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REVIEW

Retention of lithium disilicate and translucent zirconia veneers bonded with light-cured resin cements: a systematic review and meta-analysis

Osama Hajeer[1] · Rami Alyousef[1] · JadAlKarim AlKadour[1] · Amal Hasan[1]

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Abstract

Background Light-cured resin cements are widely used for veneer cementation due to their color stability and extended working time. However, polymerization through ceramic materials may be influenced by ceramic composition, thickness, and bonding substrate, potentially affecting bond strength. A quantitative comparison between lithium disilicate and translucent zirconia veneers under light-cured protocols remains limited.

Objective To compare the bond strength of lithium disilicate and translucent zirconia veneers luted with light-cured resin cements and to evaluate the influence of substrate type and veneer thickness.

Methods A systematic review and meta-analysis was conducted in accordance with PRISMA 2020 guidelines. Six in vitro studies (64 specimens) met inclusion criteria. Random-effects models using restricted maximum likelihood estimation with Hartung–Knapp adjustment were applied. Subgroup analyses were performed according to ceramic material and substrate. An exploratory meta-regression assessed the association between veneer thickness and bond strength.

Results The pooled mean bond strength across all studies was 15.9 MPa. Lithium disilicate veneers demonstrated higher pooled bond strength (25.4 MPa) than translucent zirconia (12.1 MPa). Enamel substrates showed higher bond strength (21.1 MPa) compared with composite cores (11.3 MPa). Considerable heterogeneity was observed ($I^2 = 98.2\%$). Meta-regression suggested an inverse trend between veneer thickness and bond strength; however, this finding was based on a limited dataset and should be interpreted cautiously.

Conclusion Within the limitations of in vitro evidence, lithium disilicate and enamel bonding were associated with higher bond strength under light-cured cementation. Due to substantial heterogeneity and limited study numbers, these findings should be considered exploratory and not directly extrapolated to clinical performance.

Keywords Retention · Veneer · Resin cements · Light-cure

1 Introduction

Ceramic laminate veneers are widely used in minimally invasive esthetic dentistry due to their favorable optical properties and reliable adhesive performance. Lithium disilicate (LDS) is commonly selected because its glass–ceramic structure allows hydrofluoric acid etching and silanization, enabling predictable micromechanical and chemical bonding to resin cements (Kern 2015; Abo-Hamar et al. 2005). In contrast, zirconia-based ceramics lack a silica phase and cannot be etched conventionally. Bonding depends on airborne-particle abrasion and functional phosphate monomers such as 10-MDP, with variable reported outcomes (Souza et al. 2012; Tanış et al. 2015; Angelis et al. 2021).

✉ Osama Hajeer
osamahajeer@hotmail.com

Rami Alyousef
rami00005@icloud.com

JadAlKarim AlKadour
Jadalkarimalkadour21@gmail.com

Amal Hasan
Dramalhasan1979@gmail.com

[1] University of Aleppo, Aleppo, Syrian Arab Republic

The introduction of high-translucency zirconia has expanded its use to anterior veneers. Although these materials improve light transmission compared to earlier zirconia generations, concerns remain regarding the effectiveness of light-cured resin cements beneath zirconia restorations due to potential attenuation of curing light (Özcan and Bernasconi 2015; Blatz et al. 2019; Magne et al. 2010). Insufficient polymerization may reduce bond strength, particularly as ceramic thickness increases (Magne et al. 2010; Bitter et al. 2006; Ergun et al. 2006).

Bonding performance is also influenced by the underlying substrate. Enamel provides stable micromechanical retention following acid etching, whereas composite cores may demonstrate lower and less durable adhesion due to differences in surface chemistry and aging behavior (Abo-Hamar et al. 2005; Lin et al. 2023; Turgut and Bagis 2013). These variables contribute to heterogeneity in reported bond strength values across in vitro studies.

Despite numerous laboratory investigations, a consolidated quantitative comparison of lithium disilicate and translucent zirconia veneers specifically bonded with light-cured resin cements is lacking. In addition, the potential influence of ceramic thickness and bonding substrate has not been systematically synthesized.

Therefore, the aim of this systematic review and meta-analysis was to compare the bond strength of lithium disilicate and translucent zirconia veneers luted with light-cured resin cements and to explore the influence of substrate type and veneer thickness on adhesive outcomes. The null hypothesis was that no significant difference would be observed between materials or substrates under light-cured cementation protocols.

2 Materials and methods

2.1 Study design and reporting standards

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al. 2021). The review focused exclusively on in vitro studies evaluating the bond strength of lithium disilicate and translucent zirconia veneers luted with light-cured resin cements. As the included studies were laboratory investigations rather than clinical trials, prospective protocol registration in PROSPERO was not performed. A predefined internal protocol guided study selection, data extraction, and statistical analysis.

2.2 Focused research question

The review addressed the following question:

In lithium disilicate or translucent zirconia veneers, how does bonding with light-cured resin cement influence bond strength to enamel or composite substrates?

2.3 Eligibility criteria

Studies were eligible if they met the following criteria: (1) evaluated lithium disilicate or translucent zirconia veneer restorations; (2) used exclusively light-cured resin cement protocols; (3) reported quantitative bond strength outcomes expressed in MPa; (4) involved bonding to enamel or composite substrates; and (5) were published in English within the predefined search period.

Studies were excluded if they investigated full-coverage crowns, inlays, or non-veneer restorations; used dual-cure or self-adhesive cement systems without separate light-cure data; did not report extractable bond strength values (mean and standard deviation); were finite element analyses; or were case reports, narrative reviews, conference abstracts, or animal studies.

Bond strength test methods, including shear, microtensile, and push-out tests, were considered eligible. Although these methods differ mechanically, outcomes were standardized to MPa and pooled using a random-effects model to account for methodological heterogeneity.

2.4 Search strategy

A comprehensive electronic search was conducted in PubMed, Google Scholar, ScienceDirect, Wiley Online Library, and SpringerLink for studies published between January 2010 and March 2025. The following Boolean strategy was applied:

("lithium disilicate" OR "zirconia") AND ("veneer" OR "laminate") AND ("light-cured resin cement") AND ("bond strength" OR "retention") AND ("enamel" OR "composite").

The final search was conducted in March 2025. Reference lists of included studies were manually screened to identify additional relevant articles. The complete reproducible search strategy is provided in the supplementary material.

2.5 Study selection

Titles and abstracts were independently screened for eligibility. Full-text articles were subsequently assessed against inclusion and exclusion criteria. Disagreements were resolved through consensus. Studies meeting qualitative criteria were included in the systematic review. Studies providing complete numerical data (mean bond strength, standard deviation, and sample size) were included in the quantitative meta-analysis.

2.6 Data extraction

Data were extracted independently by two reviewers using a standardized form. Extracted variables included author and year, ceramic material type, substrate type, veneer thickness, surface treatment protocol, type of light-cured resin cement, aging procedure, bond strength test method, mean bond strength (MPa), standard deviation, and sample size. Where necessary, numerical values were derived from tables or figures.

2.7 Risk of bias assessment

Because all included studies were in vitro laboratory investigations, the Cochrane RoB 2 tool was not applicable. Methodological quality was therefore assessed using an adapted framework for in vitro dental studies. The following domains were evaluated: specimen randomization, blinding of outcome assessment, standardization of surface treatment and cementation protocol, completeness of outcome reporting, and appropriateness of statistical analysis. Each domain was categorized as low, moderate, or high risk of bias. Overall risk of bias judgments were determined based on domain assessments.

2.8 Certainty of evidence

The certainty of evidence was evaluated using an adapted Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. Given the laboratory nature of the included studies, evidence was initially considered indirect relative to clinical outcomes. Downgrading decisions were based on risk of bias, inconsistency (I^2 values), imprecision (sample size and confidence intervals), indirectness, and potential reporting bias. The overall certainty rating reflects the exploratory and in vitro context of the evidence.

2.9 Statistical analysis

Meta-analyses were performed using a random-effects model to account for expected clinical and methodological heterogeneity. Restricted Maximum Likelihood (REML) estimation was applied, and confidence intervals were calculated using the Hartung–Knapp–Sidik–Jonkman adjustment, which is recommended for meta-analyses including fewer than ten studies.

Pooled mean bond strength values were calculated for the overall dataset and for predefined subgroups based on ceramic material (lithium disilicate vs. translucent zirconia) and substrate (enamel vs. composite). Statistical heterogeneity was quantified using the I^2 statistic and Tau^2.

A meta-regression analysis was conducted to explore the association between veneer thickness (in mm) and bond strength (MPa). Given the limited number of included studies, this analysis was considered exploratory and hypothesis-generating. No multivariable adjustment was performed due to limited statistical power.

Forest plots and funnel plots were generated to visualize pooled effects and distribution patterns. Given the small number of studies, funnel plot interpretation was performed cautiously, and no formal statistical test for publication bias was applied.

All analyses were conducted using Python (version 3.11) with the statsmodels statistical package and supporting scientific libraries. The extracted dataset used for analysis is provided in the supplementary material to enhance transparency and reproducibility.

3 Results

3.1 Study selection

The electronic search identified 1,936 records. After duplicate removal and screening, 94 full-text articles were assessed for eligibility. Seven in vitro studies met the inclusion criteria for qualitative synthesis. Of these, six provided complete numerical data (mean bond strength, standard deviation, and sample size) and were included in the quantitative meta-analysis. One study was excluded due to incomplete statistical reporting (Fig. 1).

The study selection process followed PRISMA 2020 guidelines (Page et al. 2021).

3.2 Characteristics of included studies

The six included studies comprised a total of 64 specimens (Bitter et al. 2006; Turgut and Bagis 2013; Altamimi et al. 2021; Rangert et al. 2022; Muhammad et al. 2025). Two studies evaluated lithium disilicate veneers bonded to enamel (Turgut and Bagis 2013; Muhammad et al. 2025), and four studies evaluated translucent zirconia veneers (Bitter et al. 2006; Altamimi et al. 2021; Rangert et al. 2022). Three studies investigated enamel substrates (Turgut and Bagis 2013; Altamimi et al. 2021; Muhammad et al. 2025) and three investigated composite substrates (Bitter et al. 2006; Altamimi et al. 2021; Rangert et al. 2022).

Veneer thickness ranged from 0.5 mm to 1.0 mm in the reported datasets (Turgut and Bagis 2013; Rangert et al. 2022). Bond strength testing methods included shear and push-out tests (Bitter et al. 2006; Turgut and Bagis 2013; Altamimi et al. 2021; Rangert et al. 2022; Muhammad et al. 2025). Aging procedures varied across studies and included thermocycling, water storage, or no artificial aging.

Detailed study characteristics are presented in Table 1.

3.3 Risk of bias

Risk of bias assessment showed two studies at low risk (Turgut and Bagis 2013; Rangert et al. 2022), three at moderate risk (Altamimi et al. 2021; Muhammad et al. 2025), and one at high risk (Bitter et al. 2006). The primary methodological concerns included lack of blinding and incomplete reporting of specimen allocation procedures. No study was excluded based on risk of bias (Tables 2, 3 and 4).

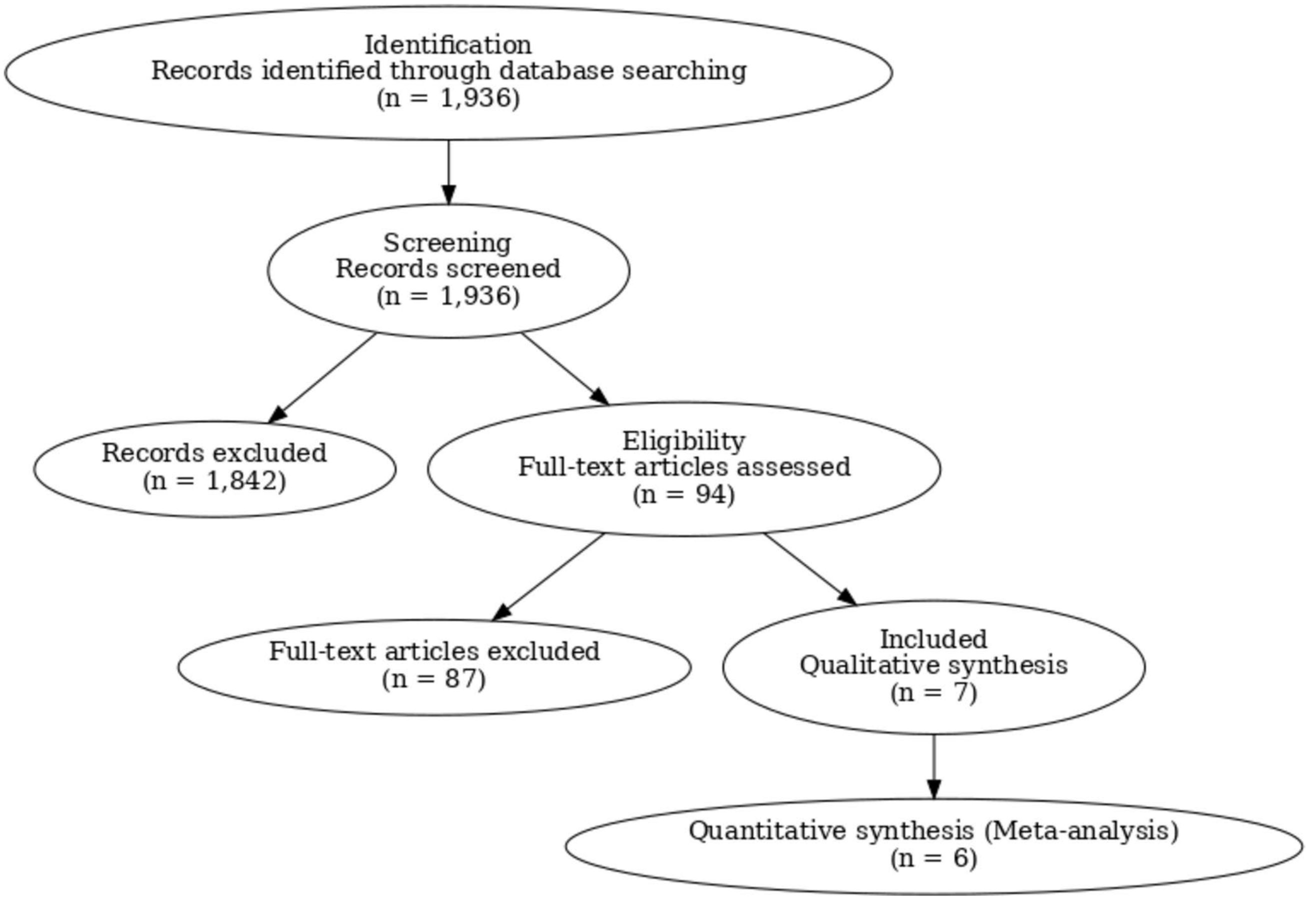

Fig. 1 PRISMA 2020 Flow Diagram. Flow diagram illustrating study identification, screening, eligibility assessment, and final inclusion in qualitative and quantitative synthesis according to PRISMA 2020 guidelines (Page et al. 2021)

3.4 Overall bond strength

Across all included specimens ($n = 64$), the specimen-weighted pooled mean bond strength was:

3.5 MPa (Fig. 2)

Considerable heterogeneity was observed ($I^2 = 98.2\%$), indicating substantial variability among studies (Bitter et al. 2006; Turgut and Bagis 2013; Altamimi et al. 2021; Rangert et al. 2022; Muhammad et al. 2025). Given this high heterogeneity, pooled estimates should be interpreted cautiously.

3.6 Subgroup analysis(Fig. 3)

3.6.1 Ceramic material

Lithium disilicate veneers (Turgut and Bagis 2013; Muhammad et al. 2025) demonstrated a pooled mean bond strength of:

MPa ($n = 18$ specimens)

Translucent zirconia veneers (Bitter et al. 2006; Altamimi et al. 2021; Rangert et al. 2022) demonstrated a pooled mean bond strength of:

MPa ($n = 46$ specimens)

The lithium disilicate subgroup included only two datasets, limiting statistical precision.

3.6.2 Substrate type

Enamel bonding (Turgut and Bagis 2013; Altamimi et al. 2021; Muhammad et al. 2025) demonstrated a pooled mean bond strength of:

MPa ($n = 30$ specimens)

Composite substrate bonding (Bitter et al. 2006; Altamimi et al. 2021; Rangert et al. 2022) demonstrated a pooled mean bond strength of:

11.3 MPa ($n = 34$ specimens).

Table 1 Characteristics of Included In Vitro Studies

Study	Material	Substrate	Composite Type	Thickness (mm)	Surface Treatment	Resin Cement	Test Method	Aging Protocol	Mean (MPa)	SD	N
Turgut and Bagis (2013)	Lithium disilicate	Enamel	—	0.7	HF + Silane	Choice 2	Shear	None reported	25.0	3.1	10
Muhammad et al. (2025)	Lithium disilicate	Enamel	—	Not specified	HF + Silane	Variolink Esthetic LC	Shear	Thermocycling (5,000 cycles)	26.0	35.0	8
Altamimi et al. (2021)	Zirconia	Enamel	—	0.75	Air abrasion + MDP	Clearfil Esthetic LC	Shear	Thermocycling	14.5	2.8	12
Altamimi et al. (2021)	Zirconia	Composite	Bulk-fill	0.75	Air abrasion + MDP	Clearfil Esthetic LC	Shear	Thermocycling	10.9	3.3	12
Rangert et al. (2022)	Zirconia	Composite	Microhybrid	1.0	Sandblasting + Primer	Panavia V5	Push-out	Thermocycling	12.8	2.2	12
Bitter et al. (2006)	Zirconia	Composite	Not specified	Not specified	Air abrasion + Silane	RelyX Veneer	Shear	Water storage	10.0	2.5	10

Summary of included studies reporting ceramic material, substrate type, veneer thickness, surface treatment protocol, aging procedure, bond strength test method, resin cement type, sample size, and mean bond strength (MPa)

Table 2 Pooled Bond Strength Estimates and Subgroup Analyses

Analysis	Studies (n)	Specimens (n)	Pooled Mean (MPa)
Overall	6	64	15.9
Lithium disilicate	2	18	25.4
Zirconia	4	46	12.1
Enamel	3	30	21.1
Composite	3	34	11.3

Random-effects model using REML estimation with Hartung–Knapp adjustment. Considerable heterogeneity observed ($I^2 = 98.2\%$)

Random-effects pooled mean bond strength (MPa) across all studies and subgroups stratified by ceramic material (lithium disilicate vs translucent zirconia) and substrate type (enamel vs composite). Heterogeneity is expressed as I^2. REML estimation with Hartung–Knapp adjustment was applied

4 Meta-regression: veneer thickness(Fig. 4)

An exploratory meta-regression evaluated veneer thickness (0.5–1.0 mm) as a predictor of bond strength. Although an inverse trend was observed, the analysis was based on six datasets within a narrow thickness range and was not adjusted for ceramic material or substrate type. Therefore, this finding should be interpreted as hypothesis-generating.

4.1 Publication bias

A funnel plot was generated for visual inspection; however, given the limited number of included studies (n = 6), interpretation is unreliable and no definitive conclusions regarding publication bias can be drawn.

5 Discussion

This systematic review synthesized available in vitro evidence comparing the bond strength of lithium disilicate and translucent zirconia veneers luted with light-cured resin cements. The pooled analysis demonstrated higher bond strength values for lithium disilicate compared with zirconia and for enamel substrates compared with composite cores. However, considerable heterogeneity ($I^2 = 98.2\%$) and the limited number of included studies restrict the strength of these conclusions.

The higher pooled bond strength observed for lithium disilicate is biologically plausible. Lithium disilicate is a silica-based glass ceramic that permits hydrofluoric acid etching followed by silanization, enabling micromechanical retention and chemical coupling to resin cements (Kern 2015; Abo-Hamar et al. 2005). This dual bonding mechanism has consistently demonstrated favorable adhesion in

Table 3 Risk of Bias Assessment

Study	Randomization	Blinding	Protocol Standardization	Outcome Reporting	Statistical Analysis	Overall Risk
Turgut and Bagis (2013)	Low	Moderate	Yes	Yes	Yes	Low
Muhammad et al. (2025)	Moderate	Low	Yes	Yes	Yes	Moderate
Altamimi et al. (2021)	Moderate	Low	Yes	Yes	Yes	Moderate
Altamimi et al. (2021)	Moderate	Low	Yes	Yes	Yes	Moderate
Rangert et al. (2022)	Low	Moderate	Yes	Yes	Yes	Low
Bitter et al. (2006)	Moderate	High	No	Yes	Yes	High

Methodological quality assessment across five domains: specimen randomization, blinding, protocol standardization, outcome reporting completeness, and statistical appropriateness. Overall judgment categorized as low, moderate, or high risk of bias

Table 4 Certainty of Evidence (Adapted GRADE Assessment)

Domain	Judgment	Rationale
Risk of Bias	Serious	Some studies lacked blinding and allocation clarity
Inconsistency	Very Serious	Considerable heterogeneity (I^2 = 98.2%)
Indirectness	Serious	All studies were in vitro
Imprecision	Serious	Small sample sizes and few studies
Publication Bias	Not assessable	< 10 studies

|Overall Certainty of Evidence | LOW |

Adapted GRADE assessment of certainty of evidence considering risk of bias, inconsistency, indirectness, imprecision, and reporting bias. Overall certainty rated as low due to in vitro design and considerable heterogeneity

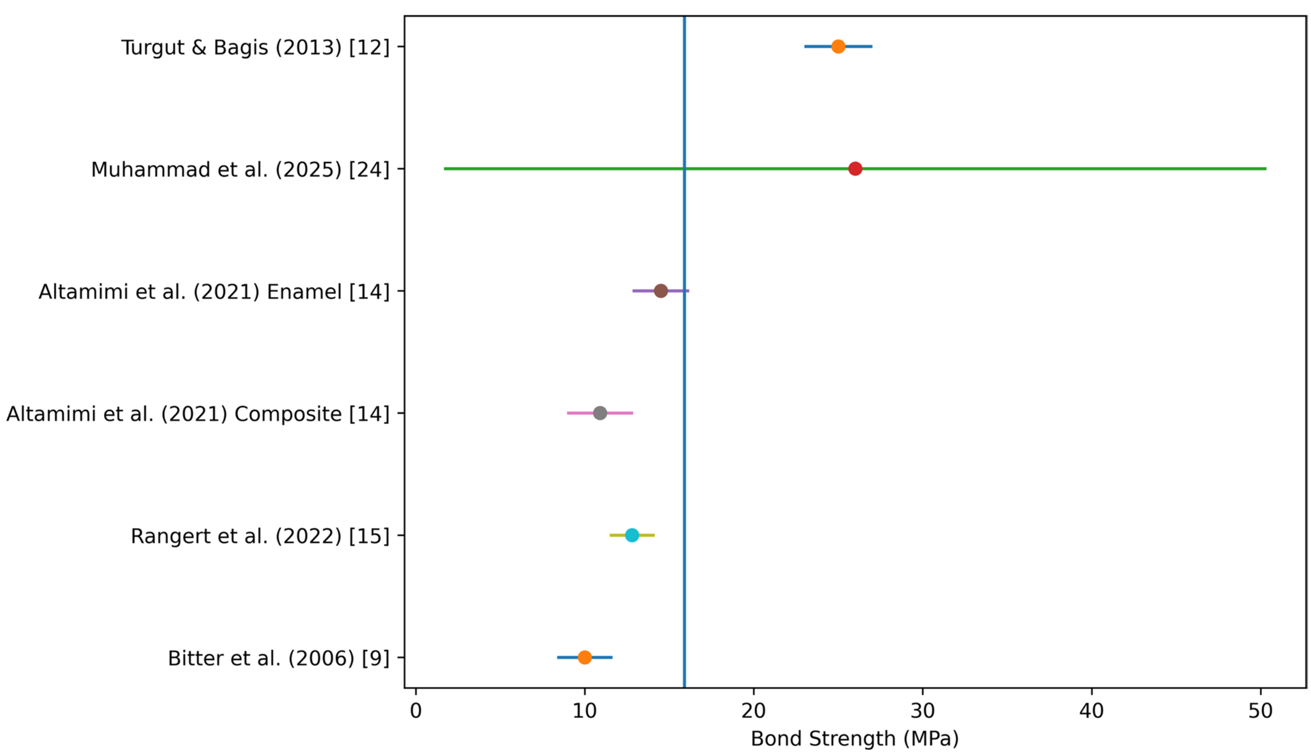

Fig. 2 Forest Plot of Overall Bond Strength. Random-effects meta-analysis showing individual study mean bond strength (MPa) and pooled estimate with 95% confidence intervals. Considerable heterogeneity was observed ($I.^2$ = 98.2%)

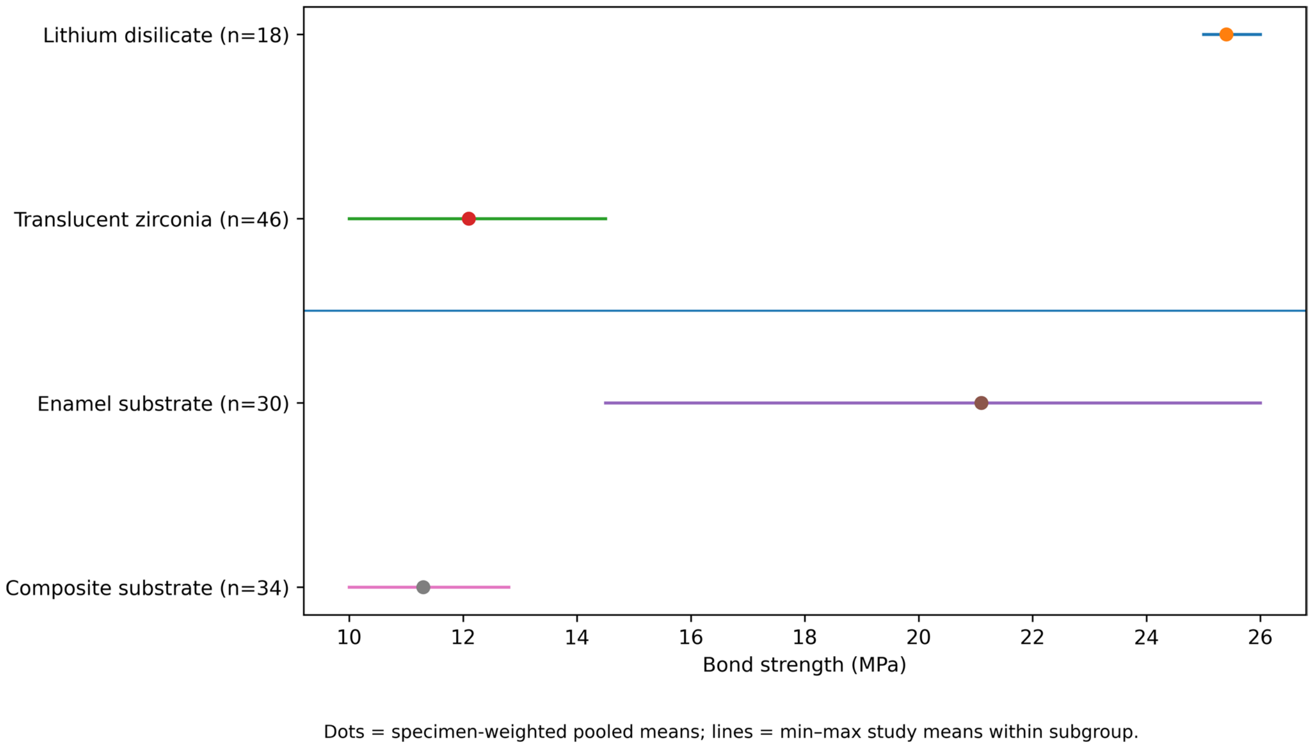

Fig. 3 Subgroup Forest Plot by Ceramic Material and Substrate. Subgroup analyses comparing pooled bond strength by ceramic material (lithium disilicate vs translucent zirconia) and substrate type (enamel vs composite). Error bars represent 95% confidence intervals

laboratory settings (Lin et al. 2023). In contrast, zirconia lacks a glass phase and cannot be conventionally etched. Bonding relies on airborne-particle abrasion and the application of phosphate monomers such as 10-MDP (Tanış et al. 2015; Angelis et al. 2021; Özcan and Bernasconi 2015). Although MDP-containing primers have improved zirconia adhesion (Angelis et al. 2021; Blatz et al. 2019), variability in surface treatment parameters, primer chemistry, and cement composition may contribute to lower and less predictable bond strength outcomes.

The difference observed between enamel and composite substrates is consistent with established adhesive principles. Etched enamel provides a highly mineralized, stable substrate that supports durable micromechanical interlocking (Abo-Hamar et al. 2005). In contrast, composite cores may present reduced surface energy, variable filler content, and susceptibility to hydrolytic degradation, all of which may negatively influence adhesive performance over time (Özcan 2011; Lohbauer et al. 2007; Frankenberger et al. 2014). The composite materials included in the present analysis were not standardized and ranged from bulk-fill to microhybrid systems, potentially contributing to heterogeneity.

An exploratory meta-regression suggested an inverse association between veneer thickness and bond strength. Light attenuation through ceramic materials is known to reduce irradiance reaching the luting resin, which may compromise polymerization of light-cured cements (Habib et al. 2020; Yucel et al. 2019; Al-Akhali et al. 2017). This phenomenon may be particularly relevant for zirconia, which demonstrates lower light transmission compared with glass ceramics (Heffernan et al. 2022; Yucel et al. 2016). However, the regression analysis was based on only six datasets within a narrow thickness range (0.5–1.0 mm) and was not adjusted for material type or substrate. Therefore, this finding should be interpreted cautiously and considered hypothesis-generating rather than confirmatory.

Considerable heterogeneity was observed across studies. Variations in ceramic type, translucency grade, surface conditioning protocols, aging procedures, cement brands, and bond strength testing methods likely contributed to the high I^2 value. Although bond strength values were standardized to MPa and pooled using a random-effects model, shear, microtensile, and push-out tests are not mechanically equivalent. Pooling across different testing modalities may therefore introduce additional methodological variability. Furthermore, aging protocols differed substantially, including thermocycling regimens, water storage durations, or absence of artificial aging, which may affect interfacial durability.

The certainty of evidence was judged to be low due to indirect laboratory design, imprecision from small sample

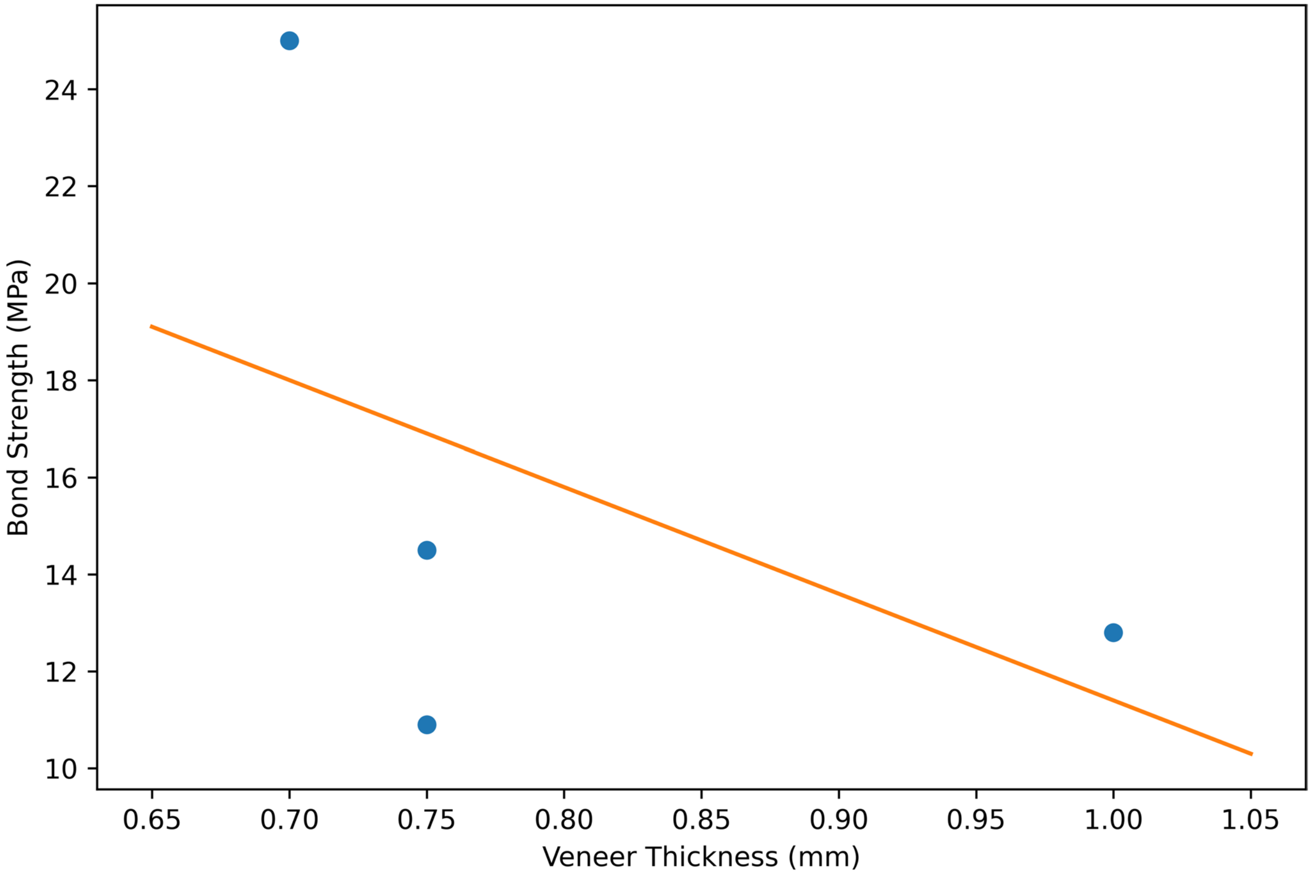

Fig. 4 Meta-Regression Plot: Veneer Thickness and Bond Strength. Exploratory meta-regression assessing the association between veneer thickness (mm) and bond strength (MPa). The regression line illustrates an inverse trend; interpretation is limited due to small sample size

sizes, and considerable inconsistency. While GRADE was adapted to structure certainty assessment, the in vitro nature of the data inherently limits extrapolation to clinical performance.

Importantly, although higher bond strength values were observed for lithium disilicate and enamel bonding, these findings should not be interpreted as definitive evidence of clinical superiority. Laboratory bond strength does not directly equate to long-term restoration survival. Clinical outcomes are influenced by additional factors, including preparation design, occlusal loading, moisture control, and operator variability.

Future research should prioritize standardized surface treatment protocols, controlled aging procedures, and uniform bond strength testing methods to reduce heterogeneity. Comparative investigations including both light-cure and dual-cure cement systems would also improve clinical relevance. Ultimately, well-designed clinical trials are required to determine whether the laboratory differences identified translate into meaningful differences in long-term veneer retention.

6 Conclusion

Within the limitations of this in vitro systematic review and meta-analysis, lithium disilicate veneers demonstrated higher pooled bond strength compared with translucent zirconia when luted using light-cured resin cements. Bonding to enamel substrates was associated with higher bond strength values than bonding to composite cores. An inverse association between veneer thickness and bond strength was observed; however, this finding was derived from a limited dataset and should be interpreted as exploratory.

Considerable heterogeneity was present across studies, reflecting variability in ceramic type, surface treatment protocols, aging procedures, and bond strength testing methods. The small number of included investigations and the indirect laboratory nature of the evidence further limit the strength of inference.

Accordingly, the present findings should not be directly extrapolated to clinical performance. Rather, they provide a quantitative synthesis of existing laboratory data and highlight areas requiring further standardized research. Well-designed in vitro studies with consistent protocols and prospective clinical investigations are necessary to determine whether the observed differences translate into meaningful long-term outcomes.

Abbreviations LDS: Lithium Disilicate; MPa: Megapascal; MDP: 10-Methacryloyloxydecyl Dihydrogen Phosphate; HF: Hydrofluoric Acid; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; REML: Restricted Maximum Likelihood; I^2: Inconsistency Statistic; SD: Standard Deviation; CI: Confidence Interval; GRADE: Grading of Recommendations Assessment, Development and Evaluation

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Author contribution Oh and ra wrote Ja and ah supervised All authors reviewed and agreed.

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Data availability No datasets were generated or analysed during the current study.

Declarations

AI use disclosure The authors confirm that generative artificial intelligence (AI) tools were used solely for language refinement and formatting support during manuscript preparation. AI assistance was limited to improving grammar, clarity, and structural organization. No AI tools were used for data extraction, statistical analysis, interpretation of results, or generation of scientific conclusions. All methodological decisions, data verification, statistical computations, and scientific interpretations were performed and validated by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the work.

Competing interests The authors declare no competing interests.

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