Is the bond strength of zirconia-reinforced lithium silicate lower than that of lithium disilicate? A systematic review and meta-analysis

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Abstract

Purpose: This study systematically reviewed the literature to compare the bond strength of resin composites with that of zirconia-reinforced lithium silicate (ZLS) and lithium disilicate (LD).

Study selection: This review was structured based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement. This study was registered at the International Prospective Register of Systematic Reviews (CRD42021256900). Studies were searched via PubMed, Web of Science, and Google Scholar databases without language or publication year limits. *In vitro* studies that evaluated the bond strength of the resin composites to ZLS and LD were included. The risk of bias in all the included articles was evaluated. Statistical analyses were performed using the Review Manager software (version 5.3, Cochrane Collaboration, Oxford, UK).

Results: Of the 90 potentially related articles, the full texts of 16 articles were evaluated after screening. Finally, seven studies were included in the qualitative synthesis and meta-analysis. All the studies presented a medium risk of bias. The results showed no significant difference in bond strength between the ZLS and LD groups ($P = 0.94$, mean difference = 0.08, and 95% confidence interval = -1.93 to 2.10). However, a significant difference was found in the subgroup analysis considering different types of aging treatments ($P = 0.0008$) and different types of bond strength tests ($P < 0.00001$).

Conclusion: The bond strength of resin composites was found to be similar to that of ZLS and LD, but different aging treatments and bond strength tests exhibited varying effects on the bond strength.

Keywords: Zirconia-reinforced lithium silicate, Lithium disilicate, Bond strength

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1. Introduction

Interest in chairside computer-aided design and computer-aided manufacturing (CAD/CAM) has been growing since its introduction to dentistry in the 1980s [1-3]. Currently, chairside restorations are fabricated in a monolithic manner using glass ceramics [4], mainly lithium disilicate (LD). LD has been widely used for anterior and posterior single-unit restorations because of its excellent esthetic and physical properties [5-8]. However, to date, no clinical evidence has presented satisfactory long-term outcomes when LD is used for fixed dental prostheses (FDPs) [9]. Kern et al. [10] reported a survival rate of 87.9% and a success rate of 69.8% when 3-unit FDPs were fabricated using LD after 10 years. Therefore, LD needs to be optimized to withstand high mechanical stresses and obtain long-term reliability, at least for multiple-unit FDPs [10].

One way to enhance LD is to add approximately 8-12% zirconia

to lithium silicate and form a new generation of CAD/CAM block materials, known as zirconia-reinforced lithium silicate (ZLS) (e.g., Celtra Duo, Dentsply Sirona, and VITA Suprinity, Vita ZahnFabrik) [11,12]. ZLS incorporates zirconia particles as reinforcing fillers to reinforce fracture resistance through crack interruption [13,14]. The lithium disilicate content in ZLS is relatively lower than that in LD (56-64% vs. 57-80%) [11]. The esthetic and mechanical properties of ZLS improve owing to fine-grained uniform glass crystals (0.5-0.7 μm) and the addition of zirconia (8-12%) [11,12,15]. It has been reported that the flexural strength of ZLS (405-553 MPa) is higher than that of LD (300-441 MPa) [14,16-18].

In addition to mechanical properties, bonding also plays a key role in the long-term survival of dental restorations [19,20]. Bonding to LD is considerably mature, yielding durable results as long as the recommended procedures are followed [21]. Currently, the recommended pretreatment for LD is hydrofluoric (HF) acid etching followed by silane application, which has been considered the gold standard for silicon-based ceramics [22]. HF acid creates an appropriate microstructure for bonding by dissolving glassy phases of porcelain and increases the surface area of ceramic bonding [23-25]. Subsequently, silanes, as chemical couplers, create sufficient bond-

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ing between the resin and silica-based ceramics [22,26]. For ZLS, a similar pretreatment has been recommended by manufacturers [27,28]. Previous studies have shown that the shear bond strength of LD ranges between 7.5 and 19.5 MPa, which is higher than that of ZLS with a range of 7.0–18.3 MPa [11,29,30]. However, controversial results have been reported in the literature [6,31]. Consequently, it is unclear whether the bond strength of ZLS is different from that of the LD gold standard following the recommended surface pretreatment. Therefore, this systematic review was conducted to compare the bond strengths of ZLS and LD to provide a reference for clinical applications. The null hypothesis is that there is no difference in the bond strength values between ZLS and LD.

2. Materials and methods

2.1. Protocol and registration

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement [32]. The PRISMA 2020 checklist is presented in **Supplementary Table 1**. The systematic review protocol was registered at the International Prospective Register of Systematic Reviews (PROSPERO) under number CRD42021256900.

2.2. Systematic literature search

Electronic literature retrieval was performed through PubMed, Web of Science, and Google Scholar databases with no limits concerning publication year or language. In addition, references from the included studies were manually searched. The last search was performed on April 25, 2021.

The following MeSH terms, search terms, and their combinations were used in the PubMed search: (((lithium silicate [MeSH Terms] OR lithium silicate reinforced glass ceramics OR glass ceramics)) AND (zirconia-reinforced lithium silicate OR zirconia-reinforced glass ceramics)) AND (adhesive OR bond OR bonding strength OR bonding agent OR adhesive performance).

The following search terms and their combinations were used in the Web of Science and Google Scholar search: (("lithium silicate" OR "lithium silicate reinforced glass ceramics" OR "glass ceramics")) AND ("zirconia-reinforced lithium silicate" OR "zirconia-reinforced glass ceramics")) AND ("adhesive" OR "bond" OR "bonding strength" OR "bonding agent" OR "adhesive performance").

2.3. Study selection

The inclusion criteria for this systematic review were as follows: *in vitro* study of the bond strength of ZLS and LD, studies that performed shear/tensile bond strength tests or micro shear/tensile bond strength tests, and pretreatment of the ceramic surface by HF acid etching and silanization.

The exclusion criteria were as follows: materials other than a resin bonded to the ceramics, and case reports, reviews, protocols, or clinical guidelines.

Two reviewers (L.Z. and D.H.) independently searched and screened the articles. If a disagreement arose, a senior reviewer (H.Y.) was asked for advice. After screening, articles conforming to the standards were included, and the two reviewers (L.Z. and D.H.) inde-

pendently assessed the full text.

2.4. Data extraction

The following data were extracted from the included studies using Microsoft Office Excel 2013 software: primary authors, publication year, number of specimens, surface pretreatment, resin cement/composite used, aging condition, and bond strength test methods.

If required, standard deviations were derived or estimated from other relevant information (e.g., standard error or confidence interval) based on calculations provided in the Cochrane Handbook for Systematic Reviews of Interventions [33].

2.5. Quality assessment

The risk of bias assessment was adapted from previous studies [34–36]. The quality of the included studies was assessed according to the description of the following parameters: sample size calculation, standardized sample preparation, use of materials recommended by the manufacturer, adequate statistical analysis, surface pretreatment performed by a single-blinded operator, and bond strength test performed by a single-blinded operator. If a parameter was found in the text, the article had a "Y" for the specific item; otherwise, the article had an "N." Articles with 1 or 2 "Y" items, 3 or 4 "Y" items, and 5 or 6 "Y" items were respectively considered to have high risk, medium risk, and low risk of bias. Two reviewers independently recorded the information and conducted a risk of bias assessment. Any discrepancies in the judgment of the risk of bias were resolved to reach a consensus, through discussion between the two reviewers and by consulting another reviewer if necessary.

2.6. Statistical Analysis

All statistical analyses were performed using Review Manager software (version 5.3, Cochrane Collaboration, UK) with a significance level of 0.05. The mean difference (MD) and 95% confidence interval (CI) were calculated for the included studies. The Cochrane Q test was used to assess statistical heterogeneity among the studies. Values greater than 50% were considered to indicate high heterogeneity. To assess the stability of the results of the meta-analysis, a sensitivity analysis was performed by excluding one study at a time from the pooled meta-analysis. Funnel plots were used to examine publication bias [33]. Finally, the potential causes of heterogeneity were explored via subgroup analyses, which considered the types of aging and bond strength tests. Samples stored in distilled water for at least three months or at least 5000 thermal cycles were considered as the aging treatments [37].

3. Results

A total of 103 studies were searched, and 22 duplicates were excluded. Fifty-two studies were excluded by reading the titles and abstracts of the articles. The remaining 16 studies were analyzed by reading the full text. Finally, seven studies were included in the systematic review and meta-analysis after a thorough evaluation. A flowchart of the study is shown in **Figure 1**.

Eligible articles were published between 2014 and 2018 (**Table 1**). All of the included articles were *in vitro* studies in English. A minimum of seven specimens per group [11] and a maximum of 100 specimens per group were used in the included studies [31]. The samples

Fig. 1. Flow diagram of study selection according to the PRISMA statement.

Table 1. Characteristics of included studies

Author/ Publication Year	Sample size	Surface treatment	Resin composite used	Aging/Storage	Bond strength test method
Ataol et al 2018 ¹¹	7	9% HF+silane+Clearfil Universal Bond; 9% HF+Clearfil Ceramic Primer	Clearfil Majesty ES-2	Distilled water for 24 h at 37°; thermocycling between 5°C and 55°C for 5,000 cycles	SBS
Yildirim et al 2018 ³⁰	10	9.5% HF+Clearfil Ceramic Primer Plus	Panavia v5	Distilled water for 24 h at 37°	SBS
Melo-Silva et al 2018 ³⁷	12	5% HF+silane+Universal Single Bond	RelyX arc	Relative humidity for 24 h	SBS
Al-Thagafi et al 2016 ⁶	30	5% HF+silane; 5% HF+silane+Heliobond	Tetric EvoCeram	Distilled water for 24 h at 37°; thermocycling between 5°C and 55°C for 5,000 cycles	μ-TBS
Secilmis et al 2016 ²⁹	12	9% HF+Clearfil porcelain bond activator+Clearfil SE bond; 9% HF+Monobond S	Panavia F 2.0; Multilink N	Distilled water for 24 h at 37°; thermocycling between 5°C and 55°C for 5,000 cycles	SBS
Frankenberger et al 2015 ³¹	100	5% HF+silane+Prime&Bond XP+SCA; 5% HF+silane	Calibra; RelyX Unicem	Water for 24 h at 37°; thermocycling between 5°C and 55°C for 10000 cycles	μ-TBS
Aboushelib et al 2014 ¹³	20	9% HF+Monobond Plus	Variolink II	Distilled water for 3 months at 37°	μ-TBS

SBS: shear bond test; μ-TBS: micro-tensile bond test

Table 2. Risk of bias in included studies

Author/Publication Year	Sample size calculation	Use of materials recommended by the manufacturer	Adequate Statistical Analysis	Standardized sample preparation	Surface treatment performed by a single-blinded operator	Bond strength test performed by a single-blinded operator	Risk of Bias
Yildirim et al 2018	Y	Y	Y	Y	N	N	Medium
Melo-Silva et al 2018	Y	Y	Y	Y	N	N	Medium
Al-Thagafi et al 2016	Y	Y	Y	Y	N	N	Medium
Secilmis et al 2016	Y	Y	Y	Y	N	N	Medium
Frankenberger et al 2015	Y	Y	Y	Y	N	N	Medium
Aboushelib et al 2014	Y	Y	Y	Y	N	N	Medium

Fig. 2. Forest plot summarizing bond strength of ZLS and LD. CI, confidence interval; SD, standard deviation; ZLS, zirconia-reinforced lithium silicate; and LD, lithium disilicate.

were aged in five studies, one of which was stored in water for three months [13], and the other four were thermocycled [6,11,29,31]. Two types of bond strength tests were used: shear bond strength tests [11,29,30,38] and micro-tensile bond strength tests [6,13,31]. Based on the parameters considered in the quality assessment, all studies presented a medium risk of bias (Table 2). Sensitivity analysis showed that the deletion of any one study did not significantly affect global change, confirming the reliability and stability of the results (Supplementary Table 2). Funnel plots were not presented because there were fewer than ten included studies [33].

In the general meta-analysis, no significant difference was found in the bond strength between ZLS and LD ($P = 0.94$, MD = 0.08, and 95% CI = -1.93 to 2.10) (Fig. 2).

Subgroup analyses were performed to assess the sources of heterogeneity. The first subgroup analysis that considered aging treatments (aged with thermocycling, aged with water storage, and non-aged) was carried out (Fig. 3). A statistically significant difference was found between the evaluated conditions ($p = 0.0008$). For the non-aged specimens, the bond strength of the LD specimen was significantly higher than that of the ZLS. For the specimens aged with thermocycling, there was no significant difference in the bond strength between the LD and ZLS. However, for the specimens aged with water storage, the bond strength of ZLS was significantly higher than that of LD. Moreover, the second subgroup analysis showed

a statistically significant difference between the different bond strength test methods (shear vs. micro-tensile) ($P < 0.00001$) (Fig. 4). When the shear bond test was adopted, bond strength value for LD was found to be statistically higher than that for ZLS. However, the bond strength of LD was significantly lower than that of ZLS in the micro-tensile bond test.

4. Discussion

A durable and strong bond improves margin adaptation, prevents microleakage, offers high retention, and increases the fracture resistance of the tooth and prosthesis [39,40]. Bonding to glass ceramics is a predictable process that can produce durable results as long as certain guidelines are followed [41,42]. However, zirconia has a low chemical reactivity and is inert to acid etching, which results in weak adhesion to resin materials [43,44]. Whether the bond strength of ZLS is comparable to that of the LD gold standard remains unclear. Based on the current findings, the null hypothesis that no significant difference would be found in the bond strength values between ZLS and LD was accepted.

LD is an acid-sensitive ceramic. Optimal bonds with the resin are obtained by micromechanical attachment and chemical bond mechanisms through HF etching and silanization [22,45]. A retrospective study showed that LD had a high reliability for bonding with resin and satisfactory clinical results [45]. In the present study,

Fig. 3. Forest plot summarizing bond strength of ZLS and LD (subgroup: aging). CI, confidence interval; SD, standard deviation; ZLS, zirconia-reinforced lithium silicate; and LD, lithium disilicate.

Fig. 4. Forest plot summarizing bond strength of ZLS and LD (subgroup: bond strength test method). CI, confidence interval; SD, standard deviation; ZLS, zirconia-reinforced lithium silicate; and LD, lithium disilicate.

ZLS exhibited a bond strength similar to that of LD, indicating that a high resin bond to ZLS was established following HF acid etching and silane application. The resin-ceramic bond is susceptible to thermal, chemical, and mechanical conditions in the oral environment [46,47]. Therefore, thermocycling and long-term water storage of bonded specimens are the most common aging methods for estimating long-term clinical behavior [19,24,48]. Thermocycling affects the bond strength due to temperature changes and subsequent repeated shrinkage and expansion stresses [19,23,37], while long-term water storage simulates the aging caused by water absorption and hydrolysis degradation of the restoration [26]. The minimum number of thermal cycles required to evaluate polymer-based materials is 5,000, as required by ISO 10477:2018 [49]. All included studies employed more than 5,000 thermal cycles, which may be equivalent to half of one year *in vivo* [50,51]. Interestingly, a significantly higher bond strength of LD than ZLS was observed for the non-aged specimens, but the bond strength of ZLS was equal to or even higher than that of LD after aging. This may be because the phase transformation of zirconia crystals in ZLS may hinder crack propagation during the aging process, enhancing the interlocking microstructure at the resin-ceramic interface [12]. Moreover, some studies [11,13,29,30] adopted a primer/adhesive containing 10-methacryloxy decyldihydrogen phosphate (10-MDP). The functional monomer 10-MDP has been proven to form stable chemical bonds with zirconium atoms, which may eliminate the negative effects of aging and enhance the adhesive durability of resin and zirconia material [52-56]. The hydroxyl group (OH) of the MDP monomer can form a stable chemical bond with the hydroxyl group of zirconia and resist hydrolysis degradation [57]. Furthermore, it can be assumed that the decyl group in MDP prevents water penetration at the interface between the dihydrogen phosphate and zirconia [56,58]. However, frequent temperature changes may reduce the abovementioned effects of aging, resulting in differences in the bond strength between water storage and thermocycling [59]. Future studies are needed to clarify these hypotheses. Finally, the relatively improved material quality and load capacity of ZLS [60] and the above findings may guarantee its long-term success.

Shear, micro-shear, tensile, and micro-tensile tests are recommended to assess the bond strength of resin-based materials to dental ceramics [37]. In the eligible studies, shear and micro-tensile bond strength tests were performed. The present findings suggest that the type of test method affects the bond strength of dental ceramics. This finding is consistent with that of a previous study [61]. However, no direct evidence is available to explain this phenomenon. The shear bond strength test has long been a popular test for evaluating the bond strength of dental ceramics [62], possibly because of its simple execution and specimen preparation [63]. However, the stress of the specimen during the shear test is very complicated. Cohesion failure easily occurs, which hinders the accurate evaluation of the adhesive interface [62,64]. In comparison, micro-tensile tests provide more accurate bond strength values for samples owing to a homogeneous stress distribution and smaller bonding area [65-67]. However, the micro-tensile tests require additional sample processing after the bonding process, making the test more difficult, technology sensitive, and labor intensive [19,62]. The standardized preparation of the bonding area is critical because of its potential impact on the results [68]. De Munck et al. [69] evaluated 2,157 bond strength tests in 298 papers, indicating that the micro-tensile test was the most commonly used test and was more discriminant than the shear test. However, whether the micro-tensile test provides more reliable findings than the shear test remains unclear in the current literature [61].

The present results showed that the bond strength value measured by the micro-tensile bond test was greater than that measured by the shear bond test, which was consistent with previous studies [66,70]. According to Griffith [71], defects at the bonding interface are related to bond strength. The smaller the bonding area, the less likely it is to find a bond-strength defect, thereby producing a higher bond strength for the sample. In fact, other bond strength tests such as enclosed-mold shear bond strength (EM-SBS) [72] and flexural bond strength (FBS) [73] tests should be considered because, in addition to being more sensitive to the flaws, these tests can eliminate the size effects on the possible defect areas and provide a more uniform stress distribution. Thus, scientific and radical development of the bond strength test method is necessary.

One limitation of this study is the small number of included articles, even though multiple databases were searched. Moreover, high heterogeneity was found in this study, and the possible reasons may be different aging protocols and different bond strength test methods. Therefore, the operating procedures should be standardized to reduce deviations. Different types of bond failure were not considered in this study because not all articles evaluated this variable. Finally, the present results should be interpreted with caution before clinical application, as all included studies were *in vitro*, which cannot completely replicate intraoral conditions.

According to the current findings, ZLS exhibited a bond strength similar to that of LD under the recommended surface pretreatment (HF+silanization). Together with the relatively higher transparency and mechanical properties [14,17], the results reveal that the indications for ZLS are similar to those for LD (e.g., veneers, inlays, onlays, and single crowns). In addition, since the addition of zirconia alleviated the edge chipping damage of the restoration [74], ZLS may be appropriate for prepless veneers. However, long-term data on the clinical performance of ZLS are limited [75,76]. Hence, more studies are needed to accurately define the clinical indications and long-term performance of ZLS.

5. Conclusion

Based on this systematic review and meta-analysis of *in vitro* studies, the following conclusions can be drawn:

- 1) After the recommended surface treatment (HF+silanization), no significant difference was found in the bond strengths of ZLS and LD.
- 2) Different aging treatments and bond strength test methods may produce different results when comparing the bond strengths of ZLS and LD.

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Conflicts of interest

The authors declare no conflict of interest.

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Supplementary Table 1. PRISMA 2020 checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1-2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 3-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 5-6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 5
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 5
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 6
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 6
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Not applicable
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 6
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 6-7
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 7
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 5
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 6
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 6
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 7
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 7
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Page 7
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 7
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 6-7
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 8
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 8
Study characteristics	17	Cite each included study and present its characteristics.	Page 8
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 8
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Page 8
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 8
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page 8
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page 8-9
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 9
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Page 9
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Page 9
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 11
	23b	Discuss any limitations of the evidence included in the review.	Page 12-13
	23c	Discuss any limitations of the review processes used.	Page 12-13
	23d	Discuss implications of the results for practice, policy, and future research.	Page 12-13
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 5
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 5
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Page 5
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 16
Competing interests	26	Declare any competing interests of review authors.	Page 16
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Not applicable

Supplementary Table 2. Results of sensitivity analyses

Study on bond strength between ZLS and LD	Number of studies	Heterogeneity		Meta-analysis		
		I^2	p	MD	95% CI	p
All included	7	93	<0.00001	0.88	-1.93 ~ 0.21	0.94
Study by Aboushelib et al. omitted	6	94	<00.0001	-0.12	-2.23 ~ 1.95	0.91
Study by Al-Thagafi et al. omitted	6	93	<0.00001	-0.58	-2.66 ~ 1.49	0.58
Study by Ataol et al. omitted	6	95	<0.00001	-0.02	-2.29 ~ 2.26	0.99
Study by Frankenberger et al. omitted	6	92	<0.00001	-0.60	-2.66 ~ 1.45	0.57
Study by Melo-Silva et al. omitted	6	90	<0.00001	1.21	-1.01 ~ 3.43	0.29
Study by Secilmis et al. omitted	6	93	<0.00001	0.65	-1.60 ~ 2.91	0.57
Study by Yildirim et al. omitted	6	94	<0.00001	0.15	-1.93 ~ 2.23	0.89

*MD: Mean Difference, CI: confidence interval.