Review Article

Comparison of bond strength of self-adhesive and self-etch or total-etch resin cement to zirconia: A systematic review and meta-analysis

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Abstract

The aim of this study was to systematically compare the bond strength of self-adhesive and self-etch or total-etch resin cement to zirconia. The PubMed, ISI (all), and Scopus databases were searched for the selected keywords up to November 1, 2021, without date or language restrictions. *In vitro* studies comparing the bond strength of self-adhesive and self-etch or total-etch resin cement to zirconia were eligible for inclusion in the study. The selected articles were divided into four groups based on the type of resin cement and the storage time. Statistical analysis was performed using the Biostat Comprehensive Meta-Analysis Software version 2 ($\alpha = 0.05$). The effect of conventional cement (Glass Ionomer (GI), Resin Modified Glass Ionomer (RMGI) and zinc phosphate) was analyzed using descriptive analysis. The initial search yielded 376 articles, of which 26 were selected after a methodological assessment. Two reviewers independently extracted data and assessed the risk of bias. The results showed that the immediate or delay bond strength of the self-adhesive resin cement to zirconia has no significant difference with the bond strength of self-etch resin cement to zirconia. The immediate and delay bond strength of total-etch cement-zirconia was significantly lower than that of self-adhesive cement-zirconia ($P = 0.00$). A descriptive analysis of the selected articles showed that the bond strength of self-adhesive resin cement to zirconia was significantly higher than total-etch cement. The results of the meta-analysis showed that both self-adhesive and self-etch resin cement (if applied according to their manufacturer's instruction) are suitable for bonding to zirconia.

Keywords: Bond strength; self-adhesive resin cement; self-etch; total-etch; zirconia

INTRODUCTION

Increasing demands on dental esthetics today have led to the development of tooth-colored restorations, either composite or ceramic based.[1] Ceramic systems are available to meet patient and dentist expectations for reliable, durable, and esthetical restorations.[2] Among various types of ceramics, yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) is becoming the commonly used ceramic due to its mechanical properties, corrosion resistance, and biocompatibility.[3,4] It, therefore, enables the clinicians to achieve higher clinical success with lower prosthetic complications while having more conservative tooth preparations.[5] However, a concern of nonglass and therefore nonetchable (with traditional acids used for glass ceramics), quasichemically inert zirconia is its limited potential for adhesive luting.[5] Various mechanical and chemical surface preparations have been recommended to improve the bonding of resin cement to zirconia,[6] such as sandblasting, tribochemical silica coating (TSC), hydrofluoric (HF) acid etching, and laser irradiation. HF acid does not provide sufficient bond strength due to the lack of a vitreous phase; however, a combination of HF, hydrochloric acid, sulfuric acid, nitric acid, and phosphoric

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acid has shown to improve the shear bond strength of adhesive resins to zirconia.[7]

Liu *et al.*, on the other hand, found that laser irradiation does not improve the surface properties of zirconia ceramics and, therefore, the bond strength and that increasing the irradiation power and extending the irradiation time does not increase the bond strength of the ceramic and might lead to material defects.[8] Although sandblasting can improve the bond strength of zirconia to resin cement, it results in a decrease in the flexural strength of zirconia as the surface of zirconia is altered to varying degrees from tetragonal to monoclinic phases.[9]

TSC roughens and activates the surfaces. TSC deposits an inhomogeneous silica layer on the zirconia surface, thus improving the bonding efficiency when coupled with 10-methacryloyloxy-decyl-dihydrogen-phosphate (10-MDP) primer.[10] In general, phosphate ester monomers have been shown to chemically bond with pure zirconia. In particular, primers and resin cement containing 10-MDP result in an acceptable and durable bond strength due to the chemical reaction of 10-MDP with zirconium oxide.[11-16]

The strong cementation of zirconium oxide-based prosthesis plays an important role in the clinical success rate. Although conventional cement can be used for luting zirconia, adhesive luting cement are recommended for increased retention, marginal conformation, and fracture resistance.

Although several types of cement and adhesive methods for bonding to zirconia have been introduced in recent years, a standard cementation protocol has not yet been identified. The aim of this meta-analysis was to compare the bond strength of self-adhesive and self-etch or total-etch adhesive resin cement to zirconia-based prosthesis. The null hypothesis was that there was no difference between the immediate and delayed bond strength of self-adhesive and self-etch or total-etch adhesive resin cement to zirconia.

MATERIALS AND METHODS

The guidelines of Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) were used in this systematic review. The PICOS was identified and shown in Table 1.

Databases such as PubMed, Scopus, the Cochrane Database of Systematic Reviews, and ISI (Web of Science core collection, Biosis Previews, Biosis Citation Index, Current Content Connect, Data Citation Index, Derwent Innovation Index, CI-Korean Journal, Russian Science Citation Index, Medline, SciELO Citation Index, and Zoological Record) were systematically searched up to November 1, 2021 without language or time restrictions for the following keywords.

((((((“zirCAD”) OR “whitesky”) OR “DC-zircon”) OR brezirkon) OR “y-tzp ceramic”) OR y-tzp ceramic) OR lava) OR “Non-etchable ceramic”) OR (((zirconia OR zirconium))))) AND ((self-adhesive OR (self-adhesive) OR self-bonding OR (self-bonding) AND (cement OR luting OR resin) OR (G-cem OR Maxcem OR “Rely X” OR “SmartCem” OR Bifix OR Biscem OR Multilink OR “SpeedCem” OR “Clearfill SA” OR Calibra OR Breeze OR “Embrace WetBond” OR Monocem OR “AURAVeneer VLC” OR Permanecem)).

The articles were imported into an EndNote library (Endnote X7, Thomson Reuters, San Francisco, CA, USA), and duplicate studies were removed. Next, a manual search for the references of the selected articles was conducted. As no relevant clinical studies were found in the selected articles, the inclusion criteria were *in vitro* studies, in which:

1. A comparison was made between the bond strength of self-adhesive resin cement and self-etch or total-etch resin cement to zirconia
2. A shear or tensile test was performed
3. Appropriate statistical tests were used to analyze the bond strength with reported sample size, *P* value, mean, and standard deviation
4. The cement was applied according to the manufacturer’s recommendations.

To select eligible articles, two reviewers (AB and FK) independently screened the literature and rated the studies

Table 1: Search strategy using PICOS analysis

	Definition	Main search terms for Pubmed (controlled vocabulary and free text terms)
Participants	Zirconia	((((((“zirCAD”) OR “whitesky”) OR “DC-zircon”) OR brezirkon) OR “y-tzp ceramic”) OR y-tzp ceramic) OR lava) OR “Non-etchable ceramic”) OR (((zirconia OR zirconium))))) AND ((self-adhesive OR (self-adhesive) OR self-bonding OR (self-bonding)
Intervention	Self etch Total etch Self adhesive	(cement OR luting OR resin) OR (G-cem OR Maxcem OR “Rely X” OR “SmartCem” OR Bifix OR Biscem OR Multilink OR “SpeedCem” OR “Clearfill SA” OR Calibra OR Breeze OR “Embrace WetBond” OR Monocem OR “AURAVeneer VLC” OR Permanecem))
Comparisons	Not applicable	-
Outcomes	Not applicable	-
Study design	All included	Search results manually screened to include all primary teeth that underwent chlorhexidine pretreatment for resin restoration

PICOS: Participants, intervention, comparisons, outcomes, study design based on the inclusion/exclusion criteria. In the case of disagreement, the issue was clarified through discussion with the third reviewer (AS).

The selected articles were thoroughly assessed for the study's scientific basis and methodological accuracy. To assess the risk of bias, six methodological elements were considered as follows: (1) randomization of teeth, (2) use of caries-free or restoration-free teeth, (3) materials used according to the specifications, (4) adhesive procedures performed by the same operator, (5) description of sample size calculation, and (6) blinding of testing machine operators. When the authors reported a parameter, the article had a Y (yes) for that specific parameter; if the information could not be found, the article received an N (no). Articles reporting 1 or 2 items were rated as high risk of bias, 3 or 4 as medium risk, and 5–6 as low risk.[17]

Data extraction and analysis

The following data were recorded for each included article; statistical data, such as the sample size, mean, and standard deviation, and the details of the cementing protocol, such as the adhesive system, bonding substrate, conditioning before bonding, thermal or mechanical cycling, and type of bond strength test.

Authors of articles with incomplete data were contacted through e-mail to retrieve the missing data. If there was no reply within 2 weeks, a second e-mail was sent. If after 1 month from the first contact still no or an incomplete answer was received, the article would be excluded.

The characteristics of the included studies are presented in Table 2.The eligible articles were divided into four groups according to the type of resin cement and storage time; (1) immediate bond strength of self-etch cement-zirconia versus self-adhesive cement-zirconia, (2) delayed bond strength of self-etch cement-zirconia versus self-adhesive cement-zirconia (storage longer than 48 h), (3) immediate bond strength of total-etch cement-zirconia versus self-adhesive cement-zirconia, and (4) delayed bond strength of total-etch cement-zirconia versus self-adhesive cement-zirconia (storage longer than 48 h).

To assess the heterogeneity of the cement type effect, the Cochrane *Q*-test was used, for which the significance level was set at 0.05. Furthermore, we used the I^2 index to quantify heterogeneity, with values >50% being taken as indicating high heterogeneity.

The analysis in the four groups was performed using the random-effect model. The comprehensive meta-analysis software version 2 (Biostat Inc., Englewood NJ, USA) was used for statistical analysis. The effect of conventional cement (GI, RMGI, and zinc phosphate) was analyzed using descriptive analysis.

RESULTS

Risk of bias

Of the total of 33 articles, only one study presented a low risk of bias, 16 studies showed medium risk of bias, and 16 studies showed high risk of bias. The results are given in Table 3, according to the parameters considered in the analysis.

Article search and meta-analysis

The PRISMA flowchart of the articles included is shown in Figure 1. Electronic and manual searches up to November 1, 2021, yielded a total of 858 articles, of which 422 were from ISI, 145 from PubMed, 164 from Scopus, 114 from Embase, and 13 from Cochrane. After removing duplicates, 376 articles remained. Further review of the title and abstract of the articles resulted in the remaining 109 articles, of which 43 were selected for full-text review. After full-text review 17 studies were excluded because they did not follow the manufacturer's instructions or the statistical analysis information was incomplete. The number of studies in each group is presented in Figure 1. All articles were in English.

Group 1: Immediate bond strength of self-etch cement-zirconia versus self-adhesive cement-zirconia.

In this group, 15 eligible articles in 32 categories were imported. The *P* value of Cochran's *Q* and I^2 tests was 0.00 and 93.50, respectively, so random-effect model was used to analyze the data. This meta-analysis showed that there was no significant difference in the immediate bond strength of self-etch cement-zirconia and self-adhesive cement-zirconia ($P = 0.055$) [Figure 2].

Group 2: Delayed bond strength of self-etch cement-zirconia versus self-adhesive cement-zirconia.

In this group, 14 eligible articles in 29 categories were imported. The *P* value of Cochran's *Q* and I^2 tests was 0.00 and 92.68, respectively, so a random-effect model was used to analyze the data. Based on the results, there was no significant difference in the delayed bond strength of self-etch cement-zirconia and self-adhesive cement-zirconia ($P = 0.143$) [Figure 3].

Group 3: Immediate bond strength of total-etch cement-zirconia versus self-adhesive cement-zirconia.

In this group, 9 eligible articles in 19 categories were imported. The *P* value of Cochran's *Q* and I^2 tests was, respectively, so random-effect model was used to analyze

Table 2: Detailed summary of studies included in the meta-analysis

Article	Cement	Test	Interface	Sample size	Mean±SD	Surface treatment	Storage
Petrauskas *et al.*[18]	RelyXU100	MSBS	c-c	30	13.6±86.56	Polished with silicon carbide paper	30 min room temperature
	Multilink polished + z primer				16.11±4.97	Sandblast: 12 s - 50 µm AL_2O_3	
	RelyXU100 sandblasted				24.02±6.41	10 mm - 2.8 bar	
	Multilink				9.64±3.98	Sandblasted + z primer	
Gundogdu and Aladag[19]	Duo link	SBS	D-C	8	16.95±3.55	Airborne particle abrasion with 50 µm AL2O3for 15 s at a pressure of 0.25 Mpa from a distance of 10 mm	Distilled water at 37°C±2°C for 24 h
	Panavia F2				11.14±2.69		
	RelyX Ultimate				17.44±2.78		
	RelyX U 200				7.68±1.76		
	Max Cem				4.42±1.53		
Tunc *et al.*[20]	Zinc phosphate	SBS	c-c	10	0.31±0.04		37°C water for 24 h in a dark room to ensure complete polymerization of the cement. After 24 h, the specimens were subjected to thermal aging
	Rely x u200				11.47±0.47		
	C and B				3.53±0.41		
Rebholz-Zaribaf and Ozcan[21]	Panavia f2 dry	MSBS	Cement-zirconia	15	5.7±1.7	Silicon carbide/clean ultrasonically	
	RelyX Unicem dry				12.1±5.2		
	Variolinkii dry				0		
	PANAVIA F2 TC				9.7±3.4		
	Rely X Unicem TC				6.3±4.3		
	Variolink II TC				0		
Stefani *et al.*[22]	Multilink Automix	MSBS	Ceramic-cement	30	37.6±4.5	Sandblasted with aluminum oxide particles	Immediate bond strength
	RelyXARC				28.1±6.6		
	Cleafil SA				46.2±3.3		
Eratilla *et al.*[23]	BisCem	SBS	Zir-cem-dentin	12	1.37±1.42		Thermal cycle 6000
	Panavia F2				2.73±1.4		
Alves *et al.*[24]	RelyX ARC	SBS	Dentin-c-ceramic	10	5.65±2.8		Water (37°C) 30 days
	RelyX U200				10.36±3.87		
Lin *et al.* (2010)[25]	Panavia	MSBS	Cement-zirconia	10	4.61±2.8		24 h storage
	Relyx Unicem				18.57±4.8		
	Maxcem				18.21±4.95		
	Multilink speed				4.59±3.14		
Lee *et al.*[26]	G-Cem link	SBS	Cement_zirconia	10	3.96±0.56		Before TC
	Maxcem Elite				2.86±0.61		
	Clearfil SA				3.9±0.58		
	PermaCem2.				4.19±0.66		
	Rely X U200				2.84±0.61		
	Smart Cem				3.93±0.48		
	Fuji CEM				1.74±0.72		
	G-Cem link				2.66±0.53		After TC (5000 thermocycling)
	Maxcem Elite				2.08±0.46		
	Clearfil SA				4.62±0.6		
	PermaCem2				2.99±0.57		
	Rely X U200				2.36±0.41		
	Smart Cem				3.44±0.59		
	Fuji CEM				2.23±0.42		
Khalil and Abdelaziz[27]	RelyX Ultimate	Push out	Dentin-cemnet-zirconia	10	5.1±0.97		24,000 cycle fatigue + 3500 thermocycling (5–55)
	RelyX Unicem				4.41±1.12		
	RelyX Ultimate				5.77±0.96		24 h
	RelyX Unicem				4.62±1.59		
Ayyilidiz *et al.*[28]	C and B	SBS	Cement-zirconia	10	3.73±0.46	Sandblasted	1 week storage 37°C water bath/thermal cycling
	RelyX U200				11.23±0.47		
	Zinc phosphate				0.29±0.03		
da Silva *et al.*[29]	RelyX Arc	MSBS	Cement-zirconia	20	5.4±1.8		Distilled water in 37°C for 24 h
	RelyX Unicem				16±1.7		
	RelyX Arc				1±0.8		Distilled water at 37°C for 6 months
	RelyX Unicem				1.1±1.7		
Sabatini *et al.*[30]	RelyX Unicem	SBS	Composite-cement-zirconia	12	18.7±1.3	Air abraded with 50 µm aluminum oxide particle at 1 bar and distance of 10 mm for 10 s	24 h storage dry condition at room temperature
	multilink automix				21.8±2.1		
	Maxcem Elite				16.8±0.5		
	FujiCem				5.6±0.3		

Contd...

Table 2: Contd...

Article	Cement	Test	Interface	Sample size	Mean±SD	Surface treatment	Storage
Geramipanah *et al.*[31]	Panavia F2	MSBS	Composite-cement-ceramic	10	12.43±4.48	Air blasted with 110 µm aluminum oxide	Water pH=7 1 week
	RelyX Unicem				13.81±2.86		
	Calibra				0.7±0.22		
Gomes *et al.*[11]	Panavia F2	MTBS	Composite-cement-ceramic	20	9.17±7.97	Air abrasion with 25/50/110 µm Al_2O_3 particle	24 h
	Bifix				0.86±3.28		
Keul *et al.*[32]	Rely X Unicem	SBS	Cement-zirconia	10	8.6±2.4		1 day
	G-Cem				8.5±1.3		
	Panavia21				6±2.3		
	Rely X Unicem				2.7±2.9		25 day + thermocycle
	G-Cem				4.2±4.5		
	Panavia21				4.6±2.6		
Gökkaya *et al.*[33]	Rely X Unicem			12	1.4±0.7		2 h
	Rely X Unicem				2.6±0.7		1500 TC
	Panavia				4±0.4		2 h
	Panavia				7.5±1		1500 TC
	Rely X Unicem				2.4±0.7		13,500 TC
	Panavia				3.3±0.6		13,500 Tc
de Sá Barbosa *et al.*[34]	Bis-Cem	MSBS	Cement-zirconia	10	32.2±4		Water storage for 24 h
	G-Cem				39.8±6.7		
	RelyX Unicem				42±3.3		
	SeT				36±7		
	RelyX ARC				26.9±4.8		
	Bis-Cem				9±5.3		Water storage for 1 year
	G-Cem				19±7.3		
	RelyX Unicem				3.8±2.3		
	SeT				6.5±5.2		
	RelyX ARC				9.9±4		
Peutzfeldt *et al.*[35]	De trey zinc	SBS	D-C	8	2.2±0.5	Air abraded with 50 µm alumina particles for 10 s at a distance of 10 cm and pressure of 4.2 bar	1-week water storage
	Fuji I				4.6±2.6		
	Fuji plus				9.2±3.2		
	Variolink II				6.5±1.9		
	Panavia F2				15±3.7		
	Multilink				6.2±1.3		
	RelyX Unicem				13.2±3.2		
	Maxcem				4.2±2.1		
Miragaya *et al.*[36]	RelyX Unicem	MSBS	Cement-zirconia	20	16±1.7		Water storage at 37°C for 24 h
	RelyX ARC				5.4±1.8		
Zhang and Degrange[37]	Variolink II	SBS	Dentin-cement	10	15.01±2.8	Al_2O_3 sandblasting/800 Sic	1-day water storage
	Multilink				21.124±6.6		
	RelyX Unicem				21.117±6.6		
	Maxcem				7.76±1.4		
	Multilink spirit				17.01±2.6		
Attia[38]	RMGI	mTBS	Composite-cement-zirconia	7	18±4.3	Airborne particle abrasion (50 µm AL_2O_3 particle)/silica coating/silica coating and silane application	1 week
	RMGI				7.3±3.5		1 month + 7500 TC
	RelyX Unicem				19.1±4.4		1 week
	RelyX Unicem				9.2±3.9		1 month + 7500 TC
Passos *et al.*[39]	Panavia F2	SBS	Cement-zirconia	12	5.87±4.35		24 h water storage
	Rely x u100				3.64±2.18		
	Maxcem				0.52±1.26		
	Variolink II				0.52±0.62		
	Panavia F2				1.22±1.22		90-day water storage + 12,000tc
	Rely x u100				0		
	Maxcem				0		
	Variolink II				0		
Capa *et al.*[40]	RelyX Unicem	SBS	Composite-cement-zirconia	10	6.55±3.82		24 h storage
	FujiCem				5.04±2.28		
Senyilmaz *et al.*[41]	Panavia F	SBS	Composite-cement-zirconia	10	3.2±1.7	Aluminum grit blasting	24 h-water immersion
	RelyX Unicem				3.7±0.8		
	Maxcem				2.5±1.5		
	Panavia F				2.4±2.1		Thermocycling: 1000 cycles
	RelyX Unicem				1.4±1.6		
	Maxcem				0.2±0.6		

Contd...

Table 2: Contd...

Article	Cement	Test	Interface	Sample size	Mean±SD	Surface treatment	Storage
Piwowarczyk *et al.*[42]	Fleck's zinc	SBS	Composite-cement-zirconia	10	1.1±0.3		30 min
	Fuji one (GI)				1.9±0.5		
	Ketacem (GI)				2.4±0.3		
	Fuji plus				5±0.8		
	Fuji cem				2.5±0.6		
	Rely x luting				1.9±0.3		
	Rely x ARC				4.6±0.9		
	Panavia f				6.6±1.7		
	Variolink II				6.9±1.6		
	Compolute				6.3±1.4		
	Rely x unicem				9.7±2.1		
	Fleck's zinc				0		14 days + 1000 thermocycle
	Fuji one (GI)				0		
	Ketac cem (GI)				0		
	Fuji plus				0.3±0.4		
	Fuji cem				0		
	Rely x luting				1.5±1.3		
	Rely x ARC				4.8±1.8		
	Panavia f				8.3±2.4		
	Variolink II				2.8±0.9		
	Compolute				0		
	Rely x unicem				12.7±2.3		
Peçanha *et al.* (2022)[43]	Rely X u100	MSBS	Cement-zirconia	5	9.9±2.2	No treatment	Stored in distilled water at 37°C for 24 h
	Rely X u100				10.3±1.6	Air abrasion	
	Panavia f				7.61±2.0	No treatment	
	Panavia f				10.1±2.1	Air abrasion	
	Panavia f				1.08±1.1	No treatment	3000 cycles with alternating temperatures of 5°C and 55°C
	Panavia f				2.77±2.3	Air abrasion	
	Rely X u100				2.83±2.2	No treatment	
	Rely X u100				9.6±2.2	Air abrasion	
Sakrana *et al.*[44]	Panavia F2.0	TBS	Composite-ceramic-cement	10	26.6±4.5	Airborne particle abrasion with 50 µm Al_2O_3	Immediate bond strength
	Panavia SA				33.5±2.8		
	TheraCem				15.2±1.7	Before thermal aging	
	Panavia F2.0				20.6±2.5	After thermal aging	
	Panavia SA				21.5±7.3	After thermal aging	
	TheraCem				15.4±1.8	After thermal aging	
Woo *et al.* (2021)[45]	Speed Cem plus	SBS	Cement-zirconia	12	27.52±8.15	Airborne particle abrasion with 50 µm Al_2O_3	Immediate bond strength
Liu *et al.*[46]	Panavia F	SBS	Cement-zirconia	20	24.35±1.45	Air abrasion with 50 µm diameter alumina particles	Stored in distilled water at 37°C for 24 h
	Clearfi SA				20.59±1.0		
	Multi link speed				33.7±0.92		
	Relyx Unicem				17.19±1.12		
	Panavia F				13.84±1.02		5000 cycles with alternating temperatures of 5°C and 55°C
	Clearfi SA				20.13±0.88		
	Multi link speed				21.29±0.82		
	Relyx Unicem				13.74±1.09		
De angelis *et al.*[47]	Panavia V5	SBS	Cement-zirconia	10	22.3±3.3	Air abrasion with 50 µm diameter alumina particles	5000 thermal cycles in a 5°C–55°C range (30 s dwell time; 5 s transport time)
	Panavia SA				21.5±2.9		
	RelyX Unicem 2				12.7±2.6		
Yang *et al.* (2020)[48]	Multilink speed	SBS	Cement-zirconia	15	8.89±0.97	Air-abrasion with 50 µm diameter alumina particles	Stored in 37°C water
	RelyX U200				7.34±1.3		
Dantas *et al.*[49]	RelyX ARC	SBS	Ceramic-cement	10	0.35±0.45	No treatment	Stored for 30 days at 37°C in distilled water
	RelyX ARC				2.46±1.56	Aluminum oxide particles	
	RelyX U200				0.14±0.1	No treatment	
	RelyX U200				10.9±5.65	Aluminum oxide particles	

the data. Based on the results, the immediate bond strength of total-etch cement-zirconia was significantly lower than that of self-adhesive cement-zirconia ($P = 0.000$) [Figure 4].

Group 4: Delayed bond strength of total-etch cement-zirconia versus self-adhesive cement-zirconia.

In this group, 9 eligible articles in 16 categories were imported. The result of Cochran's Q and I^2 tests was respectively, so random effect was used to analyze the data. Based on the results, the delayed bond strength of self-etch cement-zirconia was significantly lower than that of self-adhesive cement-zirconia ($P = 0.000$) [Figure 5].

Table 3: Risk of bias assessment

	Teeth randomization	Teeth free of caries or restoration	Materials used according to the manufacturer's instructions	Adhesive procedures performed by the same operator	Sample size calculation	Blinding of the operator of the testing machine	Risk of bias
Petrauskas A, *et al.* (2018)	Yes	No	Yes	No	No	Yes	Medium
M Gundogdu *et al.* (2018)	No	Yes	Yes	No	No	Yes	Medium
Rebholz *et al.* (2017)	Yes	No	Yes	No	No	Yes	Medium
Lin-jieli (2013)	No	Yes	No	No	No	Yes	High
Gomes *et al.* (2013)	Yes	No	Yes	No	Yes	Yes	Medium
Keul *et al.* (2013)	No	No	Yes	No	No	Yes	High
Gokkaya 2013	Yes	No	Yes	No	No	Yes	Medium
Zhang *et al.* (2010)	Yes	Yes	Yes	No	No	Yes	Medium
Eratilla *et al.* (2016)	No	Yes	Yes	Yes	No	Yes	Medium
Geramipanah *et al.* (2013)	Yes	No	Yes	No	No	Yes	High
Peutzfeldt *et al.* (2011)	Yes	Yes	Yes	No	No	No	Medium
Passos *et al.* (2010)	Yes	No	Yes	No	No	No	High
Senyilmaz *et al.* (2007)	No	No	Yes	No	No	Yes	High
Piwowarczyk (2005)	Yes	No	Yes	No	No	No	High
Stefan *et al.* (2016)	Yes	No	Yes	No	No	No	High
Khalil *et al.* (2015)	No	Yes	Yes	Yes	No	No	Medium
da Silva *et al.* (2014)	No	No	Yes	No	Yes	No	High
Desabarbosa *et al.* (2013)	Yes	No	Yes	No	No	No	High
Miragaya *et al.* (2011)	Yes	No	Yes	No	No	Yes	Medium
Tunc EP *et al.* (2017)	No	No	Yes	No	No	Yes	High
Alvez *et al.* (2016)	Yes	Yes	Yes	Yes	No	Yes	Low
Ayyilidiz *et al.* (2015)	No	No	Yes	No	No	Yes	High
Lee *et al.* (2015)	Yes	No	Yes	No	No	Yes	Medium
Sabatini *et al.* (2013)	Yes	No	Yes	No	No	Yes	Medium
Capa *et al.* (2009)	No	No	Yes	No	No	Yes	High
ATTIA *et al.* (2009)	No	Yes	Yes	No	No	Yes	Medium
Pecanha *et al.* (2021)	No	No	Yes	Yes	No	Yes	Medium
Sakrana *et al.* (2020)	No	No	Yes	No	No	No	High
Woo *et al.* (2020)	No	No	Yes	No	No	No	High
Xiu ju liu *et al.* (2020)	No	No	Yes	Yes	No	Yes	Medium
De angelis *et al.* (2020)	No	No	Yes	Yes	No	Yes	Medium
Yang *et al.* (2020)	Yes	No	No	No	No	No	High
Dantas *et al.* (2019)	Yes	No	Yes	No	No	No	High

The comparison of the bond strength of self-adhesive resin cement to zirconia with resin-modified glass ionomer, glass ionomer, and zinc phosphate cement was performed systemically. Descriptive analysis of the selected articles showed that the bond strength of self-adhesive resin cement to zirconia was significantly higher than that of resin-modified glass ionomer, glass ionomer, and zinc phosphate cement ($P < 0.001$).

DISCUSSION

Today, there is a wide range of materials available for cementing zirconia restorations on dental substrate.[8] These include conventional and resin-modified glass ionomer cement, zinc phosphate, total-etch and self-etch resin cement, and self-adhesive cement. The present study compared the bond strength of self-adhesive and self-etch or total-etch resin cement to zirconia in a meta-analysis. The bond strength of the conventional cement (GI, RMGI, and zinc phosphate) was systematically analyzed. It was concluded that self-etch and self-adhesive resin cement achieves the highest immediate and delayed bond strength to zirconia.

There are three types of bonding interfaces in the studies included in this meta-analysis: cement-zirconia, dentin-cement-zirconia, and composite-cement-zirconia. Since in most of the studies, adhesive failures were reported and only one study[19] showed cohesive failure in cement, the studies were not further divided into subgroups based on the interface.

Piwowarczyk *et al.*[42] found that resin-modified glass ionomer cement do not form a permanent bond with zirconia and that self-etch resin cement containing MDP monomer gives satisfactory results in immediate and delayed bonding. This was confirmed by Lüthy *et al.*,[50] who showed that the bond strength of glass-ionomer cement and Bis-GMA-based composites is lower than that of self-etch resin cement, especially after thermocycling.

On the other hand, Palacios *et al.*[51] showed in a clinical trial that self-etch resin, RMGI, and self-adhesive resin cement form sufficient adhesion to the zirconia copings, which is consistent with the results of Ernst *et al.*[52] However, in these studies, the preparation design as a retentive factor has made it impossible to accurately assess the bonding properties of different cement. Wegner and Kern[53]

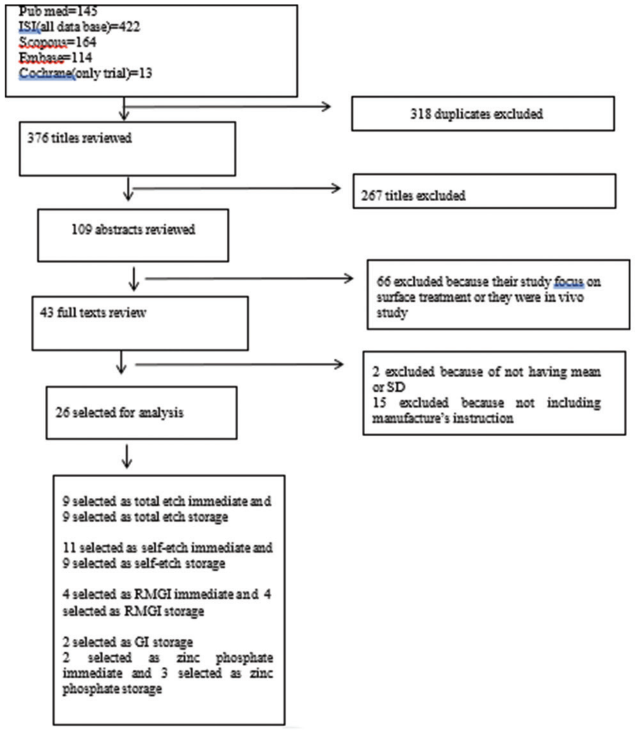


Figure 1: Preferred reporting items for systematic reviews and meta-analyses Flow Diagram. GI: Glass Ionomer, RMGI: Resin Modified Glass Ionomer

reported that Bis-GMA-based cement do not provide durable bond. Although surface treatments improved initial bond strength, their effect decreased over time. Only resin cement with phosphatic monomer resulted in acceptable and durable bond strength after thermocycling.

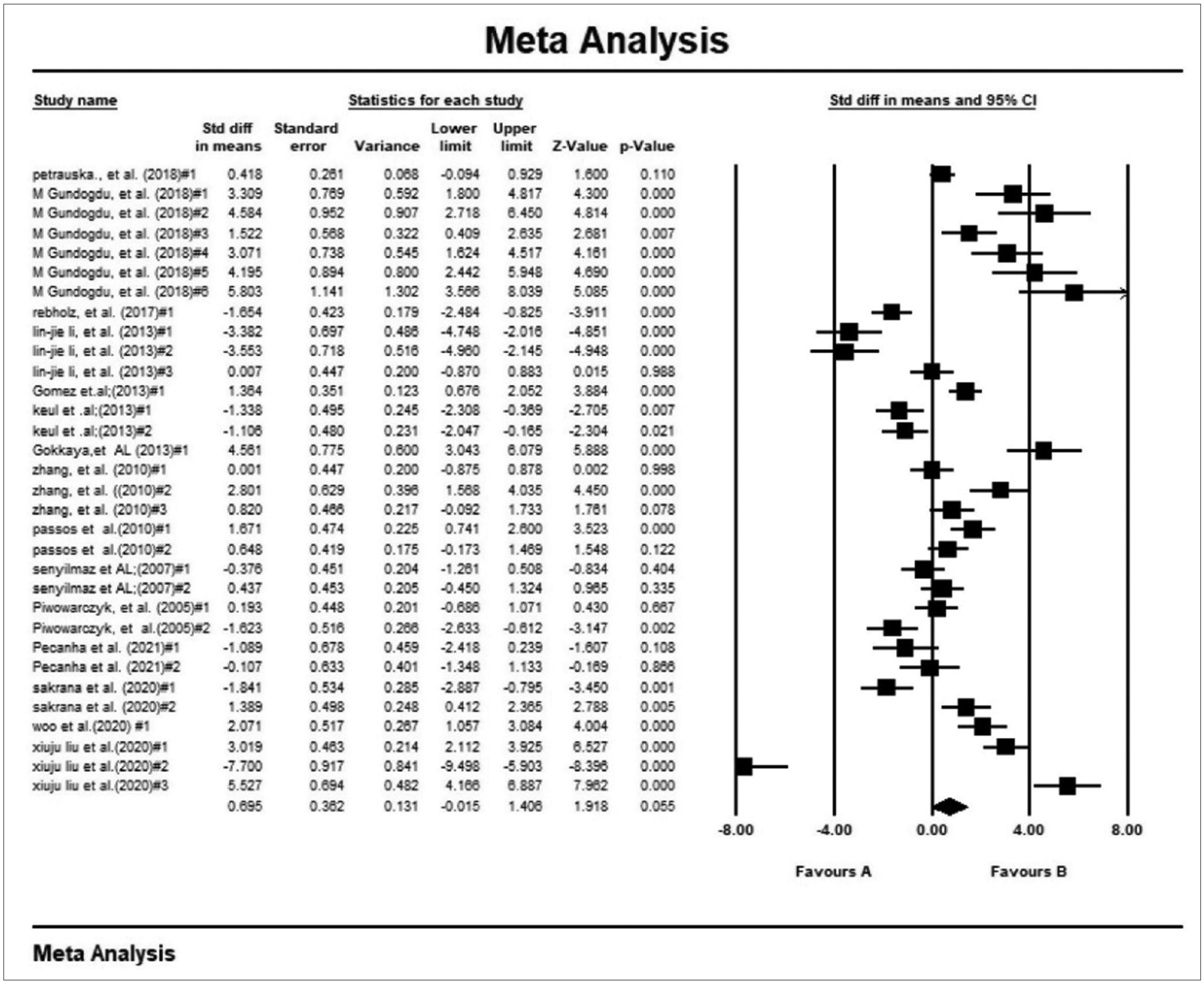
Most of the articles evaluated in this meta-analysis used RelyX Unicem (the self-adhesive cement) as the cement, which contains 10-MDP monomer. Multiple studies have shown that this monomer has the ability to chemically bond to oxides on the surface of zirconia.[11,21]

Total-etch resin cement do not have phosphate monomers in their composition and therefore do not bond with zirconia oxides, which may be a reason for the lower bond strength of these cement compared to self-adhesive resin cement.[20] Furthermore, the presence of 10-MDP in self-adhesive cement, through the formation of nanolayers, makes these cement more resistant to thermal cycles and hydrolytic degradation.[20] A key factor for bonding to zirconia is the presence of 10-MDP monomer; studies have shown that resin cement without 10-MDP have weaker bond compared to the cement containing 10-MDP.[54-56] Petrauskas *et al.*[18] showed that the bond strength of resin cement to zirconia increased with sandblasting the surface with aluminum oxide and using the cement containing 10-MDP monomer.

Many studies have shown that total-etch systems offer higher bond strengths to tooth structure due to etching and removing the smear layer and creating micromechanical retention in dentinal tissue.[57,58] With self-adhesive cement, due to the lack of etching and hybrid layer formation, there is no micromechanical trapping.

It is also noteworthy that in evaluating the bond strength of resin cement to zirconia, when zirconia is bonding to tooth tissue, there are actually two interfaces, namely, the cement-zirconia interface and the cement-dentin interface. When force is applied to evaluate the bond, the weaker interface usually breaks first. Numerous studies have shown that the cement-dentin interface is weaker and debonding usually occurs in this area.[24,59] This can be a confounding factor that prevents accurate evaluation of the bond of these cement to zirconia when tooth-cement-zirconia model is selected for testing.

In this study, the long-term adhesion of self-adhesive cement was higher than that of the total-etch cement. Da Silva *et al*.[29] studied the effect of water storage on the bond strength of RelyX Unicem and the total-etch cement RelyX ARC and reported that the bond strength was 2–3 times higher in self-adhesive cement than that of total-etch cement after 24 h of storage. The bond strength of both cement types decreased significantly after 6 months of storage in water, which was attributed to the poor wetting properties of the untreated zirconia ceramic surface. However, self-adhesive cement with surface treatment and primer MDP had twice the bond strength of total-etch cement after 6 months of storage in water, which generally suggests that self-adhesive cement offers more reliable adhesion to zirconia. Liu *et al.* and Vrochari *et al*. showed that due to the presence of hydrophilic monomers, self-adhesive cement have more water absorption than conventional resin cement and are therefore more prone to hydrolytic degradation.[60,61] de Sá Barbosa *et al*. showed that the bond strength of RelyX Unicem decreased by 81% after 1 year of storage in water. It was found that RelyX Unicem applied to fractured dentin only interacts very superficially without any appearance of a hybrid layer or deep resin tags.[34] This is in contrast to other studies showing that the bond strength of RelyX Unicem does not decrease with storage; Sousa *et al.* observed no decrease in bond strength of 10-MDP inductive adhesive cement after 60 days in water and 5000 thermocycles.[62] The reason for such a discrepancy may be the longer storage time in this study compared to others, allowing more time for water to penetrate the graft surface. Another reason may be the smaller dimensions of the samples in this study, leading to more water infiltration to the surface.[57] Some other studies have shown that without surface preparation and with the use of silane, self-adhesive cement cannot form a durable bond. On the other hand, in this study, the results showed that the immediate and delay bond strength of the



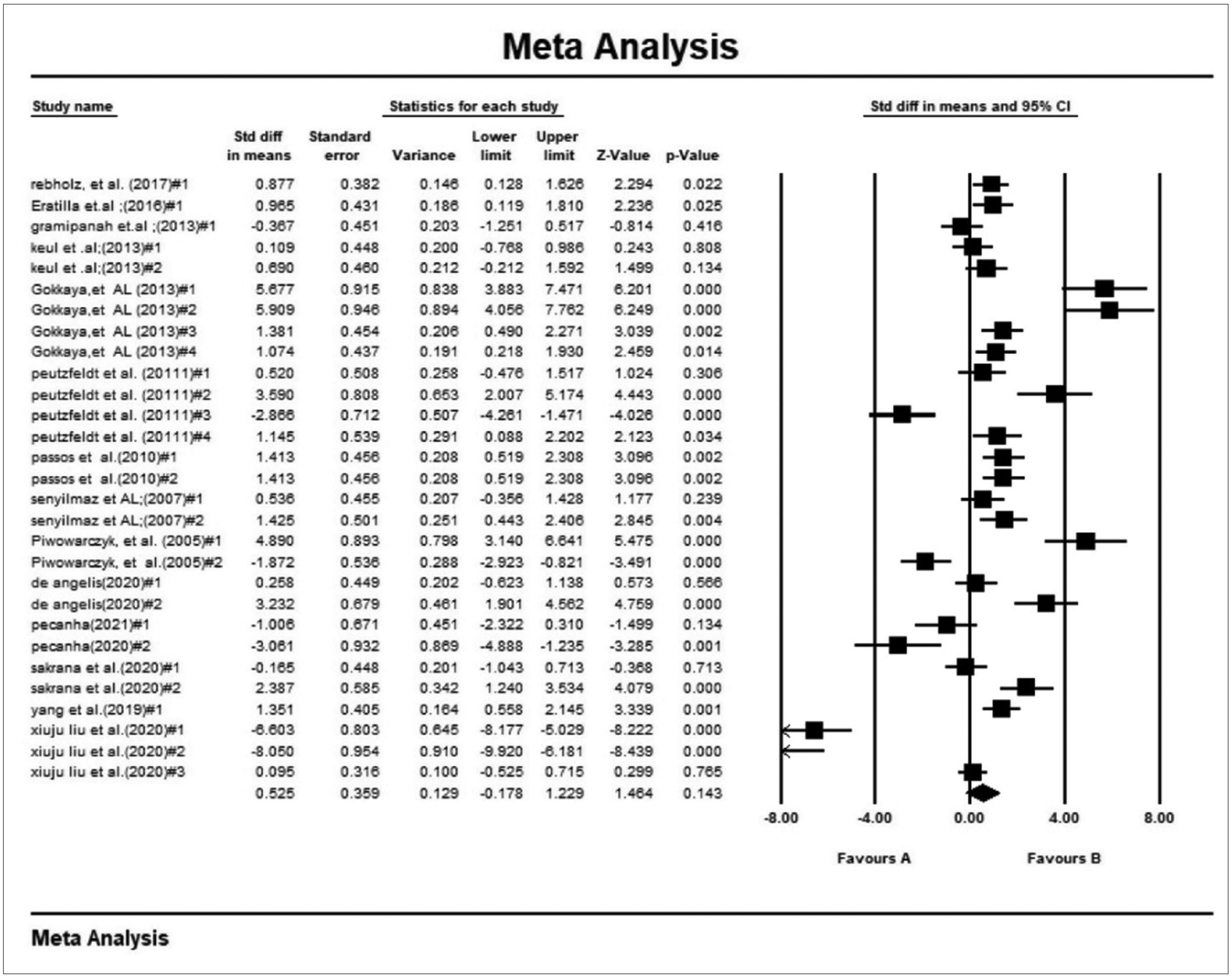
Study name	Statistics for each study						
	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
petrauska., et al. (2018)#1	0.418	0.261	0.068	-0.094	0.929	1.600	0.110
M Gundogdu, et al. (2018)#1	3.309	0.769	0.592	1.800	4.817	4.300	0.000
M Gundogdu, et al. (2018)#2	4.584	0.952	0.907	2.718	6.450	4.814	0.000
M Gundogdu, et al. (2018)#3	1.522	0.568	0.322	0.409	2.635	2.681	0.007
M Gundogdu, et al. (2018)#4	3.071	0.738	0.545	1.624	4.517	4.161	0.000
M Gundogdu, et al. (2018)#5	4.195	0.894	0.800	2.442	5.948	4.690	0.000
M Gundogdu, et al. (2018)#6	5.803	1.141	1.302	3.566	8.039	5.085	0.000
rebholz, et al. (2017)#1	-1.654	0.423	0.179	-2.484	-0.825	-3.911	0.000
lin-jie li, et al. (2013)#1	-3.382	0.697	0.486	-4.748	-2.016	-4.851	0.000
lin-jie li, et al. (2013)#2	-3.553	0.718	0.516	-4.960	-2.145	-4.948	0.000
lin-jie li, et al. (2013)#3	0.007	0.447	0.200	-0.870	0.883	0.015	0.988
Gomez et.al;(2013)#1	1.364	0.351	0.123	0.676	2.052	3.884	0.000
keul et .al;(2013)#1	-1.338	0.495	0.245	-2.308	-0.369	-2.705	0.007
keul et .al;(2013)#2	-1.106	0.480	0.231	-2.047	-0.165	-2.304	0.021
Gokkaya,et AL (2013)#1	4.561	0.775	0.600	3.043	6.079	5.888	0.000
zhang, et al. (2010)#1	0.001	0.447	0.200	-0.875	0.878	0.002	0.998
zhang, et al. ((2010)#2	2.801	0.629	0.396	1.568	4.035	4.450	0.000
zhang, et al. (2010)#3	0.820	0.466	0.217	-0.092	1.733	1.761	0.078
passos et al.(2010)#1	1.671	0.474	0.225	0.741	2.600	3.523	0.000
passos et al.(2010)#2	0.648	0.419	0.175	-0.173	1.469	1.548	0.122
senyilmaz et AL;(2007)#1	-0.376	0.451	0.204	-1.261	0.508	-0.834	0.404
senyilmaz et AL;(2007)#2	0.437	0.453	0.205	-0.450	1.324	0.965	0.335
Piwowarczyk, et al. (2005)#1	0.193	0.448	0.201	-0.686	1.071	0.430	0.667
Piwowarczyk, et al.(2005)#2	-1.623	0.516	0.266	-2.633	-0.612	-3.147	0.002
Pecanha et al. (2021)#1	-1.089	0.678	0.459	-2.418	0.239	-1.607	0.108
Pecanha et al. (2021)#2	-0.107	0.633	0.401	-1.348	1.133	-0.169	0.866
sakrana et al. (2020)#1	-1.841	0.534	0.285	-2.887	-0.795	-3.450	0.001
sakrana et al. (2020)#2	1.389	0.498	0.248	0.412	2.365	2.788	0.005
woo et al.(2020) #1	2.071	0.517	0.267	1.057	3.084	4.004	0.000
xiuju liu et al.(2020)#1	3.019	0.463	0.214	2.112	3.925	6.527	0.000
xiuju liu et al.(2020)#2	-7.700	0.917	0.841	-9.498	-5.903	-8.396	0.000
xiuju liu et al.(2020)#3	5.527	0.694	0.482	4.166	6.887	7.962	0.000
	0.695	0.362	0.131	-0.015	1.406	1.918	0.055

Figure 2: Forest plot of immediate bond strength of self-etch cement-zirconia versus self-adhesive cement-zirconia. CI: Confidence interval

self-adhesive resin cement to zirconia has no significant difference with the bond strength of self-etch resin cement to zirconia. It should be noted that with self-adhesive cement, there is no demineralization of the dentin and minimal hybrid layer formation, and therefore the bond only relies on the chemical bond. However, in self-etch resin cement a combination of micromechanical retention and chemical bond forms the ultimate bond.[19]

According to Attia, self-etch resin cement, such as Multilink Automix, contains no phosphate monomer, but dimethacrylate, Hydroxyethylmethacrylate (HEMA), and silica fillers that provide a good bond strength with zirconia similar to that of self-adhesive cement.[38] In this study, the decrease in bond strength after 30 days of storage in water may be due to the loosening of the cement and the hydrolytic effect of water on the surface between the ceramic and the cement. On the other hand, some articles have reported better results using multilink self-etching cement on the zirconia surface sandblasted with aluminum particles, which is directly related to resin cement containing hydroxyethyl methacrylate, dimethacrylate, and silica filler particles. These components are responsible for increasing the flexural strength of resin cement and do not necessarily increase the bond strength of zirconia ceramics.[20] Therefore, in addition to the functional monomer, the mechanical properties and flexural strength of resin cement seem also to influence the bond strength.

Geramipanah *et al.* found no difference in bond strength of Unicem self-adhesive cement and Panavia F2.0 self-adhesive cement to zirconia and both showed higher bond strength than conventional resin cement with bis-GMA. The reason for such a difference was the lack of functional monomers and surface hydrophobic layer, leading to more water penetration and bond hydrolysis.[31]



Study name	Statistics for each study						
	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
rebholz, et al. (2017)#1	0.877	0.382	0.146	0.128	1.626	2.294	0.022
Eratilla et.al ;(2016)#1	0.965	0.431	0.186	0.119	1.810	2.236	0.025
gramipanah et.al ;(2013)#1	-0.367	0.451	0.203	-1.251	0.517	-0.814	0.416
keul et .al;(2013)#1	0.109	0.448	0.200	-0.768	0.986	0.243	0.808
keul et .al;(2013)#2	0.690	0.460	0.212	-0.212	1.592	1.499	0.134
Gokkaya,et AL (2013)#1	5.677	0.915	0.838	3.883	7.471	6.201	0.000
Gokkaya,et AL (2013)#2	5.909	0.946	0.894	4.056	7.762	6.249	0.000
Gokkaya,et AL (2013)#3	1.381	0.454	0.206	0.490	2.271	3.039	0.002
Gokkaya,et AL (2013)#4	1.074	0.437	0.191	0.218	1.930	2.459	0.014
peutzfeldt et al. (20111)#1	0.520	0.508	0.258	-0.476	1.517	1.024	0.306
peutzfeldt et al. (20111)#2	3.590	0.808	0.653	2.007	5.174	4.443	0.000
peutzfeldt et al. (20111)#3	-2.866	0.712	0.507	-4.261	-1.471	-4.026	0.000
peutzfeldt et al. (20111)#4	1.145	0.539	0.291	0.088	2.202	2.123	0.034
passos et al.(2010)#1	1.413	0.456	0.208	0.519	2.308	3.096	0.002
passos et al.(2010)#2	1.413	0.456	0.208	0.519	2.308	3.096	0.002
senyilmaz et AL;(2007)#1	0.536	0.455	0.207	-0.356	1.428	1.177	0.239
senyilmaz et AL;(2007)#2	1.425	0.501	0.251	0.443	2.406	2.845	0.004
Piwowarczyk, et al. (2005)#1	4.890	0.893	0.798	3.140	6.641	5.475	0.000
Piwowarczyk, et al.(2005)#2	-1.872	0.536	0.288	-2.923	-0.821	-3.491	0.000
de angelis(2020)#1	0.258	0.449	0.202	-0.623	1.138	0.573	0.566
de angelis(2020)#2	3.232	0.679	0.461	1.901	4.562	4.759	0.000
pecanha(2021)#1	-1.006	0.671	0.451	-2.322	0.310	-1.499	0.134
pecanha(2020)#2	-3.061	0.932	0.869	-4.888	-1.235	-3.285	0.001
sakrana et al.(2020)#1	-0.165	0.448	0.201	-1.043	0.713	-0.368	0.713
sakrana et al.(2020)#2	2.387	0.585	0.342	1.240	3.534	4.079	0.000
yang et al.(2019)#1	1.351	0.405	0.164	0.558	2.145	3.339	0.001
xiuju liu et al.(2020)#1	-6.603	0.803	0.645	-8.177	-5.029	-8.222	0.000
xiuju liu et al.(2020)#2	-8.050	0.954	0.910	-9.920	-6.181	-8.439	0.000
xiuju liu et al.(2020)#3	0.095	0.316	0.100	-0.525	0.715	0.299	0.765
	0.525	0.359	0.129	-0.178	1.229	1.464	0.143

Figure 3: Forest plot of delayed bond strength of self-etch cement-zirconia versus self-adhesive cement-zirconia. CI: Confidence interval

In the present meta-analysis, the immediate and long-term bond strength of self-adhesive cement was higher than those of resin-modified glass ionomer cement. Yang *et al*.[48] showed that the bond strength of RMGI cement is higher than that of cement without phosphate ester monomer. Furthermore, the bond strength of RMGI cement was stronger than that of an adhesive self-adhesive cement without MDP Esther.

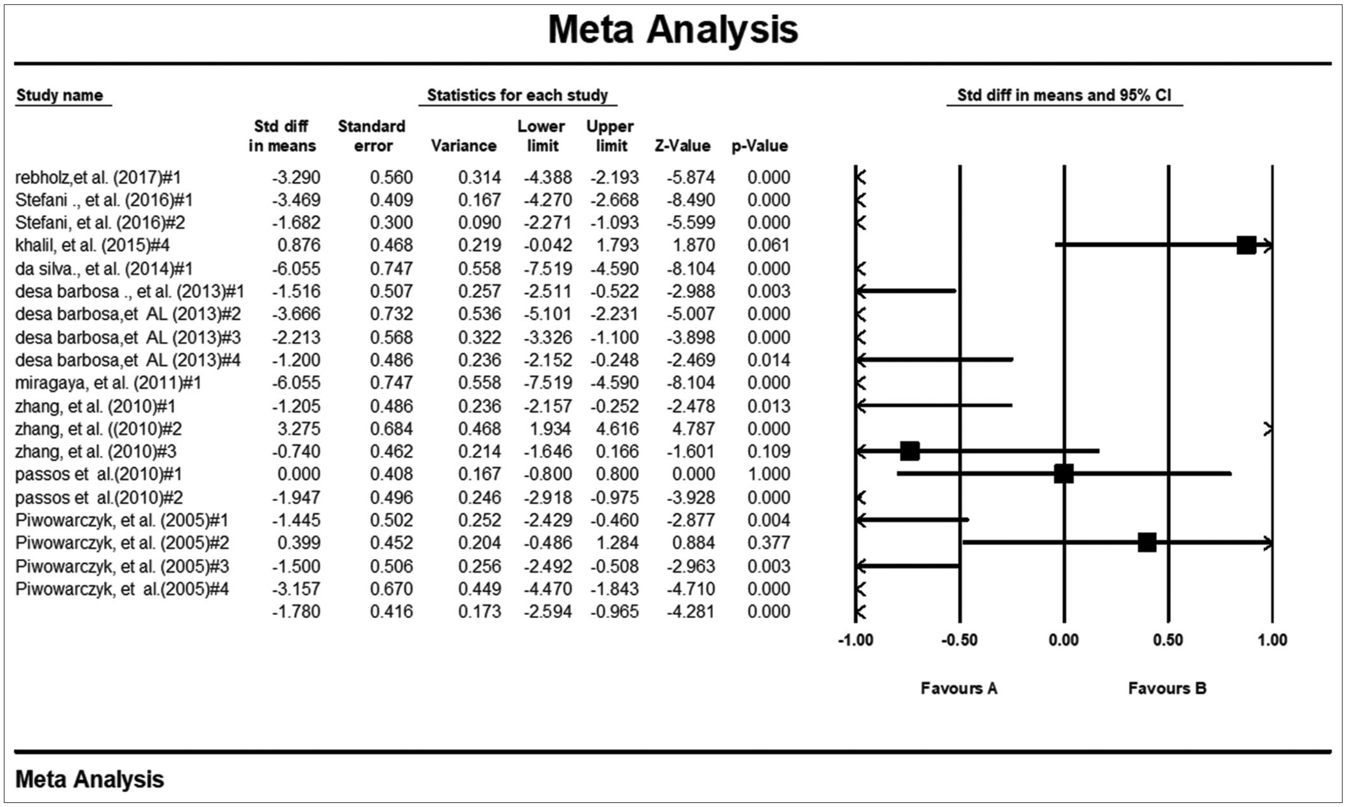
MDP bonding to zirconia has been shown to occur due to the dual function of the MDP molecule, including a hydroxyl group at one end of the phosphate group which forms a bond with zirconia and a saturated carbon at the other end causing additional polymerization with unsaturated carbon in the matrix during curing. However, it has been stated the use of MDP-containing primer before RMGI does not increase the bond strength of this cement. The lower bond strength of RMGI cement may be due to the inability of the composite resin in RMGI to produce sufficient unsaturated carbon for polymerization with MDP.[63]

A zinc phosphate cement claim that, according to the manufacturer, can be used to cement zirconia restorations. However, various studies have shown that this cement has a weaker bond than resin cement.[64]

The present study also systemically reviewed that self-adhesive cement has higher bond strength than zinc phosphate cement. Zinc phosphate cement only leads to micromechanical retention and does not form any chemical bond to the tooth structure and it is not water soluble. The effect of using MDP-containing primers on the bond strength of these cement to zirconia has also been studied, and it has been reported that the presence of 10-MDP monomer has no significant effect on the bond strength of zinc phosphate cement.[28,65]

CONCLUSION

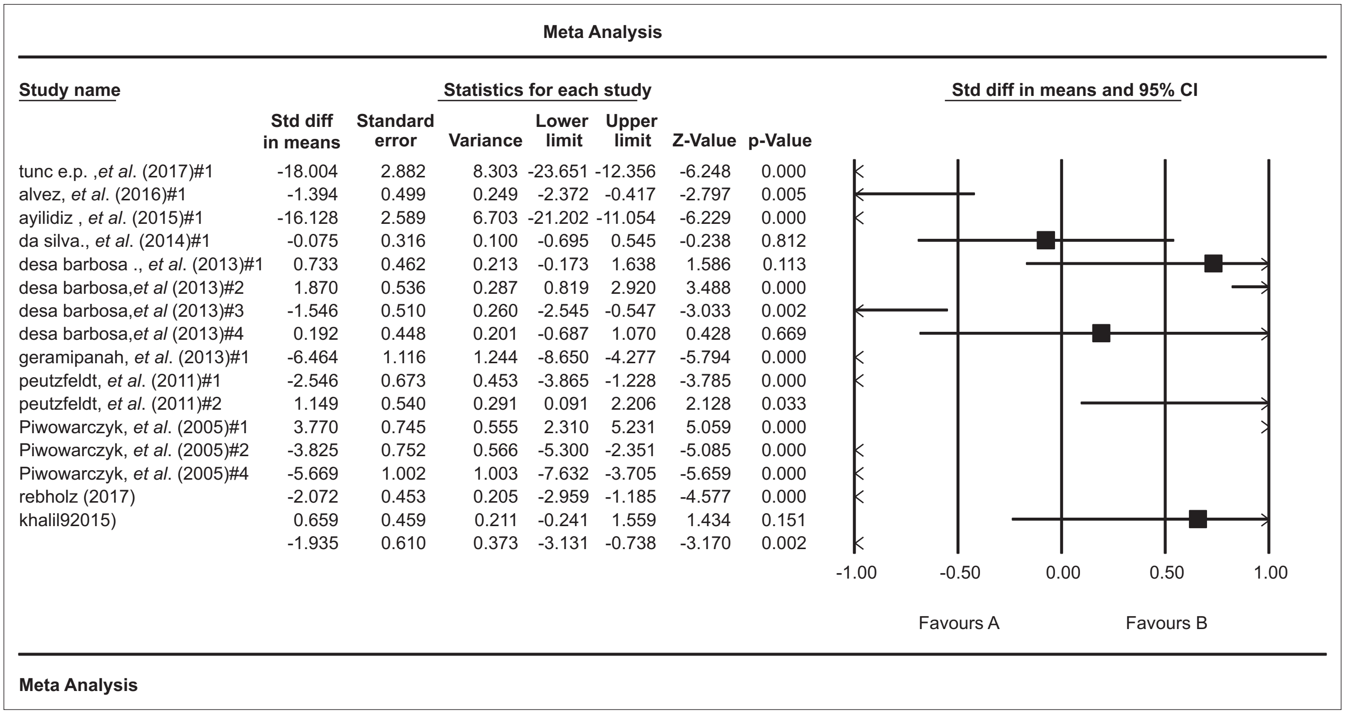
The immediate and delayed bond strength of self-adhesive



Meta Analysis

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
rebholz,et al. (2017)#1	-3.290	0.560	0.314	-4.388	-2.193	-5.874	0.000
Stefani ., et al. (2016)#1	-3.469	0.409	0.167	-4.270	-2.668	-8.490	0.000
Stefani, et al. (2016)#2	-1.682	0.300	0.090	-2.271	-1.093	-5.599	0.000
khalil, et al. (2015)#4	0.876	0.468	0.219	-0.042	1.793	1.870	0.061
da silva., et al. (2014)#1	-6.055	0.747	0.558	-7.519	-4.590	-8.104	0.000
desa barbosa ., et al. (2013)#1	-1.516	0.507	0.257	-2.511	-0.522	-2.988	0.003
desa barbosa,et AL (2013)#2	-3.666	0.732	0.536	-5.101	-2.231	-5.007	0.000
desa barbosa,et AL (2013)#3	-2.213	0.568	0.322	-3.326	-1.100	-3.898	0.000
desa barbosa,et AL (2013)#4	-1.200	0.486	0.236	-2.152	-0.248	-2.469	0.014
miragaya, et al. (2011)#1	-6.055	0.747	0.558	-7.519	-4.590	-8.104	0.000
zhang, et al. (2010)#1	-1.205	0.486	0.236	-2.157	-0.252	-2.478	0.013
zhang, et al. ((2010)#2	3.275	0.684	0.468	1.934	4.616	4.787	0.000
zhang, et al. (2010)#3	-0.740	0.462	0.214	-1.646	0.166	-1.601	0.109
passos et al.(2010)#1	0.000	0.408	0.167	-0.800	0.800	0.000	1.000
passos et al.(2010)#2	-1.947	0.496	0.246	-2.918	-0.975	-3.928	0.000
Piwowarczyk, et al. (2005)#1	-1.445	0.502	0.252	-2.429	-0.460	-2.877	0.004
Piwowarczyk, et al. (2005)#2	0.399	0.452	0.204	-0.486	1.284	0.884	0.377
Piwowarczyk, et al. (2005)#3	-1.500	0.506	0.256	-2.492	-0.508	-2.963	0.003
Piwowarczyk, et al.(2005)#4	-3.157	0.670	0.449	-4.470	-1.843	-4.710	0.000
	-1.780	0.416	0.173	-2.594	-0.965	-4.281	0.000

Figure 4: Forest plot of immediate bond strength of total-etch cement-zirconia versus self-adhesive cement-zirconia. CI: Confidence interval



Meta Analysis

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
tunc e.p. ,*et al*. (2017)#1	-18.004	2.882	8.303	-23.651	-12.356	-6.248	0.000
alvez, *et al*. (2016)#1	-1.394	0.499	0.249	-2.372	-0.417	-2.797	0.005
ayilidiz , *et al*. (2015)#1	-16.128	2.589	6.703	-21.202	-11.054	-6.229	0.000
da silva., *et al*. (2014)#1	-0.075	0.316	0.100	-0.695	0.545	-0.238	0.812
desa barbosa ., *et al*. (2013)#1	0.733	0.462	0.213	-0.173	1.638	1.586	0.113
desa barbosa,*et al* (2013)#2	1.870	0.536	0.287	0.819	2.920	3.488	0.000
desa barbosa,*et al* (2013)#3	-1.546	0.510	0.260	-2.545	-0.547	-3.033	0.002
desa barbosa,*et al* (2013)#4	0.192	0.448	0.201	-0.687	1.070	0.428	0.669
geramipanah, *et al*. (2013)#1	-6.464	1.116	1.244	-8.650	-4.277	-5.794	0.000
peutzfeldt, *et al*. (2011)#1	-2.546	0.673	0.453	-3.865	-1.228	-3.785	0.000
peutzfeldt, *et al*. (2011)#2	1.149	0.540	0.291	0.091	2.206	2.128	0.033
Piwowarczyk, *et al*. (2005)#1	3.770	0.745	0.555	2.310	5.231	5.059	0.000
Piwowarczyk, *et al*. (2005)#2	-3.825	0.752	0.566	-5.300	-2.351	-5.085	0.000
Piwowarczyk, *et al*. (2005)#4	-5.669	1.002	1.003	-7.632	-3.705	-5.659	0.000
rebholz (2017)	-2.072	0.453	0.205	-2.959	-1.185	-4.577	0.000
khalil92015)	0.659	0.459	0.211	-0.241	1.559	1.434	0.151
	-1.935	0.610	0.373	-3.131	-0.738	-3.170	0.002

Figure 5: Forest plot of delayed bond strength of total-etch cement-zirconia versus self-adhesive cement-zirconia. CI: Confidence interval

resin cement to zirconia was significantly higher than those of total-etch resin cement. No significant difference was found between the self-etched and self-adhesive resin cement in terms of bond strength to zirconia. In addition, self-adhesive cement showed significantly higher immediate and delayed bond strengths to zirconia compared to resin-modified glass ionomer and zinc phosphate cement.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Azeem RA, Sureshbabu NM. Clinical performance of direct versus indirect composite restorations in posterior teeth: A systematic review. J Conserv Dent 2018;21:2-9.
2. Guess PC, Schultheis S, Bonfante EA, Coelho PG, Ferencz JL, Silva NR. All-ceramic systems: Laboratory and clinical performance. Dent Clin North Am 2011;55:333-52, ix.
3. Zhang Y, Kelly JR. Dental ceramics for restoration and metal veneering. Dent Clin North Am 2017;61:797-819.
4. Zhang Y, Lawn BR. Novel zirconia materials in dentistry. J Dent Res 2018;97:140-7.
5. Scaminaci Russo D, Cinelli F, Sarti C, Giachetti L. Adhesion to zirconia: A systematic review of current conditioning methods and bonding materials. Dent J (Basel) 2019;7:74.
6. Zhang CY, Cheng YL, Tong XW, Yu H, Cheng H. *In vitro* cytotoxicity of self-adhesive dual-cured resin cement polymerized beneath three different cusp inclinations of zirconia. Biomed Res Int 2019;2019:7404038.
7. Ansari S, Jahedmanesh N, Cascione D, Zafarnia P, Shah KC, Wu BM, *et al.* Effects of an etching solution on the adhesive properties and surface microhardness of zirconia dental ceramics. J Prosthet Dent 2018;120:447-53.
8. Liu L, Liu S, Song X, Zhu Q, Zhang W. Effect of Nd: YAG laser irradiation on surface properties and bond strength of zirconia ceramics. Lasers Med Sci 2015;30:627-34.
9. Jiao Y, Wang JD, Deng JP. Effect of different surface treatments on the crystal structure and properties of zirconia. Beijing Da Xue Xue Bao Yi Xue Ban 2018;50:49-52.
10. Nagaoka N, Yoshihara K, Tamada Y, Yoshida Y, Meerbeek BV. Ultrastructure and bonding properties of tribochemical silica-coated zirconia. Dent Mater J 2019;38:107-13.
11. Gomes AL, Castillo-Oyagüe R, Lynch CD, Montero J, Albaladejo A. Influence of sandblasting granulometry and resin cement composition on microtensile bond strength to zirconia ceramic for dental prosthetic frameworks. J Dent 2013;41:31-41.
12. Özcan M, Bernasconi M. Adhesion to zirconia used for dental restorations: A systematic review and meta-analysis. J Adhes Dent 2015;17:7-26.
13. Nagaoka N, Yoshihara K, Feitosa VP, Tamada Y, Irie M, Yoshida Y, *et al.* Chemical interaction mechanism of 10-MDP with zirconia. Sci Rep 2017;7:45563.
14. Kitayama S, Nikaido T, Takahashi R, Zhu L, Ikeda M, Foxton RM, *et al.* Effect of primer treatment on bonding of resin cements to zirconia ceramic. Dent Mater 2010;26:426-32.
15. Koizumi H, Nakayama D, Komine F, Blatz MB, Matsumura H. Bonding of resin-based luting cements to zirconia with and without the use of ceramic priming agents. J Adhes Dent 2012;14:385-92.
16. 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;25:392-9.
17. Sarkis-Onofre R, Skupien JA, Cenci MS, Moraes RR, Pereira-Cenci T. The role of resin cement on bond strength of glass-fiber posts luted into root canals: A systematic review and meta-analysis of *in vitro* studies. Oper Dent 2014;39:E31-44.
18. Petrauskas A, Novaes Olivieri KA, Pupo YM, Berger G, Gonçalves Betiol EÁ. Influence of different resin cements and surface treatments on microshear bond strength of zirconia-based ceramics. J Conserv Dent 2018;21:198-204.
19. Gundogdu M, Aladag LI. Effect of adhesive resin cements on bond strength of ceramic core materials to dentin. Niger J Clin Pract 2018;21:367-74.
20. Tunc EP, Ozer F, Ayyildiz S, Ula TA, Sen D. The effect of MDP-based primer on shear bond strength of various cements to two different ceramic materials. J Adh Sci Technol 2017;31:1142-50.
21. Rebholz-Zaribaf N, Ozcan M. Adhesion to zirconia as a function of primers/silane coupling agents, luting cement types, aging and test methods. J Adh Sci Technol 2017;31:1408-21.
22. Stefani A, Brito RB Jr., Kina S, Andrade OS, Ambrosano GM, Carvalho AA, *et al.* Bond strength of resin cements to zirconia ceramic using adhesive primers. J Prosthodont 2016;25:380-5.
23. Eratilla V, Yildiz AD, Guven S, Eratilla EA, Karaman T, Aguloglu S, *et al.* Measuring the resistance of different substructure materials by sticking them to dentine with two different resin cements *in vitro*. Niger J Clin Pract 2016;19:730-6.
24. Alves M, Campos F, Bergoli CD, Bottino MA, Özcan M, Souza R. Effect of adhesive cementation strategies on the bonding of Y-TZP to human dentin. Oper Dent 2016;41:276-83.
25. Lin J, Shinya A, Gomi H, Shinya A. Effect of self-adhesive resin cement and tribochemical treatment on bond strength to zirconia. Int J Oral Sci 2010;2:28-34.
26. Lee SE, Bae JH, Choi JW, Jeon YC, Jeong CM, Yoon MJ, *et al.* Comparative shear-bond strength of six dental self-adhesive resin cements to zirconia. Materials (Basel) 2015;8:3306-15.
27. Khalil AA, Abdelaziz KM. Bonding values of two contemporary ceramic inlay materials to dentin following simulated aging. J Adv Prosthodont 2015;7:446-53.
28. Ayyildiz S, Emir F, Pak Tunc E, Sen D. Shear bond strength of various luting cements to fixed prosthodontic restorative materials. Appl Adh Sci 2015;3:13.
29. da Silva EM, Miragaya L, Sabrosa CE, Maia LC. Stability of the bond between two resin cements and an yttria-stabilized zirconia ceramic after six months of aging in water. J Prosthet Dent 2014;112:568-75.
30. Sabatini C, Patel M, D'Silva E. *In vitro* shear bond strength of three self-adhesive resin cements and a resin-modified glass Ionomer cement to various prosthodontic substrates. Oper Dent 2013;38:186-96.
31. Geramipanah F, Majidpour M, Sadighpour L, Fard MJ. Effect of artificial saliva and pH on shear bond strength of resin cements to zirconia-based ceramic. Eur J Prosthodont Restor Dent 2013;21:5-8.
32. Keul C, Liebermann A, Roos M, Uhrenbacher J, Stawarczyk B. The effect of ceramic primer on shear bond strength of resin composite cement to zirconia: A function of water storage and thermal cycling. J Am Dent Assoc 2013;144:1261-71.
33. Gökkaya FA, Stawarczyk B, Hämmerle CH, Sailer I. Influence of silanes on the shear bond strength of resin cements to zirconia. Quintessence Int 2013;44:591-600.
34. de Sá Barbosa WF, Aguiar TR, Francescantonio MD, Cavalcanti AN, de Oliveira MT, Giannini M. Effect of water storage on bond strength of self-adhesive resin cements to zirconium oxide ceramic. J Adhes Dent 2013;15:145-50.
35. Peutzfeldt A, Sahafi A, Flury S. Bonding of restorative materials to dentin with various luting agents. Oper Dent 2011;36:266-73.
36. Miragaya L, Maia LC, Sabrosa CE, de Goes MF, da Silva EM. Evaluation of self-adhesive resin cement bond strength to yttria-stabilized zirconia ceramic (Y-TZP) using four surface treatments. J Adhes Dent 2011;13:473-80.
37. Zhang C, Degrange M. Shear bond strengths of self-adhesive luting resins fixing dentine to different restorative materials. J Biomater Sci Polym Ed 2010;21:593-608.
38. Attia A. Bond strength of three luting agents to zirconia ceramic – Influence of surface treatment and thermocycling. J Appl Oral Sci 2011;19:388-95.
39. Passos SP, May LG, Barca DC, Ozcan M, Bottino MA, Valandro LF. Adhesive quality of self-adhesive and conventional adhesive resin cement to Y-TZP ceramic before and after aging conditions. Oper Dent 2010;35:689-96.
40. Capa N, Ozkurt Z, Canpolat C, Kazazoglu E. Shear bond strength of luting agents to fixed prosthodontic restorative core materials. Aust Dent J 2009;54:334-40.
41. Senyilmaz DP, Palin WM, Shortall AC, Burke FJ. The effect of surface preparation and luting agent on bond strength to a zirconium-based ceramic. Oper Dent 2007;32:623-30.
42. Piwowarczyk A, Lauer HC, Sorensen JA. The shear bond strength between luting cements and zirconia ceramics after two pre-treatments. Oper Dent 2005;30:382-8.

43. Peçanha MM, Amaral M, Baroudi K, Frizzera F, Vitti R, Silva-Concilio L. Improving the bonding stability between resin cements and zirconia-based ceramic using different surface treatments. Int J Prosthodont 2022;35:414-9.
44. 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;28:161-71.
45. Woo ES, Goldstein G, Choi M, Bromage TG. *In vitro* shear bond strength of 2 resin cements to zirconia and lithium disilicate: An *in vitro* study. J Prosthet Dent 2021;125:529-34.
46. Liu X, Jiang X, Xu T, Zhao Q, Zhu S. Investigating the shear bond strength of five resin-based luting agents to zirconia ceramics. J Oral Sci 2020;62:84-8.
47. 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 Restor Dent 2020;32:806-14.
48. Yang L, Chen B, Meng H, Zhang H, He F, Xie H, *et al.* Bond durability when applying phosphate ester monomer-containing primers versus self-adhesive resin cements to zirconia: Evaluation after different aging conditions. J Prosthodont Res 2020;64:193-201.
49. Dantas AM, Campos F, Pereira SM, Dos Santos EJ, Pereira LL, Moura DM, *et al.* The effect of air-particle abrasion and a zirconia primer application on resin cement bonding strength to zirconia. Minerva Stomatol 2019;68:89-94.
50. Lüthy H, Loeffel O, Hammerle CH. Effect of thermocycling on bond strength of luting cements to zirconia ceramic. Dent Mater 2006;22:195-200.
51. Palacios RP, Johnson GH, Phillips KM, Raigrodski AJ. Retention of zirconium oxide ceramic crowns with three types of cement. J Prosthet Dent 2006;96:104-14.
52. 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;93:551-8.
53. Wegner SM, Kern M. Long-term resin bond strength to zirconia ceramic. J Adhes Dent 2000;2:139-47.
54. Gerth HU, Dammaschke T, Züchner H, Schäfer E. Chemical analysis and bonding reaction of RelyX Unicem and Bifix composites – A comparative study. Dent Mater 2006;22:934-41.
55. Blatz MB, Phark JH, Ozer F, Mante FK, Saleh N, Bergler M, *et al. In vitro* comparative bond strength of contemporary self-adhesive resin cements to zirconium oxide ceramic with and without air-particle abrasion. Clin Oral Investig 2010;14:187-92.
56. Mirmohammadi H, Aboushelib MN, Salameh Z, Feilzer AJ, Kleverlaan CJ. Innovations in bonding to zirconia based ceramics: Part III. Phosphate monomer resin cements. Dent Mater 2010;26:786-92.
57. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, *et al.* Buonocore memorial lecture. Adhesion to enamel and dentin: Current status and future challenges. Oper Dent 2003;28:215-35.
58. Pisani-Proença J, Erhardt MC, Amaral R, Valandro LF, Bottino MA, Del Castillo-Salmerón R. Influence of different surface conditioning protocols on microtensile bond strength of self-adhesive resin cements to dentin. J Prosthet Dent 2011;105:227-35.
59. Bottino MA, Bergoli C, Lima EG, Marocho SM, Souza RO, Valandro LF. Bonding of Y-TZP to dentin: Effects of Y-TZP surface conditioning, resin cement type, and aging. Oper Dent 2014;39:291-300.
60. Vrochari AD, Eliades G, Hellwig E, Wrbas KT. Water sorption and solubility of four self-etching, self-adhesive resin luting agents. J Adhes Dent 2010;12:39-43.
61. Liu Q, Meng X, Yoshida K, Luo X. Bond degradation behavior of self-adhesive cement and conventional resin cements bonded to silanized ceramic. J Prosthet Dent 2011;105:177-84.
62. Sousa RS, Campos F, Sarmento HR, Alves ML, Dal Piva AM, Gondim LD, *et al.* Surface roughness and bond strength between Y-TZP and self-adhesive resin cement after air particle abrasion protocols. Gen Dent 2016;64:50-5.
63. 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;23:117-23.
64. Heboyan A, Vardanyan A, Karobari MI, Marya A, Avagyan T, Tebyaniyan H, *et al.* Dental luting cements: An updated comprehensive review. Molecules 2023;28:1619.
65. 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;113:609-15.