

Review article

Tack-cure vs conventional polymerization methods: A systematic review on resin composite cements' properties

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ABSTRACT

Objectives: This systematic review aimed to address the following research question: "What is the effect of tack-cure compared to conventional polymerization methods on the resin composite cements' properties?"

Data and sources: A comprehensive literature search was conducted across electronic databases, including Clarivate Analytics' Web of Science, Cochrane Library, EMBASE, PubMed, Scopus, and ProQuest, without language or publication date restrictions. *In vitro* studies comparing tack-cure (TC) with conventional polymerization methods (light-cure, LC, and/or self-cure, SC) were included. The risk of bias was assessed using the QUIN tool for *in vitro* studies. This systematic review was reported in accordance with PRISMA guidelines.

Results: Sixteen relevant articles were included in this systematic review. According to the QUIN tool, 1 study was ranked as "low risk," 12 studies as "medium risk," and 3 studies as "high risk" of bias. The resin cements evaluated were mainly dual-cure (DC) adhesive/multistep and self-adhesive/one step materials, whereas only 1 universal cement was investigated. Overall, TC provided comparable or superior mechanical properties compared to LC, and consistently outperformed SC alone. Furthermore, TC facilitated excess cement removal and improved interface quality. However, outcomes varied depending on the type of resin cement, polymerization protocol, and evaluation method.

Conclusions: TC can provide mechanical properties and interface quality comparable or superior to conventional polymerization methods, while facilitating excess cement removal.

Clinical significance: TC appears to be a clinically useful technique that enhances handling without adversely affecting resin composite cements' properties. Clinicians should always follow manufacturers' instructions and consider cement-specific characteristics.

1. Introduction

Resin composite cements are extensively used in contemporary restorative dentistry for the cementation of indirect restorations. Based on their luting strategy, they can be classified into adhesive/multi-step, self-adhesive/one-step, and universal cements, with the latter representing the most recent advancement in this category [1]. The clinical success and longevity of indirect restorations strongly depend on the mechanical, physical, and adhesive properties of resin composite cements which, in turn, are directly influenced by the effectiveness of the

polymerization process [2]. Adequate polymerization enhances the cement's resistance to degradation, improves bonding performance and biocompatibility, and ensures superior marginal adaptation, contributing to long-term clinical outcomes [3].

Traditionally, resin composite cements can be classified according to their polymerization mode as light-cure (LC) or self-cure (SC). LC resin cements polymerize upon exposure to light for a manufacturer-specified duration, whereas SC counterparts undergo chemical polymerization via auto-initiators after the mixing of two separate components [4]. Although LC resin cements generally exhibit superior mechanical

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properties and bonding performance compared to SC cements, the clinical scenario dictates the most appropriate choice [5]. For instance, in cases involving thick, opaque restorations or deep cavities, light transmission may be compromised, potentially leading to suboptimal polymerization [6]. To overcome these limitations, dual-cure (DC) resin cements have been developed, combining both light- and chemical-polymerization mechanisms to ensure a more reliable curing process, regardless of light accessibility [7].

Another crucial aspect of cementation procedures is the removal of excess resin cement [8] which, if inadequately cleaned, may lead to complications such as periodontal inflammation, marginal defects, and compromised mechanical and esthetic outcomes over time [9]. Excess cement removal can be particularly challenging in cases with subgingival margins or multiple restorations, where accessibility is limited [10].

To address these challenges, the tack-cure (TC) technique has been introduced as a modification of conventional polymerization protocols [11]. This technique involves an initial short-duration light exposure (typically 1 to 5 s, depending on the material and manufacturer's recommendations) to partially polymerize the cement, bringing it to a semi-gel consistency that facilitates excess removal before final polymerization is completed (Fig. 1) [12]. This method has been widely adopted in clinical practice due to its predictability and ease of use. However, concerns have been raised regarding the potential impact of TC on the final mechanical and physical properties of resin composite cements. Specifically, it has been hypothesized that interrupting the polymerization process at an early stage could lead to suboptimal polymer cross-linking, potentially affecting long-term clinical performance [13]. Despite its increasing clinical interest, the available evidence on the impact of TC on the physical and chemical properties of resin composite cements remains fragmented.

Therefore, we conducted a systematic review to critically analyze and synthesize available *in vitro* studies, addressing the following research question: "What is the effect of tack-cure compared to conventional polymerization methods on the resin composite cements' properties?"

2. Materials and methods

2.1. Study protocol, eligibility criteria and search strategy

This systematic review was reported in accordance with the PRISMA 2020 and PRISMA-S guidelines [14,15].

The following PICOS framework [16] was adopted to define the scope and inclusion criteria of the present systematic review:

Population (P) – dental resin composite cements (dual-cure or light-cure);

Interventions (I) – tack-cure;

Comparisons (C) – conventional polymerization method (light-cure and/or self-cure);

Outcomes (O) – primary outcome: mechanical properties (degree of

conversion, hardness, polymerization shrinkage); secondary outcomes: surface characteristics, biofilm formation, excess removal and interface quality;

Study design (S) – *in vitro* studies.

The exclusion criteria were as follows: (1) case reports, case series, animal studies, and clinical trials; (2) literature reviews and systematic reviews; (3) *in vitro* studies employing resin-modified glass ionomer cements; (4) *in vitro* studies employing build-up core resin materials; (5) *in vitro* studies investigating TC exclusively; (6) *in vitro* studies evaluating only conventional polymerization methods.

The final literature search was conducted between April 11 and 14, 2025, with no restrictions on language or publication date, using the following electronic databases: PubMed, Cochrane Library, EMBASE, Clarivate Analytics' Web of Science, and Scopus. Five relevant studies were used to identify records within these databases. Candidate search terms were identified by examining words in the titles, abstracts and subject indexing of these records. A draft search strategy was developed to incorporate the most common keywords, synonyms, and relevant controlled vocabulary. Search terms were also verified using the Word Freq tool on Systematic Review Accelerator (<https://sr-accelerator.com>). The complete search strategy (Table S1) was developed by an investigator (C.D.) and peer reviewed by an experienced reviewer (U.J.), following the PRESS checklist [17]. To identify grey literature, including conference abstracts, dissertations, and theses, and to minimize publication bias, a complementary search was conducted on ProQuest (<https://www.proquest.com>). Finally, manual search on relevant journals and citation mining were performed to ensure the inclusion of the relevant studies that may not have been identified through database search.

2.2. Study selection and data extraction

All search results were imported into a review software (Rayyan Systems Inc, Doha, Qatar) for duplicate removal and screening. After training and calibration, two investigators (E.B. and C.D.) independently screened the titles and abstracts of all retrieved articles, reviewed full-texts for inclusion, and discussed inconsistencies until consensus was reached. In case of disagreement, a third researcher (C.M.) was consulted for the final decision.

Finally, relevant articles were included for data extraction, performed by E.B. and C.D. using a custom-made extraction form in Word to minimize errors and bias. The following data were extracted: author and year, resin composite cement tested, polymerization type (TC and conventional methods), outcome and type of test, information on the polymerization method, including the type of curing unit and application distance, and results expressed as mean and standard deviation.

When data were missing or unclear, the corresponding author was contacted by an e-mail for further details. In cases where numerical data were unavailable, DigitizeIt software (<https://www.digitizeit.xyz>, DigitizeIt, Braunschweig, Germany) was used to extract mean and standard deviation values from box-plot and bar graphs.



Fig. 1. Cementation of lithium disilicate crowns using a universal resin composite cement (Panavia SA, Kuraray Noritake). Following crowns placement (A), a short light-curing cycle (tack-cure) of 3 s was performed using a polywave LED curing unit (VALO, Ultradent) (B). This technique induces a semi-gel consistency of the cement, allowing easy removal of excess material in a single mass (C). Finally polymerization was then performed according to the manufacturer's instructions (in this specific case, 10 s per surface).

2.3. Risk of bias assessment

Risk of bias in the included studies was assessed using the QUIN tool (Quality Assessment Tool For *In Vitro* Studies) [18]. Two investigators (E.B. and C.D.) independently evaluated each study and recorded supporting information and justifications from judgments of risk of bias for each domain. A third investigator (U.J.) was consulted to resolve disagreements.

The QUIN tool consists of 12 criteria (clearly stated aims/objectives; detailed explanation of sample size calculation; detailed explanation of sampling technique; details of comparison group; detailed explanation of methodology; operator details; randomization; method of measurement of outcome; outcome assessor details; blinding; statistical analysis; presentation of results). For assessing the risk of bias of the included *in vitro* studies, the two investigators scored each of the 12 criteria as adequately specified (2 points), inadequately specified (1 point), not specified (0 point), and not applicable (excluded criteria from calculation). The total score obtained was used to grade the overall risk of bias (high, medium, or low risk) on a study level according to the formula presented in the QUIN tool article.

3. Results

3.1. Study selection

The literature search (Fig. 2) resulted in 2171 articles across all the databases. After excluding 362 duplicates, 1809 studies remained for review.

Following titles and abstracts screening, 1751 studies were excluded. A total of 48 studies, 7 master's theses, and 3 doctoral dissertations were retrieved for full-text evaluation. Additionally, 5 eligible studies were identified through the manual search on relevant journals and citation mining. Of these, 47 studies were excluded due to wrong population, wrong intervention and wrong comparison. At the end of the literature search, 16 studies were included in the current systematic review [9,12,13,19–31].

3.2. Qualitative synthesis of the included studies

The details extracted from the 16 included studies are summarized in Table S2.

3.2.1. Type of resin cement

Various types of resin composite cements have been investigated across the included studies. Three studies examined LC resin cements [12,26,31], while the majority focused on DC adhesive/multi-step [13,19,20,22,23,26,27,31] and self-adhesive/one-step [9,12,19,21–25,28,30] resin cements, with only G-CEM ONE (GC) investigated as universal cement [29].

3.2.2. Degree of conversion evaluation

Four studies investigated the degree of conversion of resin composite cements using different methods: 2 employed Fourier Transform Infrared (FTIR) analysis [13,24], 1 used Fourier Transform Near-Infrared (FT-NIR) method [26], and 1 applied Raman spectroscopy [29]. Only 1 study evaluated the degree of conversion through a lithium

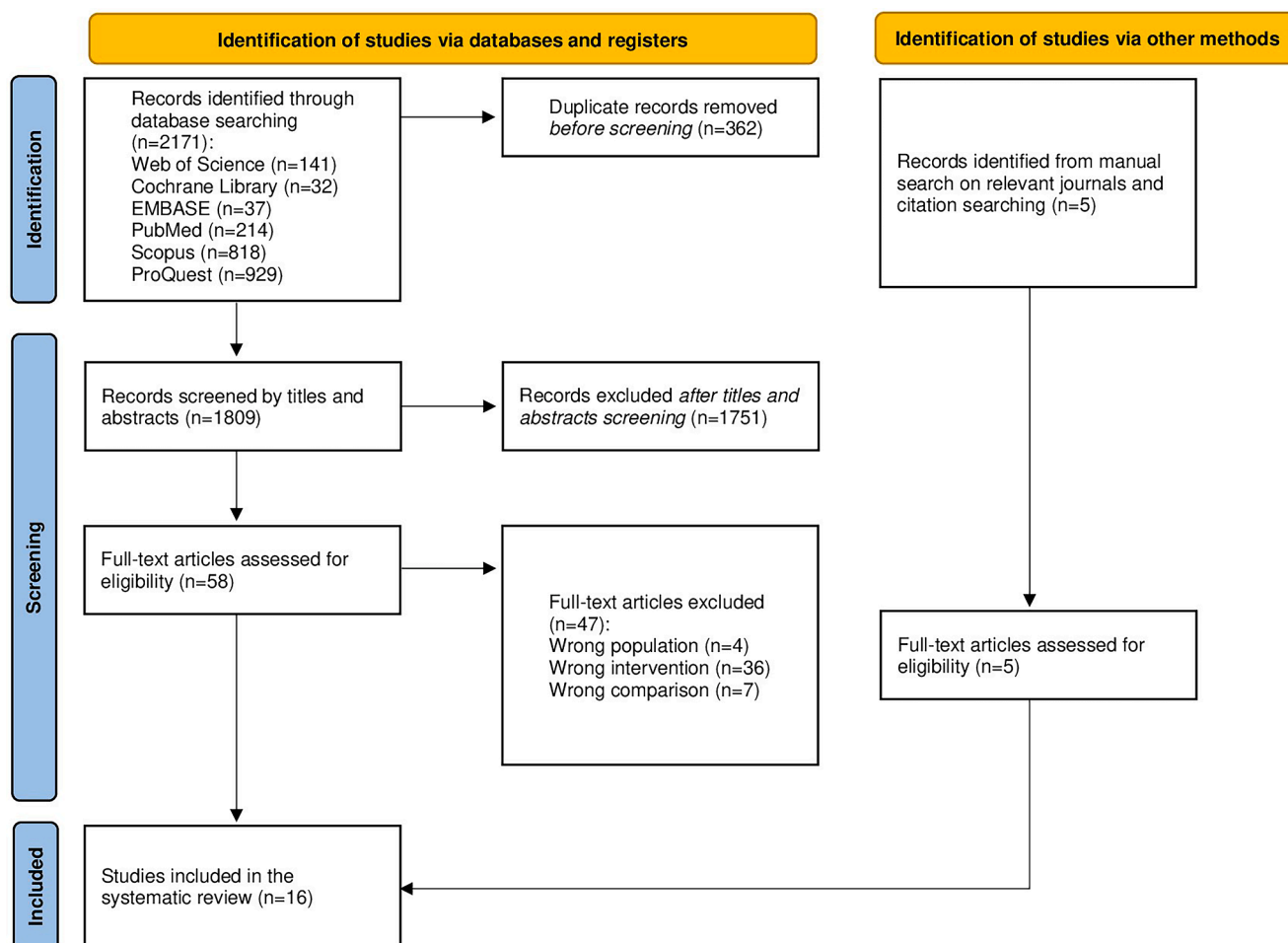


Fig. 2. PRISMA 2020 flow diagram for new systematic reviews.

disilicate crown [29], attempting to simulate a clinical scenario. The remaining 3 studies conducted tests on geometric samples [13,24,26]; however, either a 2 mm composite layer [26] or a 1.5 mm thick lithium disilicate disk [24] was interposed between the resin cement and the light-curing tip. Overall, findings suggest that TC does not negatively impact the final degree of conversion when followed by either LC or SC. Specifically, resin cements subjected to TC usually exhibited either higher or equivalent degree of conversion values compared to those subjected to SC, while outcomes varied in comparison to LC, yielding either equivalent or slightly lower values.

Some studies reported that LC modes usually produced comparable final degree of conversion values [29], whereas SC significantly reduced the degree of conversion [13,24]. Notably, over an extended period of up to 28 days, the effects of TC+LC and LC alone were not statistically different. Furthermore, an increasing trend in degree of conversion over time was observed [26].

The combination of TC+SC resulted in a superior overall degree of conversion compared to SC alone [15].

Initial light activation did not appear to significantly alter the intrinsic properties of DC resin cements. When light transmission through an indirect restoration was adequate, especially in cases of reduced thickness, a sufficient final degree of conversion was achieved [29]. Furthermore, Sebar et al. demonstrated that the degree of conversion remained consistent throughout the cement layer and was not significantly affected by the distance from the curing light [29]. However, when comparing LC and DC resin cements, the former achieved a higher degree of conversion over time [26]. Despite these overall trends, degree of conversion values exhibited material-dependent variations, highlighting the influence of resin composite cement brand and composition.

3.2.3. Hardness evaluation

Three studies assessed Vickers hardness using a microhardness indenter [12,19,24]. The tests were performed on geometric samples; specifically, a 2.5 mm thick leucite-reinforced ceramic disk [19] or a 1.5 mm thick lithium disilicate disk [24] was interposed between the resin cement and the light-curing tip. Overall, TC resulted in hardness values comparable to those obtained through conventional LC polymerization [12,19,24]. Notably, Stegall et al. reported an increased microhardness following TC, suggesting improved conversion throughout the depth of the resin cement [12]. In this study, hardness was measured up to a depth of 7 mm to investigate the effect of curing light distance. Both LC and DC resin cements exhibited a significant decrease in hardness with increasing depth. Specifically, LC resin cements demonstrated the lowest depth of cure due to light attenuation through the material, whereas DC resin cements benefited from the TC step, showing significantly higher hardness values near the surface and slightly improved values throughout depth. In contrast, SC alone failed to achieve adequate polymerization, as evidenced by a marked reduction in hardness with depth, reinforcing the necessity of LC, as highlighted in some studies [19,24]. Additionally, Flury et al. found that prolonged LC time exposure (5 min) yielded the highest microhardness values, whereas SC alone resulted in the lowest, regardless of resin cement type [19].

3.2.4. Polymerization shrinkage evaluation

Three studies analyzed parameters related to polymerization shrinkage: 2 assessed axial polymerization shrinkage [23,25], while 1 examined polymerization shrinkage strain and stress [24]. The results showed that when DC resin cements underwent TC+SC, shrinkage was significantly lower compared to SC alone [23,25]. However, when LC was performed following excess cement removal, neither TC nor its duration (≤ 5 s) had a significant effect on final polymerization shrinkage compared to LC alone, suggesting that TC does not adversely affect the shrinkage process [23–25].

Interestingly, when comparisons were made between SC and LC polymerization methods, some authors found that TC+LC or LC alone

resulted in higher shrinkage values than TC+SC or SC alone [23,24]. These results are in contrast with those of Choi et al. where lower polymerization shrinkage was reported for TC+LC or LC alone compared to SC alone [25].

3.2.5. Surface characteristics and biofilm formation

Two studies evaluated surface roughness average (Ra) at the interface using a profilometer [20,21]. Anami et al. found that the cement removal technique had no significant impact on Ra. In contrast [20], Pereira et al. reported a significant reduction in Ra when TC was followed by removal with a scalpel blade, compared to removal with a brush or microbrush in a conventional approach [21]. Furthermore, polishing ceramic and tooth marginal areas significantly improved surface smoothness, regardless of the cement removal method [21].

The cement removal technique also influenced bacterial adhesion. Anami et al. observed significantly higher bacterial adhesion when a Teflon spatula was used before polymerization, compared to TC followed by a scalpel blade or a conventional brush approach, even after final polishing with silicon tips [20]. Conversely, Pereira et al. found that, after polishing, TC combined with a scalpel blade resulted in greater biofilm accumulation. However, no significant differences were observed between conventional cement removal with a brush or microbrush and TC followed by an explorer [21]. These findings suggest that factors other than surface roughness may contribute to bacterial adhesion, with the cement removal techniques playing a more crucial role than the polymerization mode.

Finally, neither biofilm thickness nor biovolume was significantly influenced by the cement removal technique or polishing [20,21].

3.2.6. Excess removal and interface quality

Six studies evaluated excess resin cement removal and cement layer quality in relation to different polymerization methods [21,22,27,28,30,31].

Melo Freire et al. reported that 1-s TC did not significantly affect marginal discrepancy, suggesting that a short initial light activation may enhance the efficiency of clinical procedures without compromising the accuracy [22].

The excess removal technique also influences the integrity of the cement layer. Tack-curing for up to 5 s, followed by excess removal with a probe, explorer or dental floss, resulted in less residual cement at the margins compared to removing uncured cement before LC [21,27,31]. Additionally, polishing improved both the width and depth of marginal voids, with TC demonstrating superior performance compared to SC alone [30]. Only 1 study examined the cementation of implant-supported restorations, finding that TC followed by excess removal with a probe or similar instrument was more effective in minimizing residual cement at the margins compared to other cleaning methods. However, TC did not completely prevent excess resin cement around dental implants, as discoloration was observed after thermocycling [28].

3.3. Risk of bias assessment

Table 1 presents the results of the risk of bias analysis for the 16 studies included in this systematic review. Based on the QUIN tool assessment, 3 studies were rated as “high risk of bias” [20,28,29], 12 studies were rated as “medium risk of bias” [13,21,22,12,23–27,9,30,31], and 1 study was rated as “low risk of bias” [19].

The point leading to downgrading in Item 1 was the absence of a clearly stated null or research hypothesis [13,20,24,29]. Item 2 posed a significant issue in the risk of bias assessment, as a method for sample size calculation was missing in all articles except in 4 studies, which explicitly reported it [9,19,26,31]. No studies had concerns related to Item 3. The problem associated with Item 4 was the absence of clearly specified comparison groups resulting in downgrading the score in 4 studies [20,21,30,31]. The raised concerns related to risk of bias arising

Table 1
Risk of bias assessment of the included studies using the QUIN tool.

Author, Year	Clearly Stated Aims/Objectives	Detailed Explanation of Sample Size Calculation	Detailed Explanation of Sampling Technique	Details Of Comparison Group	Detailed Explanation of Methodology	Operator Details	Randomization	Method of Measurement of Outcome	Outcome Assessor Details	Blinding	Statistical Analysis	Presentation of Results	Total Score	Final Score %	Risk of Bias
Flury et al. [19]	2	1	2	2	2	1	n/a	2	1	0	2	2	17	77,27	low
Anami et al., [20]	1	0	2	1	1	0	1	2	0	0	1	2	11	45,83	high
Chen et al., [13]	1	0	2	2	2	0	0	2	0	0	1	2	12	50,00	medium
Pereira et al., [21]	2	0	2	1	1	0	2	2	0	0	2	2	14	58,33	medium
Melo Freire et al., [22]	2	0	2	2	1	0	1	2	0	0	2	2	14	58,33	medium
Stegall et al., [12]	2	0	2	2	2	0	0	2	0	0	2	1	13	54,17	medium
Kim et al., [23]	2	0	2	2	1	0	n/a	2	0	0	2	2	13	59,09	medium
Yang et al., [24]	1	0	2	2	1	0	n/a	2	0	0	1	2	11	50,00	medium
Choi et al., [25]	2	0	2	2	1	0	n/a	2	0	0	2	2	13	59,09	medium
Tosco et al., [26]	2	1	2	2	2	0	n/a	2	0	0	2	2	15	68,18	medium
Gaile et al., [27]	2	0	2	2	0	2	0	2	2	0	1	2	15	62,50	medium
Mohammed and Koheil, [28]	2	0	2	2	0	0	0	2	0	0	1	2	11	45,83	high
Sebar et al., [29]	1	0	2	2	0	2	0	2	0	0	0	1	10	41,67	high
Peters et al., [9]	2	1	2	2	1	2	0	2	2	0	1	1	16	66,67	medium
Beierlein et al., [30]	2	0	2	1	0	0	1	2	0	0	2	2	12	50,00	medium
Otani et al., [31]	2	1	2	1	1	2	2	2	0	0	2	1	16	66,67	medium

from Item 5 were the lack of information regarding curing time [9,20,22–25,28], polymerization unit [21,27,30] and distance [25,27,28], and the unclarity of methodology [30]. One of the most common biases was related to Item 6, as the majority of studies did not report the number of operators or provide details regarding their training and calibration, except for 5 studies [9,19,27,29,31]. For Item 7, the main reason for downgrading was the lack of explicit use of randomization software for allocation concealment [20,22,30], while studies not clearly specifying the randomization process in the text obtained 0 points [9,12,13,27–29]. In 5 studies this Item was marked as “not applicable” due to the inherent impossibility of randomization in their study design [19,23–26]. Item 8 posed the least risk of bias, as all studies received the full score regarding the method used to measure outcomes. The risk of bias judgment was affected by the limited reporting of Item 9 and 10. Only 3 studies provided details on the number and/or calibration of outcome assessors [9,19,27], while none reported sufficient information about the blinding of operators, assessors or statisticians. Item 11 was downgraded in 6 studies due to the absence of details regarding the statistical software used for data analysis [9,13,20,24,27,28], while 1 study lacked the statistical analysis information [29]. Finally, Item 12, regarding the presentation of results, was downgraded when data were not clearly presented in a table or when standard deviation values were missing [9,12,29,31].

4. Discussion

The continuous evolution of resin composite cements for luting indirect restorations has led to extensive *in vitro* research assessing their properties [1]. However, fragmented evidence is available regarding the impact of TC, despite its recommendation by some manufacturers as a cement excess removal strategy and its widespread use in clinical practice [23]. Notably, this systematic review identified 16 relevant studies that directly or indirectly investigated TC polymerization as a key variable.

Due to the heterogeneity in interventions, study settings, study designs, and outcome measures across the included *in vitro* studies, a meta-analysis could not be conducted.

4.1. Type of resin cement

The majority of the included studies investigated DC adhesive/multi-step and self-adhesive/one-step resin cements. This distribution reflects clinical practice, as DC resin cements are widely used for luting a broad range of indirect posterior restorations, including inlays, onlays, crowns, endocrowns, and fiber posts, due to their ability to polymerize via both light and chemical activation [5,32]. However, DC resin cements typically contain tertiary amines as co-initiators, which degrade over time and may lead to discoloration at the restoration-tooth interface. Consequently, DC resin cements are not recommended for highly esthetic restorations, such as veneers, where LC cements are preferred due to the superior stability of their photoinitiators [33]. Notably, LC resin cements were evaluated in only 3 studies [12,26,31]. Although many studies have explored the TC technique as a method to stabilize restorations and facilitate excess removal, they did not investigate TC as a variable, leading to their exclusion from this systematic review. Furthermore, despite the growing body of literature on universal resin cements, only 1 study examined TC in this cement category [29], highlighting a gap that warrants further investigation.

4.2. Degree of conversion evaluation

The degree of conversion is a direct measure of the percentage of C=C bonds formed in resin-based materials during polymerization, and it is commonly assessed using FTIR and Raman spectroscopy [34]. A proper degree of conversion is crucial for the long-term success of indirect restorations, as it impacts on the chemical and mechanical

properties of resin composite cements, as well as their biocompatibility and color stability [3]. Several factors influence the degree of conversion in resin-based materials. LC resin cements primarily rely on radiant exposure, which is determined by the product of irradiance and light application time. In contrast, DC resin cements initiate chemical curing immediately upon mixing components, with the final degree of conversion depending not only on radiant exposure but also on the mobility of free radicals within the polymeric chain [2].

Evidence from medium-risk bias studies suggested that TC does not negatively impact the final degree of conversion in DC resin cements compared to delayed [24] or immediate [13,26] LC polymerization. In contrast, SC alone has a detrimental effect on the degree of conversion, as chemical curing requires more time to complete polymerization and reach high values [35] and the presence of acidic monomers in self-adhesive/one step cements can interfere with amine initiators of SC components [12]. Furthermore, DC resin cements contain higher concentrations of inhibitors to extend their manipulation and clinical working time [36], but these inhibitors can impair polymerization, especially when materials are not exposed to LC [6,37,38]. Thus, the literature consistently indicates that SC alone results in a lower degree of conversion compared to TC and LC.

Notably, only 1 study assessed the degree of conversion over an extended period of up to 28 days, reporting an increasing trend over time [26]. This finding emphasizes the so-called “uncured chamber” process in which, during polymerization, monomers begin to cure while the material becomes rigid, trapping unreacted monomers within the matrix. Thus, the curing process can take between 1 and 7 days to fully complete, warranting further investigations over time. In contrast, concerns about the early increase in viscosity (vitrification) due to insufficient initial light exposure, which may hinder the migration of initiators for subsequent SC and compromise overall polymerization appears unfounded [39].

These findings cannot be directly applied to universal cements, as the degree of conversion has only been investigated by Sebar et al. [29], who compared TC with delayed LC polymerization after 1 min of SC, but did not include pure SC. Most universal cements incorporate an optional activator that is applied to the tooth structure to initiate a touch-cure mechanism, enhancing SC and reducing the material's dependence on light irradiance to achieve optimal conversion [40].

Beyond cement type and polymerization mechanism, other factors may influence the formation of the C=C network. Notably, the duration of TC appears to be a critical variable. Indeed, TC durations of 2–3 s resulted in highly variable degrees of conversion, ranging from 15 % to 51 %, depending on the resin composite cement brand [13]. Generally, the initial degree of conversion achieved by resin composite cements is approximately 60 %, with values continuing to increase over time [6]. This variability suggests that different products may require specific TC duration to achieve the semi-gel state necessary for effective excess cement removal without hampering mechanical properties. Therefore, strict adherence to the manufacturer's instructions is essential to optimize clinical outcomes.

4.3. Hardness evaluation

Hardness measurement using Vickers Hardness (HVN) or nano-indentation is a well-established indirect method for evaluating the degree of conversion, as a strong positive correlation between these parameters has been demonstrated [12,24,24]. Among the included studies, HVN was the most commonly employed test [12,19,24], with findings aligning with the degree of conversion results discussed earlier. Specifically, TC resulted in similar or higher surface hardness compared to LC, while SC consistently produced the lowest values. Variations in HVN across different resin cements likely reflect compositional differences [19].

However, it is important to consider that resin cement thickness varies depending on the type of indirect restorations, with layers up to 6

mm reported in fiber posts luting procedures [41]. To better replicate these clinical conditions, an HVN profile assessment up to 7 mm in depth has been suggested [12]. In this regard, Stegall et al. observed that DC resin cements exhibited improved HVN at greater depths when TC was applied, compared to LC. These findings suggest that slightly increasing light exposure may enhance hardness, reinforcing the idea that manufacturer-recommended curing times should be considered as minimum requirements rather than optimal durations [12]. Indeed, extending LC time is well known to improve monomer-to-polymer conversion and enhance the material's physical properties [19].

Additionally, the mechanical properties of resin composite cements are influenced by light intensity [3]. Notably, considerable variation exists among studies regarding the type of curing units and power outputs used. Most of the included studies specified the curing unit and power output, with light-emitting diode (LED) units being the most frequently used, consistent with their widespread clinical application. Over time, LC technology has evolved from quartz-tungsten-halogen (QTH) lamps to LED systems. Research indicates that resin cements polymerized with QTH units often exhibit lower microhardness compared to those cured with LED units, likely due to the higher energy density delivered by LEDs [42]. Furthermore, the power output of LED curing units varied significantly across the included studies, ranging from 500 mW/cm² [23] to 2127 mW/cm² [12]. A systematic review concluded that high light intensity (>1300 mW/cm²) enhances the polymerization efficiency of resin composites [43].

4.4. Polymerization shrinkage evaluation

Polymerization shrinkage is a key factor contributing to the failure of luted restorations [44] and is strongly correlated with the polymerization rate [24,45]. According to the qualitative analysis, TC leads to higher polymerization shrinkage compared to SC, but demonstrates similar shrinkage levels to LC. As previously mentioned, TC duration varied among the included studies. In this context, Choi et al. reported that TC duration of 1, 2, 3 or 5 s did not significantly influence the polymerization shrinkage of the tested self-adhesive/one-step resin cement (G-CEM LinkACE, GC) when subsequently LC [25].

4.5. Surface characteristics and biofilm formation

The timing and method of excess cement removal also impact interface quality, particularly in terms of surface roughness and biofilm adhesion [20,21]. A smoother cement surface with lower roughness reduces bacterial colonization, lowering the risk of marginal discoloration and secondary caries [46]. Regarding excess removal timing, studies indicate that TC produces smoother surfaces compared to SC or removal with a brush or a microbrush before polymerization [21].

Biofilm retention is another critical concern, though only 2 studies specifically evaluated the influence of TC on this parameter [20,21]. Scanning electron microscope (SEM) [20] and μ -CT [27] imaging revealed that excess cement removal can leave porosities and voids on the cements surface. Interestingly, Anami et al. found that TC followed by polishing resulted in a more retentive surface for bacteria adhesion compared to brush removal before polymerization in the DC adhesive/multi-step Variolink II (Ivoclar) [20]. The authors hypothesized that abrasive particles detached from polishing tips may increase surface roughness. Conversely, other studies emphasized that final polishing at the margins plays a more crucial role than the cement removal technique itself [21,27]. Pereira et al. reported that, for the DC self-adhesive/one-step RelyX U200 (Solventum), TC followed by polishing resulted in a smoother surface, although the CFU/ml bacterial count remained unchanged [21]. These discrepancies highlight the need for further research on polishing techniques, as well as the antibacterial properties of different resin cements [47,48].

4.6. Excess removal and interface quality

The interface between the indirect restoration and the tooth structure is sealed by the resin cement [49]. Clinically, a cement line thickness between 50 and 120 μ m, free of cracks or irregularities, is considered acceptable [50]. Larger discrepancies can lead to complications such as microleakage, cement dissolution, secondary caries or loss of retention [51,52]. Therefore, interface quality is a critical factor for long-term success of indirect restoration.

The width of the cement line has been evaluated in crowns [22,30] and veneers [27] with studies consistently reporting that neither TC nor SC+LC significantly influence cement line width. However, other factors, such as the type of restorative material used [22] and thermocycling [27], may play a role. Additionally, interface quality has been assessed based on the presence of voids, with DC resin cements either exhibiting no voids or a higher number of them in SC+LC groups [27,30].

Different instruments have also been compared for excess cement removal. Clinicians commonly use brushes, explorers, probes, curettes, scalers, or scalpels in accessible areas, while various types of floss are preferred for interproximal regions [10]. When brushes or microbrushes are used before polymerization, the technique is also known as the "wipe-off method". In contrast, when excess cement is removed in the semi-gel state after TC or after SC, it can be referred to as the "switched-off method" [8]. The latter, using a probe or explorer, has been found to be more effective than the wipe-off method, as TC simplifies and accelerates excess cement removal, leading to cleaner margins and reduced residual cement [31]. In contrast, although a brush has been proposed as a simple and effective method, controlling excess cement removal before polymerization remains challenging due to the material's inherently sticky and fluid consistency [28].

Residual resin cement is a major concern for periodontal and peri-implant health. However, only 1 study specifically investigated cemented implant crowns, and it was rated as high risk of bias [28], underscoring the need for further research. Additionally, variability exists in the methods used to evaluate excess cement. Recent studies favor non-invasive techniques, such as high-resolution optical microscopy and/or μ -CT imaging [9].

Lastly, some observations deriving from this systematic review should be mentioned. Despite efforts to simulate clinical conditions and the advantage of controlled variables, *in vitro* studies inherently differ from clinical reality [53]. The opacity and thickness of the indirect restoration vary widely depending on the material, affecting radiant exitance [54]. Furthermore, the time interval between TC and final polymerization should be standardized, considering the extended removal time required in clinical settings due to the adjacent teeth and operative challenges. Variability in curing times may alter the interaction between SC and LC, ultimately affecting polymerization outcomes [55]. Thus, future research should incorporate factors such as restoration thickness, material opacity and different delay time to enhance clinical relevance of findings.

5. Conclusions

The findings based on laboratories studies indicate that TC provides mechanical properties and interface quality comparable or superior to conventional polymerization methods. Additionally, it may facilitate excess cement removal and provide smoother surfaces. However, these outcomes can be influenced by the type and brand of resin composite cement.

CRediT authorship contribution statement

Carlo D'Alessandro: Writing – original draft, Methodology, Investigation, Formal analysis. **Eugenia Baena:** Writing – original draft, Methodology, Investigation, Formal analysis. **Uros Josic:** Writing –

review & editing, Validation, Methodology, Investigation. **Tatjana Maravic:** Writing – review & editing, Validation, Methodology. **Edoardo Mancuso:** Validation, Methodology, Investigation. **Laura Ceballos:** Writing – review & editing, Supervision. **Annalisa Mazzoni:** Writing – review & editing, Supervision. **Markus B. Blatz:** Writing – review & editing, Validation. **Lorenzo Breschi:** Writing – review & editing, Supervision, Conceptualization. **Claudia Mazzitelli:** Writing – review & editing, Supervision, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jdent.2025.105917](https://doi.org/10.1016/j.jdent.2025.105917).

References

- [1] T. Maravić, C. Mazzitelli, E. Mancuso, F. Del Bianco, U. Josić, M. Cadenaro, L. Breschi, A. Mazzoni, Resin composite cements: current status and a novel classification proposal, *J. Esthet. Restor. Dent.* (2023), <https://doi.org/10.1111/jerd.13036>.
- [2] R. Fidalgo-Pereira, O. Torres, Ó. Carvalho, F.S. Silva, S.O. Catarino, M. Özcan, J.C. M. Souza, A scoping review on the polymerization of resin-matrix cements used in restorative dentistry, *Mater. (Basel)* 16 (2023) 1560, <https://doi.org/10.3390/ma16041560>.
- [3] G. De Souza, R.R. Braga, P.F. Cesar, G.C. Lopes, Correlation between clinical performance and degree of conversion of resin cements: a literature review, *J. Appl. Oral Sci.* 23 (2015) 358–368, <https://doi.org/10.1590/1678-775720140524>.
- [4] A. Maletín, M.J. Knežević, D.D. Koprivica, T. Veljović, T. Puškar, B. Milekić, I. Ristić, Dental resin-based luting materials—Review, *Polym. (Basel)* 15 (2023) 4156, <https://doi.org/10.3390/polym15204156>.
- [5] S. Ghodsi, M. Shekarian, M.M. Aghamoheeni, S. Rasaiepour, S. Arzani, Resin cement selection for different types of fixed partial coverage restorations: a narrative systematic review, *Clin. Exp. Dent. Res.* 9 (2023) 1096–1111, <https://doi.org/10.1002/cre2.761>.
- [6] M. Aldhafyan, N. Silikas, D.C. Watts, Influence of curing modes on conversion and shrinkage of dual-cure resin-cements, *Dent. Mater.* 38 (2022) 194–203, <https://doi.org/10.1016/j.dental.2021.12.004>.
- [7] C. Mazzitelli, T. Maravic, U. Josic, E. Mancuso, L. Generali, V. Checchi, L. Breschi, A. Mazzoni, Effect of adhesive strategy on resin cement bonding to dentin, *J. Esthet. Restor. Dent.* 35 (2023) 501–507, <https://doi.org/10.1111/jerd.12978>.
- [8] C.A. Mitchell, M.R. Pintado, L. Geary, W.H. Douglas, Retention of adhesive cement on the tooth surface after crown cementation, *J. Prosthet Dent.* 81 (1999) 668–677, [https://doi.org/10.1016/S0022-3913\(99\)70105-8](https://doi.org/10.1016/S0022-3913(99)70105-8).
- [9] B.C. Peters, R. Cook, T. Donovan, T.A. Sulaiman, Microcomputed tomography void analysis after cement cleanup methods, *J. Prosthet Dent.* 129 (2023) 449–455, <https://doi.org/10.1016/j.prosdent.2021.06.010>.
- [10] Y.F. Mansour, Pintado, R. Maria, C.A. Mitchell, Optimizing resin cement removal around esthetic crown margins, *Acta Odontol. Scand.* 64 (2006) 231–236, <https://doi.org/10.1080/00016350600613443>.
- [11] D. Hornbrook, Tack and Wave technique: Predictable Veneer Cementation, *Perio Implant Advisory*, 2012.
- [12] D. Stegall, D. Tantbirojn, J. Perdigão, A. Versluis, Does tack curing luting cements affect the final cure? *J. Adhes. Dent.* 19 (2017) 239–243, <https://doi.org/10.3290/jjad.a38410>.
- [13] L. Chen, B.I. Suh, C. Gleave, W.J. Choi, J. Hyun, J. Nam, Effects of light-, self-, and tack-curing on degree of conversion and physical strength of dual-cure resin cements, *Am. J. Dent.* 29 (2016) 67–70.
- [14] M.J. Page, J.E. McKenzie, P.M. Bossuyt, I. Boutron, T.C. Hoffmann, C.D. Mulrow, L. Shamseer, J.M. Tetzlaff, E.A. Akl, S.E. Brennan, R. Chou, J. Glanville, J. M. Grimshaw, A. Hróbjartsson, M.M. Lalu, T. Li, E.W. Loder, E. Mayo-Wilson, S. McDonald, L.A. McGuinness, L.A. Stewart, J. Thomas, A.C. Tricco, V.A. Welch, P. Whiting, D. Moher, The PRISMA 2020 statement: an updated guideline for reporting systematic reviews, *BMJ* 372 (2021) n71, <https://doi.org/10.1136/bmj.n71>.
- [15] M.L. Rethlefsen, S. Kirtley, S. Waffenschmidt, A.P. Ayala, D. Moher, M.J. Page, J. B. Koffel, PRISMA-S Group, PRISMA-S: an extension to the PRISMA Statement for reporting literature searches in systematic reviews, *Syst. Rev.* 10 (2021) 39, <https://doi.org/10.1186/s13643-020-01542-z>.
- [16] A.M. Methley, S. Campbell, C. Chew-Graham, R. McNally, S. Cheraghi-Sohi, PICOS and PICO, SPIDER: a comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews, *BMC Health v Res.* 14 (2014) 579, <https://doi.org/10.1186/s12913-014-0579-0>.
- [17] J. McGowan, M. Sampson, D.M. Salzwedel, E. Cogo, V. Foerster, C. Lefebvre, PRESS Peer Review of Electronic search strategies: 2015 guideline statement, *J. Clin. Epidemiol.* 75 (2016) 40–46, <https://doi.org/10.1016/j.jclinepi.2016.01.021>.
- [18] V.H. Sheth, N.P. Shah, R. Jain, N. Bhanushali, V. Bhatnagar, Development and validation of a risk-of-bias tool for assessing *in vitro* studies conducted in dentistry: the QUIN, *J. Prosthet. Dent.* 131 (2024) 1038–1042, <https://doi.org/10.1016/j.prosdent.2022.05.019>.
- [19] S. Flury, A. Peutzfeldt, A. Lussi, The effect of polymerization procedure on Vickers hardness of dual-curing resin cements, *Am. J. Dent.* 24 (2011) 226–232.
- [20] L.C. Anami, C.A. Pereira, E. Guerra, R.O.D.A.E Souza, A.O.C. Jorge, M.A. Bottino, Morphology and bacterial colonisation of tooth/ceramic restoration interface after different cement excess removal techniques, *J. Dent.* 40 (2012) 742–749, <https://doi.org/10.1016/j.jdent.2012.05.005>.
- [21] S. Pereira, L. Anami, C. Pereira, R. Souza, K. Kantorski, M. Bottino, A. Jorge, L. Valandro, Bacterial colonization in the marginal region of ceramic restorations: effects of different cement removal methods and polishing, *Oper. Dent.* 41 (2016) 642–654, <https://doi.org/10.2341/15-206-L>.
- [22] C.Melo Freire, G. Borges, D. Caldas, R. Santos, S. Ignácio, R. Mazur, Marginal adaptation and quality of interfaces in lithium disilicate crowns — influence of manufacturing and cementation techniques, *Oper. Dent.* 42 (2017) 185–195, <https://doi.org/10.2341/15-288-L>.
- [23] Y.-S. Kim, S.-H. Choi, B.-N. Lee, Y.-C. Hwang, I.-N. Hwang, W.-M. Oh, J. Ferracane, H.-S. Chang, Effect of tack cure on polymerization shrinkage of resin-based luting cements, *Oper. Dent.* 45 (2020) E196–E206, <https://doi.org/10.2341/19-159-L>.
- [24] B. Yang, Q. Huang, B. Holmes, J. Guo, Y. Li, Y. Heo, H.P. Chew, Y. Wang, A. Fok, Influence of curing modes on the degree of conversion and mechanical parameters of dual-cured luting agents, *J. Prosthodont. Res.* 64 (2020) 137–144, <https://doi.org/10.1016/j.jpor.2019.06.002>.
- [25] Y. Choi, Y.-K. Heo, J.-H. Jung, H.-S. Chang, Effect of tack cure time on polymerization shrinkage of dual-cure resin cement, *Intern. J. Oral Biol.* 46 (2021) 184–189, <https://doi.org/10.11620/IJOB.2021.46.4.184>.
- [26] V. Tosco, R. Monterubbiansi, G. Orilisi, S. Sabbatini, C. Conti, M. Özcan, A. Putignano, G. Orsini, Comparison of two curing protocols during adhesive cementation: can the step luting technique supersede the traditional one? *Odontology* 109 (2021) 433–439, <https://doi.org/10.1007/s10266-020-00558-0>.
- [27] M. Gaile, E. Papi, V. Zalite, J. Locs, U. Soboleva, Resin cement residue removal techniques: *in vitro* analysis of marginal defects and discoloration intensity using micro-CT and stereomicroscopy, *Dent. J.* 10 (2022) 55, <https://doi.org/10.3390/dj10040055>.
- [28] D. Moheemmed, S. Koheil, Resin cement around tissue and bone level dental implants after two cementation techniques (An *In Vitro* Study), *Ijhs* (2022) 47433–47447, <https://doi.org/10.53730/ijhs.v6n87.13255>.
- [29] L.E. Sebar, E. Angelini, A. Baldi, A. Comba, M. Parvis, S. Grassini, Nanoindentation and raman spectroscopy measurements on dual-cure luting cement for dental conservative restoration, in: 2022 IEEE International Symposium on Medical Measurements and Applications (MeMeA), Messina, Italy, IEEE, 2022, pp. 1–6, <https://doi.org/10.1109/MeMeA54994.2022.9856528>.
- [30] G. Beierlein, L. Haas, S. Hahnel, M. Schmidt, M. Rosentritt, Influence of cement type, excess removal, and polishing on the cement joint, *Quintessence Int.* 55 (2024) 98–105, <https://doi.org/10.3290/j.jad.b2838131>.
- [31] A.C. Otani, M.P. Pattussi, A.M. Spohr, M.L. Grossi, Evaluation of the ceramic laminate veneer-tooth interface after different resin cement excess removal techniques, *Clin. Oral Invest.* 28 (2024) 136, <https://doi.org/10.1007/s00784-024-05536-2>.
- [32] U. Josic, C. Mazzitelli, T. Maravic, A. Comba, E. Mayer-Santos, F. Florenzano, L. Breschi, A. Mazzoni, Evaluation of Fiber post adhesion to root dentin achieved with different composite cements: 1-year *In vitro* results, *J. Adhes. Dent.* 24 (2022) 95–104, <https://doi.org/10.3290/j.jad.b2838131>.
- [33] L. Hardan, R. Bourgi, T. Hernández-Escamilla, E. Piva, W. Devoto, M. Lukomska-Szymanska, C.E. Cuevas-Suárez, Color stability of dual-cured and light-cured resin cements: a systematic review and meta-analysis of *in vitro* studies, *J. Prosthodont.* 33 (2024) 212–220, <https://doi.org/10.1111/jpor.13757>.
- [34] M. David-Pérez, J.P. Ramírez-Suárez, F. Latorre-Correa, A.A. Agudelo-Suárez, Degree of conversion of resin-cements (light-cured/dual-cured) under different

- thicknesses of vitreous ceramics: systematic review, *J. Prosthodont. Res.* 66 (2022) 385–394, https://doi.org/10.2186/jpr.JPR_D_20_00090.
- [35] T.R. Aguiar, M. Di Francescantonio, C.A.G. Arrais, G.M.B. Ambrosano, C. Davanzo, M. Giannini, Influence of curing mode and time on degree of conversion of one conventional and two self-adhesive resin cements, *Oper. Dent.* 35 (2010) 295–299, <https://doi.org/10.2341/09-252-L>.
- [36] A.L. Faria-e-Silva, C.S. Pfeifer, Development of dual-cured resin cements with long working time, high conversion in absence of light and reduced polymerization stress, *Dent. Mater. (Basel)* 36 (2020) e293–e301, <https://doi.org/10.1016/j.dental.2020.06.005>.
- [37] M. Aldhafyan, N. Silikas, D.C. Watts, Influence of curing modes on thermal stability, hardness development and network integrity of dual-cure resin cements, *Dent. Mater.* 37 (2021) 1854–1864, <https://doi.org/10.1016/j.dental.2021.09.016>.
- [38] M. Aldhafyan, N. Silikas, D.C. Watts, Influence of curing modes on monomer elution, sorption and solubility of dual-cure resin-cements, *Dent. Mater.* 38 (2022) 978–988, <https://doi.org/10.1016/j.dental.2022.03.004>.
- [39] F.A. Rueggeberg, W.F. Caughman, The influence of light exposure on polymerization of dual-cure resin cements, *Oper. Dent.* 18 (1993) 48–55.
- [40] M. Dimitriadi, A. Petropoulou, S. Zinelis, G. Eliades, Degree of conversion of dual-cured composite luting agents: the effect of transition metal-based touch-cure activators, *J. Dent.* 147 (2024) 105147, <https://doi.org/10.1016/j.jdent.2024.105147>.
- [41] G.M. Gomes, E.C. Rezende, O.M. Gomes, J.C. Gomes, A.D. Loguercio, A. Reis, Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin, *J. Adhes. Dent.* 16 (2014) 71–78, <https://doi.org/10.3290/j.jad.a30878>.
- [42] S. Wongsirisuwan, N. Intarak, S. Prommanee, N. Sa-Ard-lam, S. Namano, D. Nantanapiboon, T. Pornraveetus, Influence of light-polymerizing units and zirconia on the physical, chemical and biological properties of self-adhesive resin cements, *BMC Oral Health N. Hav.* 24 (2024) 1172, <https://doi.org/10.1186/s12903-024-04941-z>.
- [43] N. Francis, R.R. Rajan, V. Kumar, A. Varughese, V. Karuveetil, C.M. Sapna, Effect of irradiance from curing units on the microhardness of composite - a systematic review, *Evid. Based Dent.* (2022) 1–8, <https://doi.org/10.1038/s41432-022-0824-z>.
- [44] G. Nima, P. Makishi, B.M. Fronza, P.V.C. Ferreira, R.R. Braga, A.F. Reis, M. Giannini, Polymerization kinetics, shrinkage stress, and bond strength to dentin of conventional and self-adhesive resin cements, *J. Adhes. Dent.* 24 (2022) b3441537, <https://doi.org/10.3290/j.jad.b3441537>.
- [45] C.J. Soares, A.L. Faria-E-Silva, M. de P. Rodrigues, A.B.F. Vilela, C.S. Pfeifer, D. Tantbirojn, A. Versluis, Polymerization shrinkage stress of composite resins and resin cements – What do we need to know? *Braz. Oral Res.* 31 (2017) e62, <https://doi.org/10.1590/1807-3107BOR-2017.vol31.0062>.
- [46] S. Glauser, M. Astasov-Frauenhoffer, J.A. Müller, J. Fischer, T. Waltimo, N. Rohr, Bacterial colonization of resin composite cements: influence of material composition and surface roughness, *Eur. J. Oral Sci.* 125 (2017) 294–302, <https://doi.org/10.1111/eos.12355>.
- [47] R. Saini, S.K. Vaddamanu, M.A. Kanji, S.A. Quadri, S.A.B. Hassan, S. Anil, D. Shrivastava, K.C. Srivastava, Comparison of the antibacterial properties of Resin cements with and without the addition of nanoparticles: a systematic review, *BMC Oral Health N. Hav.* 24 (2024) 1426, <https://doi.org/10.1186/s12903-024-05013-y>.
- [48] U. Josic, G. Teti, A. Ionescu, T. Maravic, C. Mazzitelli, S. Cokic, B. Van Meerbeek, M. Falconi, E. Brambilla, A. Mazzoni, L. Breschi, Cytotoxicity and microbiological behavior of universal resin composite cements, *Dent. Mater.* 40 (2024) 1515–1523, <https://doi.org/10.1016/j.dental.2024.07.004>.
- [49] E. Mancuso, C. Mazzitelli, T. Maravic, J. Pitta, A. Mengozzi, A. Comba, A. Baldi, N. Scotti, A. Mazzoni, V. Fehmer, I. Sailer, L. Breschi, The influence of finishing lines and margin location on enamel and dentin removal for indirect partial restorations: a micro-CT quantitative evaluation, *J. Dent.* 127 (2022) 104334, <https://doi.org/10.1016/j.jdent.2022.104334>.
- [50] E. Mancuso, T. Gasperini, T. Maravic, C. Mazzitelli, U. Josic, A. Forte, J. Pitta, A. Mazzoni, V. Fehmer, L. Breschi, I. Sailer, The influence of finishing line and luting material selection on the seating accuracy of CAD/CAM indirect composite restorations, *J. Dent.* 148 (2024) 105231, <https://doi.org/10.1016/j.jdent.2024.105231>.
- [51] Z. Keci, M.A. Kılıçarslan, B. Bilecenoğlu, M. Ocak, Micro-CT evaluation of the marginal and internal fit of crown and inlay restorations fabricated via different digital scanners belonging to the same CAD-CAM system, *Int. J. Prosthodont.* 34 (2021) 381–389, <https://doi.org/10.11607/ijp.6822>.
- [52] E. Mancuso, A. Forte, T. Maravic, C. Mazzitelli, A. Comba, A. Baldi, V. Fehmer, I. Sailer, N. Scotti, A. Mazzoni, P.L. Breschi, Effects of preparation design on the marginal and internal fit of CAD-CAM overlay restorations: a µCT evaluation, *J. Prosthet. Dent.* (2025), <https://doi.org/10.1016/j.prosdent.2024.12.023>, S0022-3913(25)00007-1.
- [53] S.C. Bayne, Correlation of clinical performance with 'in vitro' tests' of restorative dental materials that use polymer-based matrices, *Dent. Mater. (Basel)* 28 (2012) 52–71, <https://doi.org/10.1016/j.dental.2011.08.594>.
- [54] A. Tagami, R. Takahashi, T. Nikaido, J. Tagami, The effect of curing conditions on the dentin bond strength of two dual-cure resin cements, *J. Prosthodont. Res.* 61 (2017) 412–418, <https://doi.org/10.1016/j.jpor.2016.12.012>.
- [55] M. Alovisi, N. Scotti, A. Comba, E. Manzon, E. Farina, D. Pasqualini, R. Michelotto Tempesta, L. Breschi, M. Cadenaro, Influence of polymerization time on properties of dual-curing cements in combination with high translucency monolithic zirconia, *J. Prosthodont. Res.* 62 (2018) 468–472, <https://doi.org/10.1016/j.jpor.2018.06.003>.