface treatments. *J Prosthet Dent*. 1996;76(3):246-249.
124. Inokoshi SYT, Takatsu T. Bond strengths of resin to enamel and dentin treated with low-pressure air abrasion. *Oper*. 1996;21:218-224.
125. Thammajaruk P, Burandam S, Thanatvarakorn O, Guzzato M. Influence of nano-structured alumina coating on composite-zirconia bonding and its characterization. *J Adhes Dent*. 2018;20(3):233-242.
126. Strasser TPV, Behr M, Rosentritt M. Roughness, surface energy, and superficial damages of CAD/CAM materials after surface treatment. *Clin Oral Investig*. 2018;22(8):2787-2797.
127. Tzanakakis EG, Tzoutzas IG, Koidis PT. Is there a potential for durable adhesion to zirconia restorations? A Systematic Review. *J Prosthet Dent*. 2016;115(1):9-19.
128. Magne PPM, Burnett LH Jr. New zirconia primer improves bond strength of resin-based cements. *Dent Mater*. 2010;26(4):345-352.
129. Ho BJTJ, Liu D, Lung CYK, Wong HM, Matinlinna JP. Effects of sandblasing distance and angles on resin cement bonding to zirconia and titanium. *INT J Adhes*. 2015;62:25-31.
130. Su NYL, Liu W, Zhang H, Li X, Wang H, Shen J. The effect of various sandblasting contitions on surface changes of dental zirconia and shear bond strength between zirconia core and indirect composite resin. *J Adv Prosthodont*. 2015;7:214-223.
131. Chen YMSR, Yip KH, Sung WJ. Translucency and biaxial flexural strength of four ceramic core materials. *Dent Mater*. 2008;24(11):1506-1511.
132. Zhang FIM, Batuk M, Hadermann J, Naert I, Van Meerbeek B, Vleugels J. Stregnth and toughness and aging stability of highly-translucent Y-TZP ceramics for dental restorations. *Dent Mater*. 2016;32(12):e327-e337.
133. Zandparsa R, Talua NA, Finkelman MD, Schaus SE. An in vitro comparison of shear bond strength of zirconia to enamel using different surface treatments. *J Prosthodont*. 2014;23(2):117-123.
134. Lohbauer U, Zipperle M, Rischka K, Petschelt A, Müller FA. Hydroxylation of dental zirconia surfaces: characterization and bonding potential. *J Biomed Mater Res B Appl Biomater*. 2008;87(2):461-467.
135. Hallmann L, Ulmer P, Lehmann F, et al. Effect of surface modifications on the bond strength of zirconia ceramic with resin cement resin. *Dent Mater*. 2016;32(5):631-639.
136. Xie H, Chen C, Dai W, Chen G, Zhang F. In vitro short-term bonding performance of zirconia treated with hot acid etching and primer conditioning etching and primer conditioning. *Dent Mater J*. 2013;32(6):928-938.
137. Piascik JR, SWIFT JR EJ. Resin bonding to zirconia. *J Esthet Dent*. 2012;24(6):417-420.
138. Kaimal A, Ramdev P, Shruthi CS. Evaluation of effect of zirconia surface treatment, using plasma of argon and Silane, on the shear bond strength of two composite resin cements. *J Clin Diagn Res*. 2017;11(8):ZC39-ZC43.
139. Amaral M, Belli R, Cesar PF, Valandro LF, Petschelt A, Lohbauer U. The potential of novel primers and universal adhesives to bond to zirconia. *J Dent*. 2014;42(1):90-98.
140. Attia A, Lehmann F, Kern M. Influence of surface conditioning and cleaning methods on resin bonding to zirconia ceramic. *Dent Mater*. 2011;27(3):207-213.
141. Xie H, Li Q, Zhang F, et al. Comparison of resin bonding improvements to zirconia between one-bottle universal adhesives and tribochemical silica coating, which is better? *Dent Mater*. 2016;32(3):403-411.
142. Dal Piva AMO, Carvalho RLA, Lima AL, Bottino MA, Melo RM, Valandro LF. Silica coating followed by heat-treatment of MDP-primer for resin bond stability to yttria-stabilized zirconia polycrystals. *J Biomed Mater Res B Appl Biomater*. 2019;107(1):104-111.
143. Tanaka R, Fujishima A, Shibata Y, Manabe A, Miyazaki T. Cooperation of phosphate monomer and silica modification on zirconia. *J Dent Res*. 2008;87(7):666-670.
144. Chen C, Kleverlaan CJ, Feilzer AJ. Effect of an experimental zirconia-silica coating technique on micro tensile bond strength of zirconia in different priming conditions. *Dent Mater*. 2012;28(8):e127-e134.
145. Yao C, Yu J, Wang Y, Tang C, Huang C. Acidic pH weakens the bonding effectiveness of silane contained in universal adhesives. *Dent Mater*. 2018;34(5):809-818.
146. Chen B, Lu Z, Meng H, et al. Effectiveness of pre-silanization in improving bond performance of universal adhesives or self-adhesive resin cements to silica-based ceramics: chemical and in vitro evidences. *Dent Mater*. 2019;35(4):543-553.
147. Yang B, Barloi A, Kern M. Influence of air-abrasion on zirconia ceramic bonding using an adhesive composite resin. *Dent Mater*. 2010;26(1):44-50.
148. Sanli S, Comlekoglu MD, Comlekoglu E, Sonugelen M, Pamir T, Darvell BW. Influence of surface treatment on the resin-bonding of zirconia. *Dent Mater*. 2015;31(6):657-668.
149. Martins AR, Gotti VB, Shimano MM, Borges GA, Gonçalves LS. Improving adhesion between luting cement and zirconia-based ceramic with an alternative surface treatment. *Braz Oral Res*. 2015;29(1):1-2.
150. Valentino TA, Borges GA, Borges LH, Platt JA, Correr-Sobrinho L. Influence of glazed zirconia on dual-cure luting agent bond strength. *Oper Dent*. 2012;37(2):181-187.
151. Vanderlei A, Bottino MA, Valandro LF. Evaluation of resin bond strength to yttria-stabilized tetragonal zirconia and framework marginal fit: comparison of different surface conditionings. *Oper Dent*. 2014;39(1):50-63.
152. Rippe MP, Amaral R, Oliveira FS, et al. Evaluation of tensile retention of Y-TZP crowns cemented on resin composite cores: effect of the cement and Y-TZP surface conditioning. *Oper Dent*. 2015;40(1):e1-e10.
153. Oyagüe RC, Monticelli F, Toledano M, Osorio E, Ferrari M, Osorio R. Effect of water aging on microtensile bond strength of dual-cured resin cements to pre-treated sintered zirconium-oxide ceramics. *Dent Mater*. 2009;25(3):392-399.
154. de Oyagüe RC, Monticelli F, Toledano M, Osorio E, Ferrari M, Osorio R. Influence of surface treatments and resin cement selection on bonding to densely-sintered zirconium-oxide ceramic. *Dent Mater*. 2009;25(2):172-179.
155. Oilo G. Bond strength testing--what does it mean? *Int Dent J*. 1993;43(5):492-498.
156. Hadavi F, Hey J, Ambrose E, Louie P, Shinkewski D. The effect of dentin primer on the shear bond strength between composite resin and enamel. *Oper*. 1993;18(2):61-65.
157. Blatz MB, Sadan A, Kern M. Resin-ceramic bonding: a review of the literature. *J Prosthet Dent*. 2003;89(3):268-274.
158. Della Bona A, Van Noort R. Shear vs. tensile bond strength of resin composite bonded to ceramic. *J Dent Res*. 1995;74(9):1591-1596.
159. Palacios RP, Johnson GH, Phillips KM, Raigrodski AJ. Retention of zirconium oxide ceramic crowns with three types of cement. *J Prosthet Dent*. 2006;96(2):104-114.

160. Heintze S. Crown pull-off test (crown retention test) to evaluate the bonding effectiveness of luting agents. *Dent Mater*. 2010;26(3):193-206.
161. Nicholls J. Tensile bond of resin cements to porcelain veneers. *J Prosthet Dent*. 1988;60(4):443-447.
162. Ozcan M, Bernasconi M. Adhesion to zirconia used for dental restorations: a systematic review and meta-analysis. *J Adhes Dent*. 2015;17(1):7-26.
163. Valandro LF, Ozcan M, Amaral R, Vanderlei A, Bottino MA. Effect of testing methods on the bond strength of resin to zirconia-alumina ceramic: microtensile versus shear test. *Dent Mater J*. 2008;27(6):849-855.
164. Betamar NM, Cardew G, Van Noort R. Influence of specimen designs on the microtensile bond strength to dentin. *J Adhes Dent*. 2007;9(2):161-168.
165. Ernst CP, Cohnen U, Stender E, Willershausen B. In vitro retentive strength of zirconium oxide ceramic crowns using different luting agents. *J Prosthet Dent*. 2005;93(6):551-558.
166. Della-Bona A. Characterizing ceramics and the interfacial adhesion to resin: II-the relationship of surface treatment, bond strength, interfacial toughness and fractography. *J App Oral Sci*. 2005;13(2):101-109.
167. Bona AD. Important aspects of bonding resin to dental ceramics. *J Adhes Sci Technol*. 2009;23(8):1163-1176.
168. Hooshmand T, van Noort R, Keshvad A. Bond durability of the resin-bonded and silane treated ceramic surface. *Dent Mater*. 2002;18(2):179-188.
169. Ehlers V, Kampf G, Stender E, Willershausen B, Ernst CP. Effect of thermocycling with or without 1 year of water storage on retentive strengths of luting cements for zirconia crowns. *J Prosthet Dent*. 2015;113(6):609-615.
170. Khalil AA, Abdelaziz KM. Bonding values of two contemporary ceramic inlay materials to dentin following simulated aging. *J Adv Prosthodont*. 2015;7(6):446-453.
171. Asaad RS. Effect of thermo-mechanical cycling on the shear bond strength of porcelain to milled and cast cobalt-chromium alloys. *Egypt Dent J*. 2019;65(3):2709-2722.
172. Joias RM, Tango RN, de Araujo JEJ, et al. Shear bond strength of a ceramic to co-Cr alloys. *J Prosthet Dent*. 2008;99(1):54-59.
173. Troia MG Jr, Henriques GE, Nobilo MA, Mesquita MF. The effect of thermal cycling on the bond strength of low-fusing porcelain to commercially pure titanium and titanium–aluminium–vanadium alloy. *Dent Mater*. 2003;19(8):790-796.
174. Komine F, Tomic M, Gerds T, Strub JR. Influence of different adhesive resin cements on the fracture strength of aluminum oxide ceramic posterior crowns. *J Prosthet Dent*. 2004;92(4):359-364.

**How to cite this article:** Alammar A, Blatz MB. The resin bond to high-translucent zirconia—A systematic review. *J Esthet Restor Dent*. 2022;34(1):117-135. doi:10.1111/jerd.12876