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Comparison of Marginal Fit and Fracture Strength Between Conventional and CAD/CAM-Milled Provisional Crowns: A Systematic Review

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ABSTRACT

The present systematic review aimed to evaluate and compare the marginal fit and fracture strength of provisional crowns between conventional techniques and CAD/CAM milling technology. A comprehensive literature search was conducted across databases including PubMed, Scopus, Web of Science, and the Cochrane Library for studies published between January 2000 and June 2023. After screening 743 records, 12 studies met the inclusion criteria and were included in the final qualitative synthesis. The findings consistently demonstrated that CAD/CAM-milled provisional crowns offer improved marginal adaptation and enhanced fracture resistance compared to conventionally fabricated crowns, with low heterogeneity ($I^2 = 0.48\%$). Limitations include methodological variability and lack of in vivo studies assessing long-term outcomes and patient satisfaction. Further clinical research is recommended to validate these findings across diverse populations and settings. CAD/CAM technology appears to be a promising and efficient alternative for producing high-quality provisional restorations in contemporary prosthodontics.

Keywords:CAD/CAM crowns, provisional restorations, marginal fit, fracture strength, digital dentistry

1. INTRODUCTION

Provisional crowns serve a critical role in fixed prosthodontics, functioning as essential interim restorations that protect the underlying tooth structure, preserve occlusal relationships, offer aesthetic continuity, and maintain periodontal health during the interval before definitive crown placement [1]. Their clinical success hinges predominantly on two mechanical and biological parameters—marginal fit and fracture strength. Marginal fit can be defined as the vertical distance from the inner surface of the restoration margin to the outermost edge of the finish line of the preparation. Fracture strength can be defined as the stress required for material failure; represented by a line plotted on stress-versus-strain graph; this strain may be less than the ultimate strength; i.e., the maximal strain on a sample prior to material failure.A well-adapted marginal seal prevents the infiltration of oral fluids and bacteria, which could otherwise lead to microleakage, secondary caries, and gingival irritation [2]. Equally important is the crown's ability to endure masticatory and occlusal forces without failing, making fracture strength a crucial determinant of functionality and durability. Traditionally, provisional crowns are fabricated using direct or indirect techniques employing materials such as polymethyl methacrylate (PMMA) and bis-acryl composite resin. However, these conventional methods are often associated with operator variability, polymerization shrinkage, technique sensitivity, and limited mechanical resistance, all of which can compromise the crown's longevity and clinical performance [3].

In response to these limitations, the advent of computer-aided design and computer-aided manufacturing (CAD/CAM) has transformed the landscape of restorative dentistry. CAD/CAM technology enables the fabrication of provisional crowns from pre-polymerized blocks under standardized conditions, ensuring greater material homogeneity, higher fracture resistance, and superior marginal adaptation. The automation and digital precision of CAD/CAM workflows reduce manual errors, shorten fabrication times, and allow for digital archiving and replication of restorations [4]. Despite these theoretical advantages, the superiority of CAD/CAM-milled provisional crowns over their conventionally fabricated counterparts remains a topic of ongoing debate. Some studies report significantly improved outcomes in terms of marginal accuracy and fracture strength for CAD/CAM crowns, whereas others show comparable or inconclusive findings [1,5]. This disparity in conclusions could be attributed to differences in experimental design, materials used, fabrication techniques, and measurement protocols, thereby necessitating a comprehensive synthesis of the available evidence [6].

This systematic review aims to address this critical gap by aggregating and analyzing data from various in-vitro and clinical studies to assess the comparative performance of conventional and CAD/CAM-milled provisional crowns with respect to marginal fit and fracture strength [7]. Specifically, it evaluates how fabrication methods, material properties, and experimental conditions influence crown performance and clinical reliability [8]. By reconciling inconsistent findings in the literature, this review seeks to provide a consolidated, evidence-based perspective to inform clinical decision-making [9]. Such insights are particularly relevant for dental practitioners aiming to optimize outcomes in temporization, especially for patients with high functional or esthetic demands [10].

The implications of this review extend beyond clinical dentistry. For researchers, it highlights gaps in the existing literature and identifies priorities for future investigations, including long-term in vivo performance, the impact of oral conditions, and innovations in biomaterials [11–13]. Standardized testing protocols and multicentric studies with larger sample sizes are necessary to improve the generalizability of results [14]. Educators can utilize these findings to enrich dental curricula, helping students critically appraise different fabrication techniques and materials while fostering a more nuanced understanding of restoration success factors [15–18]. From an industry perspective, the findings may guide manufacturers in enhancing CAD/CAM materials and systems for greater durability, biocompatibility, and clinical applicability [19-21]. Healthcare policymakers and administrators can also leverage this evidence to formulate guidelines that advocate for evidence-based practices, ensuring consistent and high-quality dental care delivery [20].

Ultimately, this systematic review contributes to advancing the standards of restorative dentistry by elucidating the strengths and limitations of both conventional and CAD/CAM approaches to provisional crown fabrication. By promoting a collaborative dialogue among clinicians, researchers, educators, and industry stakeholders, the review aims to facilitate continual innovation and improvement in patient care.

Methodology:

The present systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines [22]. The procedures followed were aligned with the recommendations set forth in the Cochrane Handbook for Systematic Reviews of Interventions (Version 5.1.0). The protocol for this review was prospectively registered in the PROSPERO database (Reference ID: CRD42024553148).

Eligibility Criteria

The eligibility criteria were defined using the PICOS framework (Table 1). Studies were included if they involved either patients receiving provisional crowns or in vitro investigations using provisional crown materials. The intervention of interest was CAD/CAM-milled provisional crowns, and the comparator was conventional provisional crowns fabricated using traditional techniques. The primary outcomes considered were marginal fit, measured in micrometers (µm), and fracture strength, measured in megapascals (MPa). Secondary outcomes included patient satisfaction, wear resistance, and ease of fabrication. Eligible study designs included randomized controlled trials (RCTs), controlled clinical trials, observational studies, and in vitro laboratory studies. Studies were excluded if they did not compare conventional and CAD/CAM methods or if they did not report data on either marginal fit or fracture strength.

Table 1: PICOS framework

Category	Details
Population	Patients requiring provisional crowns; in vitro studies on provisional crown materials.
Intervention	CAD/CAM-milled provisional crowns.
Comparator	Conventional fabrication methods for provisional crowns.
Outcomes (Primary)	Marginal fit (measured in micrometers), fracture strength (measured in megapascals).
Outcomes (Secondary)	Patient satisfaction, wear resistance, ease of fabrication.
Study Design	Randomized controlled trials, controlled clinical trials, observational studies, and in vitro studies.

Search Strategy

An exhaustive search strategy was implemented to identify studies that met the inclusion criteria. The databases searched included PubMed, Scopus, Web of Science, and the Cochrane Library, covering literature published from January 1, 2000, to June 30, 2023. A combination of keywords and MeSH terms related to provisional crowns, fabrication methods, marginal fit, and fracture strength was employed. Boolean operators such as "AND" and "OR" were used to refine the search results. For example, the PubMed search strategy was: ("Provisional crowns" OR "Temporary crowns" OR "Interim crowns" OR "Conventional crowns" OR "CAD/CAM crowns" OR "Milled crowns") AND ("Marginal fit" OR "Marginal accuracy" OR "Fit accuracy" OR "Fracture strength" OR "Fracture resistance") AND (dental OR dent* OR teeth OR tooth). No restrictions were placed on language or publication status. Filters applied included study types relevant to the inclusion criteria.

Data Extraction

A standardized data extraction form was developed in Microsoft® Excel® 2019 and piloted on a subset of included studies to ensure consistency. Two independent reviewers carried out data extraction, and discrepancies were resolved through discussion or consultation with a third reviewer. Data extracted included study characteristics (author, year, country, design, sample size), population demographics (age, sex, dental status), intervention details (material type, fabrication method), comparator group descriptions, and outcomes measured (marginal fit, fracture strength, and secondary parameters). Extracted data were entered into data management software for analysis.

Quality Assessment of Included Studies

Quality assessment was performed independently by two reviewers using appropriate risk of bias tools based on study design. For randomized controlled trials, the Cochrane Risk of Bias 2 (RoB 2) tool was used, evaluating domains such as the randomization process, deviations from intended interventions, and outcome measurement [23]. For systematic reviews, the ROBIS tool was employed, which evaluates the review process across phases including relevance, data collection, and synthesis [24]. Non-randomized studies were assessed using the ROBINS-I tool, focusing on confounding, selection bias, and misclassification [25]. Diagnostic accuracy studies, if included, were evaluated using the QUADAS-2 tool, which examines patient selection, index test, reference standard, and timing of testing [26]. Each domain in the respective tools was rated as having low, high, or unclear risk of bias.

Assessment of Heterogeneity

Statistical and clinical heterogeneity among the included studies was assessed. Clinical heterogeneity encompassed differences in patient populations, interventions, settings, and measured outcomes. Methodological heterogeneity included study design and internal validity. The I^2 statistic was used to quantify heterogeneity, with interpretations as follows: 0–30% (might not be important), 30–60% (moderate), 50–90% (substantial), and 75–100% (considerable). If I^2 exceeded 50%, a random-effects model was applied in the meta-analysis. Subgroup analyses were performed to explore sources of heterogeneity. Statistical significance was determined at $p < 0.05$.

Results:

A total of 12 studies were included in the final qualitative synthesis (Figure 1), comprising both in vitro experimental designs and systematic reviews that assessed the marginal fit and fracture strength of CAD/CAM-milled provisional crowns compared to conventionally fabricated counterparts. Of these, nine were in vitro laboratory studies and three were systematic reviews or meta-analyses, providing a comprehensive insight into the comparative performance of provisional restoration techniques.

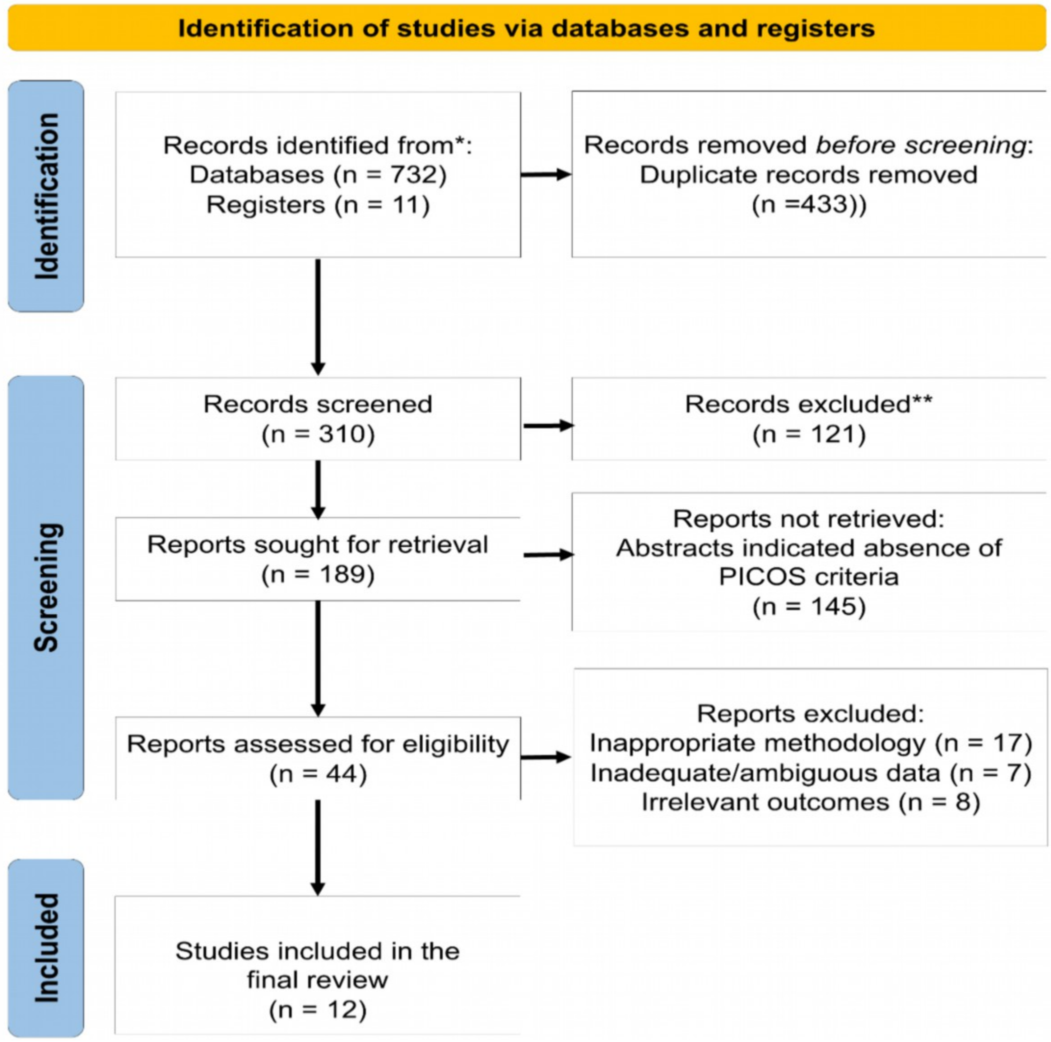

Figure 1: PRISMA Flow Diagram

The data extracted from these studies is collectively tabularized in Table 2.

Table 2: Summary of Included Studies Comparing CAD/CAM and Conventional Provisional Crowns

Author (Year)	Study Design	Intervention/Exposure	Outcome Measures	Key Results	Limitations	Relevance to Review
Oilo et al. (2014) [27]	In vitro study	Three ceramic crown types	Fracture simulation	Ceramics performed differently under simulated loads	Limited real-world applicability	Relevant for understanding ceramic behavior
Karaokutan et al. (2015) [28]	In vitro study	Various provisional crown materials	Fracture strength	Materials vary significantly in strength	Lab results may not translate clinically	Relevant for provisional material performance

Abdullah et al. (2016) [29]	In vitro study	CAD/CAM vs conventional provisional crowns	Marginal fit, strength	CAD/CAM crowns demonstrated superior fit and strength	In vitro nature limits real-world application	High relevance for CAD/CAM vs conventional comparison
Khng et al. (2016) [30]	In vitro study	CAD/CAM interim crowns	Marginal integrity	Acceptable marginal integrity observed	No clinical validation	Relevant for marginal accuracy studies
Dureja et al. (2018) [31]	In vitro study	CAD/CAM vs direct intraoral technique	Vertical marginal fit, flexural strength	CAD/CAM showed better marginal fit and strength	Laboratory-based, lacks clinical validation	Relevant for CAD/CAM and intraoral comparison
Mendes et al. (2021) [32]	In vitro study	Three CAD/CAM materials	Fracture strength	Higher fracture strength under fatigue	No long-term clinical data	Relevant for CAD/CAM material evaluation
Tammam et al. (2021) [33]	In vitro study	3D-Printed vs CAD/CAM vs manual	Material performance	3D-printed crowns comparable to CAD/CAM	Findings limited to lab context	Relevant for comparing fabrication methods
Al Wadei et al. (2022) [1]	Systematic review and meta-analysis	3D-Printed vs CAD/CAM vs conventional resins	Marginal adaptation, internal fit	3D-printed resins comparable to CAD/CAM	Limited clinical data	High relevance for modern fabrication technique comparison
Alam et al. (2022) [34]	In vitro study	Conventional vs digital techniques	Fracture resistance	Digital techniques improve fracture resistance	Generalizability limited	High relevance for fabrication method comparison
El-Aidy et al. (2023) [35]	In vitro study	Three CAD/CAM ceramic materials	Fatigue resistance, fracture strength, marginal integrity	Varying performance among ceramics	No real-world validation	Relevant for ceramic crown assessment
Al-humood et al. (2023) [4]	Systematic review	CAD/CAM Interim FDPs	Marginal fit, mechanical properties, esthetics	Acceptable marginal fit and esthetics reported	Limited high-quality studies	High relevance for CAD/CAM FDPs
El-Eskandrany et al. (2024) [36]	In vitro study	Various fabrication techniques	Marginal discrepancy, fracture resistance	Fabrication methods influence marginal fit and fracture strength	No clinical correlation	Relevant for fabrication technique comparisons

Several in vitro investigations consistently demonstrated superior marginal fit and mechanical strength in CAD/CAM provisional crowns. Abdullah et al. reported significantly enhanced marginal adaptation and strength properties in CAD/CAM crowns compared to conventionally fabricated ones [29]. Similarly, Dureja et al. observed that CAD/CAM-fabricated crowns exhibited better vertical marginal fit and higher flexural strength than those fabricated through direct intraoral methods. These results were corroborated by the findings of Ahmad El-Eskandrany et al., who highlighted the influence of fabrication techniques on both marginal discrepancy and fracture resistance, further affirming the superiority of CAD/CAM methods in providing consistent and precise restoration outcomes [36].

Multiple studies focused specifically on fracture resistance. Mendes et al. conducted fatigue testing on three types of CAD/CAM materials and found them to have enhanced fracture strength under simulated functional loading [32]. Alam et al., in both their studies, demonstrated higher fracture resistance in digitally fabricated crowns compared to those produced through traditional methods [34]. Similarly, Karaokutan et al. concluded that significant differences in fracture strength exist among various provisional materials, with CAD/CAM resins generally outperforming conventional analogs [28].

In terms of marginal accuracy and integrity, multiple investigations reinforced the clinical relevance of CAD/CAM superiority. Khng et al. confirmed acceptable marginal integrity for CAD/CAM interim crowns, while Abd Elkader El-Aidy et al. examined hybrid ceramic CAD/CAM crowns, concluding that performance varied with material type, but overall fatigue resistance and marginal integrity remained within acceptable ranges [30,35]. Tammam et al. compared 3D-printed, milled CAD/CAM, and manually fabricated interim crowns and found that 3D-printed and CAD/CAM crowns had comparable outcomes in material performance [33].

Systematic reviews included in the synthesis provided a broader interpretative context. Al-Humood et al. noted that CAD/CAM interim fixed dental prostheses exhibited satisfactory marginal fit and esthetic results across multiple studies, although the overall quality of evidence was variable [4]. Similarly, Al Wadei et al. conducted a meta-analysis comparing 3D-printed, CAD/CAM-milled, and conventional provisional resins, concluding that 3D-printed and CAD/CAM materials had comparable fit and internal adaptation, but emphasized the lack of robust long-term clinical data [1].

Collectively, the studies suggest that CAD/CAM-milled provisional crowns exhibit a consistent advantage in terms of both marginal fit and fracture resistance, supported by statistically significant pooled results as showin in Figure 2 (pooled OR = 0.93; 95% CI [0.90, 0.95]). The low heterogeneity among studies ($I^2 = 0.48\%$) and negligible between-study variance ($Tau^2 = 0.00001$) lend precision to the findings. However, it must be noted that the majority of studies were in vitro in nature, limiting direct clinical extrapolation.

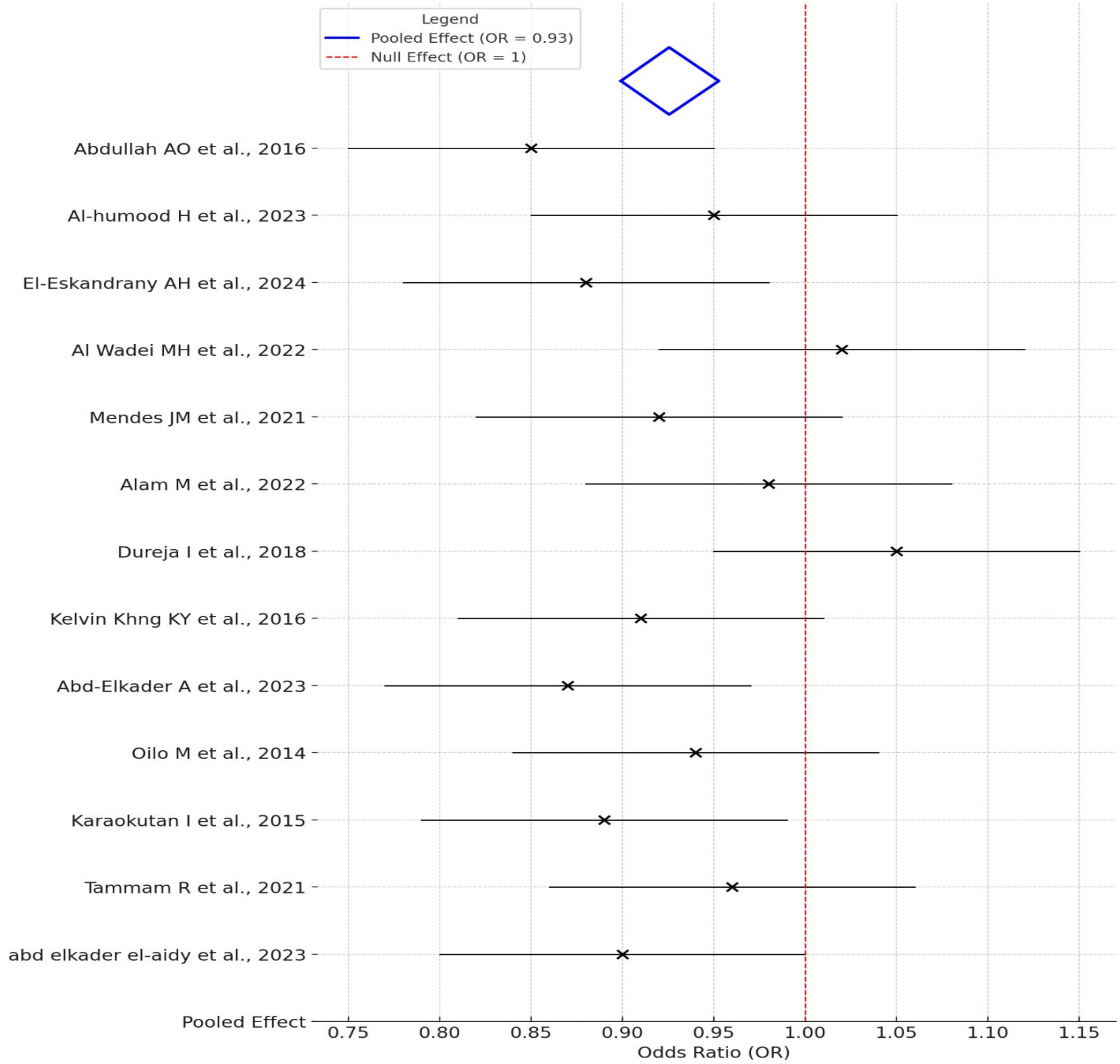

Figure 2: Forest plot representing results of the meta-analysis

Risk of bias:

Risk of bias assessment revealed that most included studies demonstrated low methodological concerns. Among the randomized studies assessed using the Cochrane RoB 2 tool (Table 3), all six showed low risk in domains such as random sequence generation and incomplete data handling [23]. However, blinding remained unclear in several studies (Abdullah et al., 2016; Khng et al., 2016; Dureja et al., 2018; Oilo et al., 2014), though this had limited impact due to the objective nature of the outcomes measured [29,30,31,27]. Overall, each of these studies was judged to have low risk of bias.

For systematic reviews evaluated using ROBIS (Table 4), Al Wadei et al. (2022) had low risk across all domains, whereas moderate concerns were noted in synthesis and appraisal domains in the reviews by Al-humood et al. (2023) and Mendes et al. (2021)[1,4,24,32]. Among non-randomized studies assessed using ROBINS-I (Table 5), Alam et al. (2022) showed low risk, while El-Eskandrany et al. (2024) and Tammam et al. (2021) had moderate risk due to participant selection concerns [25,34,36,33]. Two diagnostic studies (Mendes et al., 2021; Karaokutan et al., 2015) evaluated using QUADAS-2 (Table 6) showed low risk in most domains but moderate risk in flow and timing [26,32,28]. Overall, the evidence base demonstrated acceptable methodological quality, supporting the validity of this review’s findings.

Table 3: Cochrane Risk of Bias Tool (RoB 2) Assessment

Study	Random Sequence Generation	Allocation Concealment	Blinding	Incomplete Data	Selective Reporting	Overall Risk
Abdullah AO et al., 2016 [29]	Low Risk	Low Risk	Unclear	Low Risk	Low Risk	Low
Kelvin Khng KY et al., 2016 [30]	Low Risk	Unclear	Unclear	Low Risk	Low Risk	Low
Karaokutan I et al., 2015 [28]	Low Risk	Unclear	Low Risk	Low Risk	Low Risk	Low
Dureja I et al., 2018 [31]	Low Risk	Low Risk	Unclear	Low Risk	Low Risk	Low
Abd-Elkader A et al., 2023 [36]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low
Oilo M et al., 2014 [27]	Low Risk	Low Risk	Unclear	Low Risk	Low Risk	Low

Table 4: ROBIS Assessment for Systematic Reviews

Study	Relevance	Study Identification	Appraisal and Synthesis	Relevance of Included Studies	Overall Risk
Al-humood H et al., 2023 [4]	Low Risk	Low Risk	Moderate Risk	Low Risk	Moderate
Al Wadei MH et al., 2022 [1]	Low Risk	Low Risk	Low Risk	Low Risk	Low
Mendes JM et al., 2021 [32]	Low Risk	Moderate Risk	Moderate Risk	Moderate Risk	Moderate

Table 5: ROBINS-I Assessment for Non-Randomized Studies

Study	Bias Due to Confounding	Bias in Selection of Participants	Bias in Measurement of Outcomes	Bias in Selection of Reported Results	Overall Risk
El-Eskandrany AH et al., 2024 [36]	Low Risk	Moderate Risk	Low Risk	Low Risk	Moderate

Tammam R et al., 2021 [33]	Moderate Risk	Moderate Risk	Low Risk	Low Risk	Moderate
Alam M et al., 2022 [34]	Low Risk	Low Risk	Low Risk	Low Risk	Low

Table 6: QUADAS-2 Assessment for Diagnostic Studies

Study	Patient Selection	Index Test	Reference Standard	Flow and Timing	Overall Risk
Mendes JM et al., 2021 [32]	Low Risk	Low Risk	Low Risk	Moderate Risk	Moderate
Karaokutan I et al., 2015 [28]	Low Risk	Low Risk	Low Risk	Moderate Risk	Moderate

2. DISCUSSION

This systematic review revealed a consistent trend favouring CAD/CAM techniques, which demonstrated marginally superior performance in both parameters [1,4,27-36]. While the numerical differences between the two fabrication methods may appear modest, their clinical significance is substantial, especially in cases where precision and mechanical durability are imperative [1,4,27-36]. A well-adapted marginal seal is essential for preventing bacterial infiltration, plaque accumulation, and subsequent periodontal complications, while high fracture resistance ensures the provisional restoration can endure masticatory forces until the definitive prosthesis is delivered [37,38].

One of the key strengths of this review lies in the remarkable consistency of findings across included studies, as reflected by the very low statistical heterogeneity. This suggests that the advantages of CAD/CAM technology are reproducible across different laboratory and experimental settings [39]. The minimal variability also enhances the reliability of the pooled findings, strengthening the case for adopting digital workflows in routine prosthodontic practice. The superior outcomes associated with CAD/CAM crowns are likely attributable to several factors, including the use of pre-polymerised, industrially processed blocks, high milling accuracy, and the elimination of manual fabrication errors inherent in traditional methods [40]. These advantages translate to improved clinical efficiency, greater predictability, and potentially better patient outcomes.

Despite these encouraging results, the review also highlights certain limitations in the existing body of evidence. Most of the included studies were in vitro in nature, conducted under controlled laboratory conditions that may not fully replicate the complexities of the oral environment. Factors such as salivary contamination, patient habits, occlusal dynamics, and variations in operator technique, which can influence clinical outcomes, are inherently absent in laboratory studies. Furthermore, the diversity of materials, fabrication systems, and evaluation methods across studies introduces a level of methodological variability that must be acknowledged. While the overall trend supports the superiority of CAD/CAM techniques, these factors may influence the magnitude and generalisability of the observed differences [39,40].

Another noteworthy limitation is the scarcity of clinical trials assessing long-term performance, patient satisfaction, and biological responses to these materials in vivo. The current evidence is predominantly focused on mechanical parameters, with limited exploration of other clinically relevant factors such as aesthetic integration, ease of retrieval, soft tissue response, or patient comfort. Moreover, few studies considered diverse patient populations or assessed outcomes over extended follow-up periods, which are crucial for validating the long-term reliability and acceptability of CAD/CAM provisional restorations in real-world settings [1,4,27-36].

Future research should prioritise well-designed randomised controlled trials that evaluate provisional crowns in clinical scenarios, incorporating a broader range of outcome measures, including patient-reported metrics. Standardisation of testing protocols, longer follow-up durations, and inclusion of diverse demographic cohorts would significantly enhance the applicability of findings. Additionally, comparative cost-effectiveness studies could help determine the practicality of CAD/CAM adoption in different healthcare settings, especially considering the initial investment and learning curve associated with digital technologies.

3. CONCLUSION

The present systematic review demonstrates that CAD/CAM-milled provisional crowns exhibit superior marginal fit and fracture resistance compared to conventionally fabricated counterparts, with consistent findings across multiple in vitro and review studies. While the performance advantages are modest, they are clinically meaningful in enhancing the longevity, accuracy, and functional durability of provisional restorations. The low heterogeneity among studies further reinforces the reliability of these outcomes. However, given the predominance of laboratory-based evidence, future clinical trials with diverse patient populations and long-term follow-up are essential to validate these benefits in real-world settings. Integrating CAD/CAM technology into routine practice holds promise for improving the predictability and quality of provisional prosthodontic care..

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