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Review

Current Evidence and Advances in CAD-CAM Resin Composite Blocks for Chairside Dental Restorations: Where Are We Now? A Scoping Review

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Abstract: Objective: This study aimed to determine the status of the scientific literature on CAD-CAM resin blocks by mapping the available evidence and identifying knowledge gaps. Data/Source: A systematic search of studies investigating CAD-CAM resin blocks was conducted. Risk of bias was assessed, and data on study designs, level of evidence, compositional classification, manufacturer, commercial brand, and properties investigated were extracted. This review followed Arksey and O'Malley's five-stage framework and utilized Medline (OVID), EMBASE, and Scopus (Elsevier) databases. Study Selection: Study selection resulted in 27 studies for data extraction out of 209 studies screened from an initial pool of 529 studies. High sampling bias related to sample size and randomization was observed in almost all studies. Most studies (99%) were conducted in vitro, with low levels of evidence. The most common composition was "nano-ceramic". 3M ESPE was the manufacturer with the most investigated blocks, and their product, 3M™ Lava™ Ultimate Restorative, was predominant in the selected investigations. Methodological heterogeneity was extensive among the studies, with mechanical properties (38%) and bond strength (35%) being the most commonly investigated outcomes. Conclusion: This scoping review indicates an increasing trend in dental research assessing CAD-CAM resin blocks. However, the overall level of evidence derived from these studies is low, predominantly consisting of in vitro investigations. Clinical Significance: The findings underscore the need for clinical trials to augment the level of evidence and enable long-term assessment of CAD-CAM resin blocks. Dentists should be cautious while interpreting the findings from in vitro studies, as the outcomes may not directly translate to clinical success.

Keywords: dental materials; CAD-CAM; polymers; resin composites; oral biofilm; indirect restorations

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1. Introduction

CAD-CAM resin blocks are advanced dental materials used for creating indirect restorations such as crowns, inlays, onlays, and veneers through computer-aided design and manufacturing systems. These blocks are composed of a resin matrix, typically containing monomers like UDMA and TEGDMA, and are reinforced with inorganic fillers such as silica and zirconia, which enhance their mechanical properties. CAD-CAM resin blocks are primarily indicated for various indirect dental restorations, including crowns, inlays, onlays, and veneers [1]. They are particularly useful in clinical scenarios where ease of fabrication and repair is crucial. These blocks are also suitable for long-term temporary restorations due to their ability to produce less abrasion on enamel antagonists compared to ceramic materials.

Currently, most computer-aided design/computer-aided manufacturing (CAD-CAM) restorations are fabricated using glass ceramics (particularly heat-pressed glass-ceramics), crystalline ceramics (alumina), and polycrystalline (alumina and zirconia) ceramics [1]. These materials consist of inorganic materials, such as silica, feldspar, and alumina, which

are processed at high temperatures to create a crystalline structure. This composition results in a highly wear-resistant material with high strength, making it ideal for dental restorations to withstand the forces of biting and chewing [2,3]. However, they do tend to fracture and are susceptible to chipping when undergoing the milling procedure. With that, the development of CAD-CAM resin blocks has been driven by the need for restorations that are biocompatible, aesthetic, easy to handle, and mechanically strong enough to withstand the forces of the oral environment. Figure 1 provides a concise historical overview of CAD-CAM dentistry, charting its evolution through a timeline of key advancements.

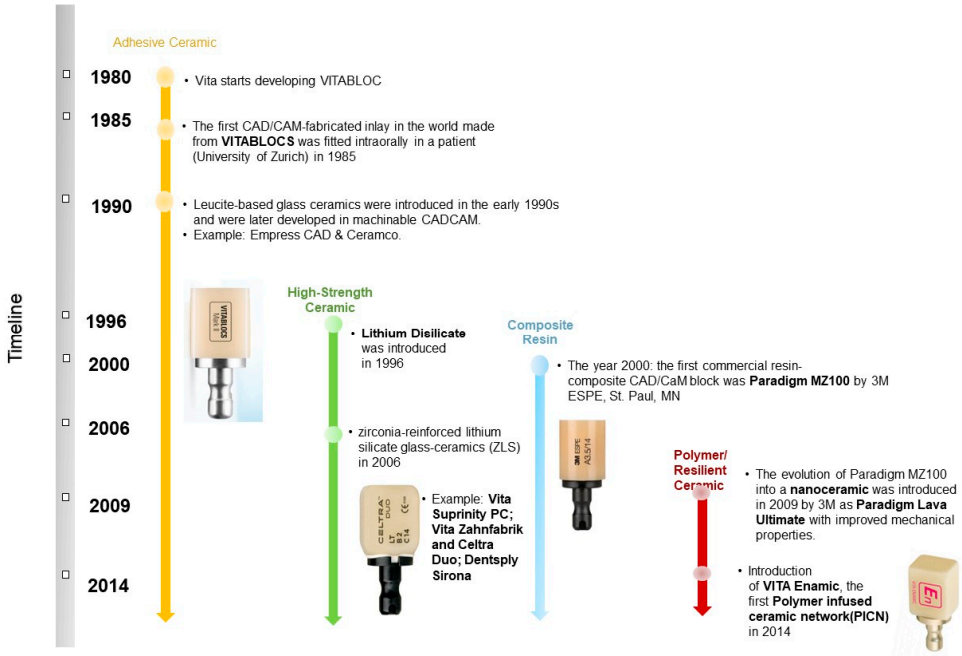


Figure 1. Timeline of CAD-CAM blocks, including the introduction of CAD-CAM resin composite blocks.

One key aspect of CAD-CAM resin blocks is the spectrum of filler composition and proportion between ceramic and resin content. The ratio of ceramic to resin content in CAD-CAM materials can vary widely, with some materials leaning towards a higher ceramic fraction (80–86%), resembling traditional ceramics, while others lean towards a higher resin content (25–40%) [4]. This variation allows for a tailored approach to material selection, enabling dentists to choose the most suitable CAD-CAM material based on the specific clinical scenario, patient needs, and restoration requirements. This category of material gains the benefits of both material classes, ceramic and resin elements, with a balance of strength, flexibility, and milling ease, effectively [2].

The range of formulations and the cure mode vary among the CAD-CAM resin blocks [5]. However, they are often manufactured using conventional filler–resin mixing composite technology under specific temperatures and pressure. Since the introduction of the first CAD-CAM block in 2000, Paradigm MZ100, featuring 85 wt.% ultrafine zirconia-silica ceramic fillers, we have several additions to the array of CAD-CAM resins blocks, such as Lava Ultimate block (3M ESPE) using a resin nano ceramic material with approximately 80 wt.% of zirconia-silica nano ceramic fillers and Cerasmart (GC Corporation, Tokyo, Japan), a hybrid ceramic block containing 75 wt.% of nano ceramic particles in a highly crosslinked resin matrix [6,7].

Under the umbrella of CAD-CAM blocks, we have blocks with particular formulations/compositions, such as Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany), using a Polymer-Infiltrated Ceramic Network (PICN) technology [8,9]. This method offered a novel means to increase filler loading capacity, forming a porous ceramic network (86 wt.%) followed by infiltration with polymeric resins, which led to it being classified as a

genuine hybrid material. Another example is the blocks presenting nano-ceramics as fillers, incorporating nanoscale ceramic particles into their matrix, endowing them with enhanced mechanical properties and wear resistance. As the name suggests, these blocks are often called nano-ceramics [10–12].

Compared to glass or ceramics, CAD-CAM resin blocks offer advantages in ease of fabrication and repair. The blocks can be easily repaired intraorally using composite resins, which bond well to the material, and various surface treatments enhance this bond strength. These factors collectively streamline the clinical workflow, making CAD-CAM resin blocks a versatile and efficient option for dental restorations [13,14]. It is worth noting that while there have been advancements in the formulation and polymerization processes, CAD-CAM resin blocks, in terms of their mechanical properties, typically do not attain the same level of strength as glass ceramics or ceramics [15,16].

As CAD-CAM resin blocks are rising in the market, dentists are presented with various options for indirect restorations. This prompts questions about their mechanics, optics, bonding strength, surface properties, adaptability, and biological performance compared to traditional ceramic materials. To provide clarity, we conducted a scoping review, evaluating the scientific literature and its levels of evidence, aiming to provide a valuable resource to aid dentists in making informed material selections.

2. Materials and Methods

This section provides background information and related works, including the scoping review method and design strategy.

2.1. Study Design

Based on the reasons above regarding the advantages offered by resin blocks, a scoping review was conducted to explore the current literature on available CAD-CAM RCB blocks. This review adhered to Arksey and O'Malley's five-stage framework, further refined by the recommendations of Levac, Colquhoun, and O'Brien [17]. The framework includes defining the research question, searching for relevant studies, identifying and selecting suitable studies, organizing and extracting data, and documenting the findings.

2.2. Stage I: The Research Question

For structuring the scoping review and addressing the aim of this study, the research questions are outlined as follows:

- What level of evidence supports the use of CAD-CAM RCBs for indirect restorations?
- What are the characteristics, assessment, and results of the existing research on using CAD-CAM RCBs?
- What gaps exist in the current body of evidence in response to the CAD-CAM resin blocks?

2.3. Stage II: Searching for Relevant Studies

The research librarian searched databases for keywords, text words, and subject terms related to studies investigating CAD-CAM resin blocks. Two independent reviewers (S.A. and L.M.) performed the searches using PubMed and Scopus (Elsevier) databases. Both searches utilized the following search strategy: ((("CAD-CAM" [tiab]) OR ("Computer-Aided Design" [Mesh:NoExp]) OR ("Computer-Aided Manufacturing" [Mesh]) OR ("CAD/CAM" [tiab])) AND (("Resin" [Mesh]) OR ("Resin Composite" [tiab]) OR ("Composite Material" [Mesh]) OR ("Composite Resins" [Mesh])) AND (("Clinical Trial" [Publication Type]) OR ("Randomized Controlled Trial" [Publication Type]) OR ("Clinical Trials as Topic" [Mesh]) OR ("Prospective Studies" [Mesh]) OR ("Controlled Clinical Trials as Topic" [Mesh]) OR ("Random Allocation" [Mesh]) OR ("In Vitro" [Publication Type]) OR ("In Vitro Techniques" [Mesh])) AND (english [Filter]))

Search terms related to resin-based CAD-CAM blocks were included but not limited to dental adhesives, dental primers, dental cements, ceramic CAD-CAM blocks, and resin composites. Accepted manuscripts were only in English and published after 2000.

2.4. Stage III: Study Selection

The overall inclusion criteria for study selection were based on stage I and II methodologies. The inclusion criteria encompass peer-reviewed journal articles published in English, focusing on studies investigating CAD-CAM resin blocks. These studies should evaluate CAD-CAM resin blocks' clinical and in vitro performance, examining mechanical properties, wear resistance, biocompatibility, and clinical outcomes. The review also includes studies published within a specified time frame to ensure relevance and contemporaneity since the first CAD-CAM resin block came to the market around 2000. Figure 2 summarizes the studies included in the systematic scoping review in the PRISMA flow diagram.

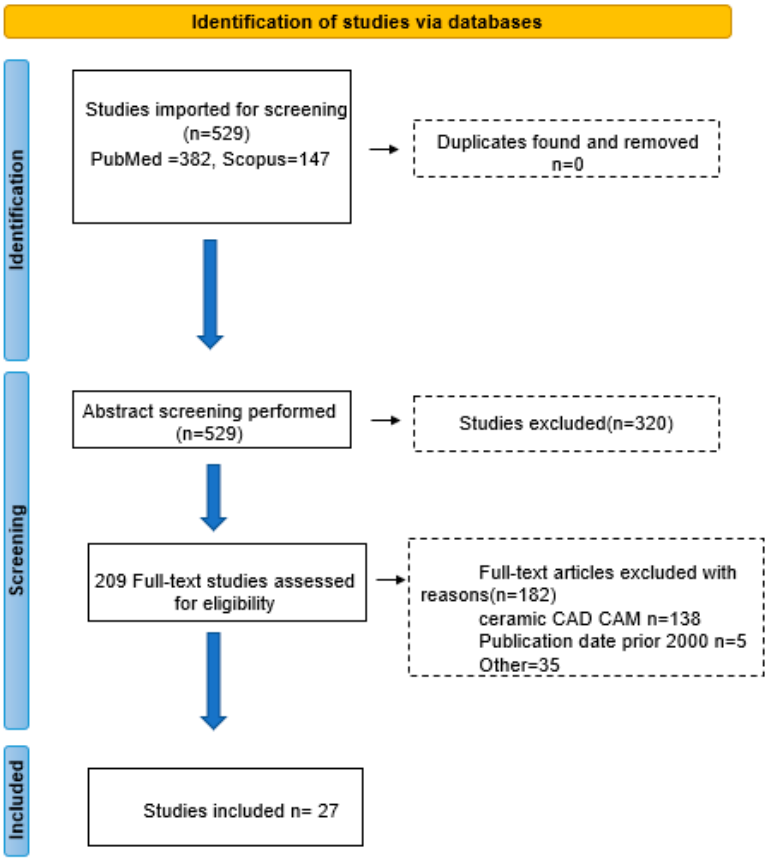


Figure 2. PRISMA flow diagram of studies in the systematic scoping review with reasons for exclusion. Based on "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement".

On the other hand, exclusion criteria were (1) studies that exclusively investigated Glass Ceramic, Zirconia, or Polymethyl methacrylate (PMMA) CAD-CAM blocks without the inclusion of resin in its composition; (2) studies that investigated direct composite restoration instead of indirect Composite Resin CAD-CAM blocks; (3) languages other than English for the ease of retrieving from the database; and (4) any literature published before the 2000s.

Search results were imported into Convidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org), a library web-based screening and data extraction tool recommended by the Cochrane Collaboration. All articles were duplicated into two identical sets to facilitate independent

review. The reviewers then assessed full-text articles. If there were disagreements between the reviewers, the paper in question was discussed until a consensus was achieved.

A literature search was conducted between February and April of 2022. The database search identified 529 manuscripts published between 1984 and 2022. No duplicate studies were identified during this process. The titles and abstracts of the identified manuscripts were screened. Excluded studies (n = 320) primarily fell into four categories: (1) those exclusively investigating Glass Ceramic, Zirconia, or Polymethyl methacrylate (PMMA) CAD-CAM blocks without resin inclusion (N = 272); (2) studies focusing on direct composite restoration rather than indirect restorations using CAD-CAM resin blocks [18–20] (3) non-English language publications (4); and (4) literature published before the 2000s (13).

2.5. Stage IV: Charting the Data

A data extraction template was developed using Convidence and reviewed by all authors to record the variables to be extracted to answer the research questions. The authors (S.A. and L.M.) extracted the data from the included studies.

2.6. Stage V: Data Extraction

The data were typically organized by study design type, evidence level, compositional classification, manufacturer, brand, bond strength, and various investigated properties, including mechanical, optical, biological, surface, and adaptability characteristics. The studies were also evaluated for risk of bias using the Cochrane collaboration bias tool, categorized as high, low, or unclear risk in the following areas:

Sampling Bias—Sample Size: Low risk if the authors provided a sample size calculation; high risk if no justification was reported; or unclear if there was insufficient information to decide.

Sampling Bias—Randomization: the study authors describe a random process to assign enamel, dentin, or teeth samples if used (low risk); the process of setting samples was not random (high risk); no clear information was given to decide (not clear); or no enamel, dentin, or teeth samples (i.e., only resin samples) were used (not applicable).

Reporting Bias: If the outcomes detailed in the methods section aligned with those presented in the results section, it was considered low risk; if there was a discrepancy between the two sections, it was classified as high risk.

Other Bias—Conflict: If no conflict of interest was reported, it was deemed low risk; if a conflict of interest was disclosed, it was considered high risk; and if the information was insufficient to decide, it was classified as unclear.

Reporting Bias—Funding: If there was no evidence of funding bias, it was classified as low risk; if it was identified, it was deemed high risk; and if the information was insufficient to conclude, it was considered unclear.

3. Results and Discussion

3.1. Study Selection

Twenty-seven manuscripts published between 2011 and 2021 were included in the review. A full-text assessment was conducted on 209 manuscripts, excluding 182 studies following the exclusion criteria, as shown in Figure 2. Figure 3 summarizes the risk of bias.

The frequency of publications has been rising, reflecting the increased attention on this subject due to their broad applicability. Results showed that most studies were conducted in Japan, followed by Turkey, Switzerland, Brazil, China, Egypt, USA, Canada, Chile, Germany, and Jordan.

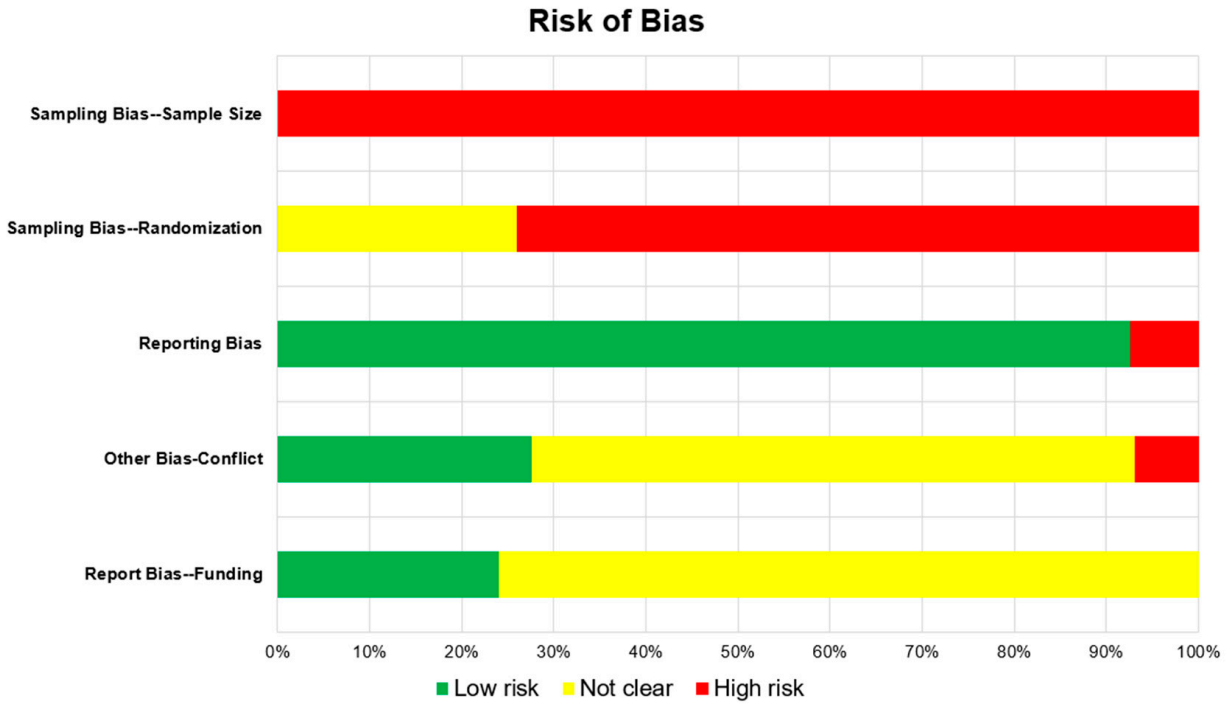


Figure 3. Risk of bias graph: review authors' judgments about each risk of bias item presented as percentages across all included studies (a plot of the distribution of assessments (low risk of bias, unclear risk of bias, and high risk of bias) across studies for each risk of bias item).

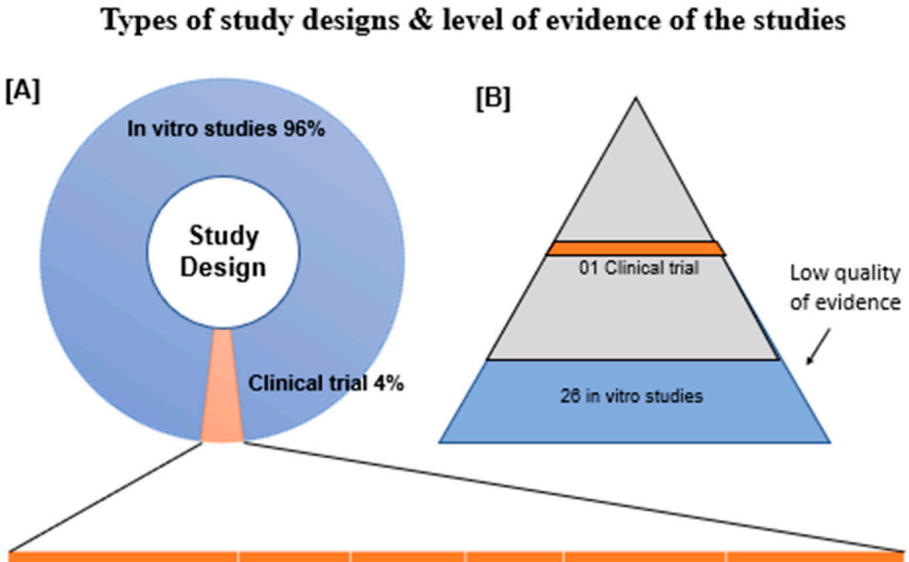
The outcomes were categorized according to study designs, level of evidence of the studies, compositional classification, manufacturer, commercial brand, and mechanical, optical, biological, surface, adaptability, and bond strength properties investigated.

3.2. Types of Study Designs and Level of Evidence of the Studies

In our results, 96% of the studies represented an in vitro study design, and based on the hierarchy of study designs, it is on the lowest level of evidence. Only one study represented a clinical trial [21].

Figure 4 displays the different categories of study designs and their level of evidence. A clinical trial [22] investigated indirect particle-filled composite resin restorations fabricated using the CAD-CAM method (CEREC Bluecam intraoral scanner, CEREC MCXL milling unit) by calibrated dental students. Forty-two partial crown restorations were cemented in 30 patients, treating caries lesions or replacing insufficient restorations (baseline). Strict inclusion criteria were followed for patient selection. Follow-up evaluation included 40 restorations after 12 months and 33 restorations after 24 months. The following evaluation criteria were modified FDI criteria with grades (1) to (5), with (5) representing clinical failure.

In the cited study, the success rate of indirect particle-filled composite resin CAD-CAM restorations after 12 months was 95.0%, with only two debonding cases observed. CAD-CAM. On the other hand, the success rate after 24 months was 85.7%, with two tooth fractures and one debonding [23]. Statistical significances were found when comparing baseline and 24-month follow-up evaluation regarding anatomic form and marginal adaptation according to the FDI criteria guidelines (Wilcoxon Test, $p < 0.05$).



Name		CAD-CAM RCB	Time frame	Success rate	Complications	Conclusion
Clinical Evaluation of Indirect Particle-Filled Composite Resin CAD/CAM Partial Crowns after 24 Months		Lava Ultimate, 3M ESPE	12 Months	95%	Two deboning's observed N=40 restorations	CAD/CAM RCB restorations have a clinical success rate of 85.7% after 24 months. Ensuring careful adherence to adhesive bonding procedures for these restorations is crucial.
Inclusion Criteria	**Exclusion Criteria**					
Oro-vestibular defect size: >50% of tooth cusp distance Complete or partial reconstruction of tooth cusp Molars or premolars with antagonist	Oro-vestibular defect size: <50% of tooth cusp distance Need of direct/indirect capping before reconstruction Bruxism/CMD		24 months	85%	Two tooth fractures, one debonding N=38 restorations	

Figure 4. The categorization graph of the study design type and the evidence level represented by these studies. (**A**). Schematic diagram of the percentage of studies considering the study design. The study reporting a clinical trial is further described in detail. (**B**). Schematic diagram of the type of studies selected and the level of evidence according to the levels of evidence pyramid.

3.3. Compositional Classification, Manufacturer, and Commercial Brand

Figure 5 illustrates the distribution of studies based on compositional classification, manufacturer, and commercial brand. Most studies (50%) primarily considered CAD-CAM RCBs with a "nano ceramic" composition, characterized by a blend of nanoparticles agglomerated into clusters, embedded in a highly cross-linked polymer matrix. This composition integrates nanotechnology with ceramics, featuring approximately 80% ceramic load [24]. The second most prevalent classification (30%) pertained to "polymer-infiltrated ceramic network (PICN)". A further 20% of studies focused on simplified compositions denoted as "resin composite blocks", which incorporate ceramics, glass ceramics, glasses, or a blended composition as reinforcement fillers [23,25].

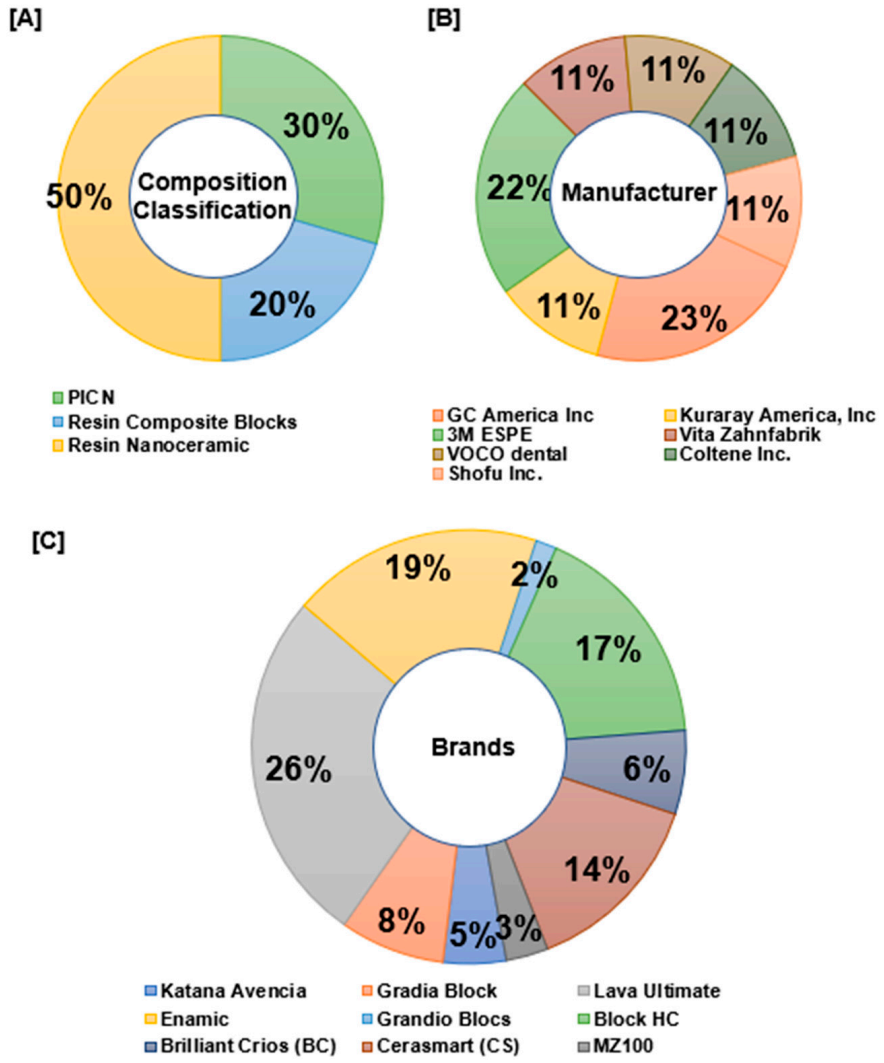


Figure 5. Schematic diagrams of the percentage of studies considering the (**A**). compositional classification, (**B**). manufacturer, and (**C**). commercial brands.

CAD-CAM resin blocks comprise a resin matrix and various fillers designed to optimize their mechanical and aesthetic properties for dental restorations. The resin matrix typically includes monomers such as Urethane Dimethacrylate (UDMA) and Triethylene Glycol Dimethacrylate (TEGDMA), which provide flexibility and ease of handling. The filler composition often consists of inorganic materials like silica and zirconia, which enhance the strength and wear resistance of the blocks. These fillers can vary in content, usually from 70% to 80% by weight, and in size, from micro to nano particles, contributing to the material's overall durability and performance. Additionally, silane coupling agents improve the bond between the resin matrix and the fillers, with typical ratios around 50% to 60%. This combination of resin monomers, filler composition, and silane coupling agents results in a material that is not only strong and durable but also capable of being precisely milled and easily repaired, making CAD-CAM resin blocks a versatile choice for various dental applications.

Notably, 3M ESPE emerged as the most prominent manufacturer, with their product 3M™ Lava™ Ultimate Restorative being the predominant focus in the selected investigations. GC America was the second most prevalent manufacturer, with Vita Enamic as the second most investigated commercial brand. Vita Enamic, classified as PICN, emerged as a comparable material in the studies due to its availability in the market.

3.4. Material Properties

Many factors are significantly associated with material selection in single-unit crowns, or indirect partial restorations in the anterior and posterior dentitions. For example, the top three materials of choice in restoring posterior crowns were all-zirconia (32%), PFM (31%), and lithium disilicate (21%), according to The National Dental Practice-Based Research Network findings [26].

For that, assessing the materials' properties introduced in the market is very relevant [27]. Figure 6 describes the percentage of studies that consider the materials' properties investigated. B. Mechanical properties, C. bond strength, D. surface analysis of CAD-CAM RCBs were investigated in the included studies. Figure 6A highlights that the mechanical properties and bond strength of CAD-CAM RCBs were the most investigated in this material class.

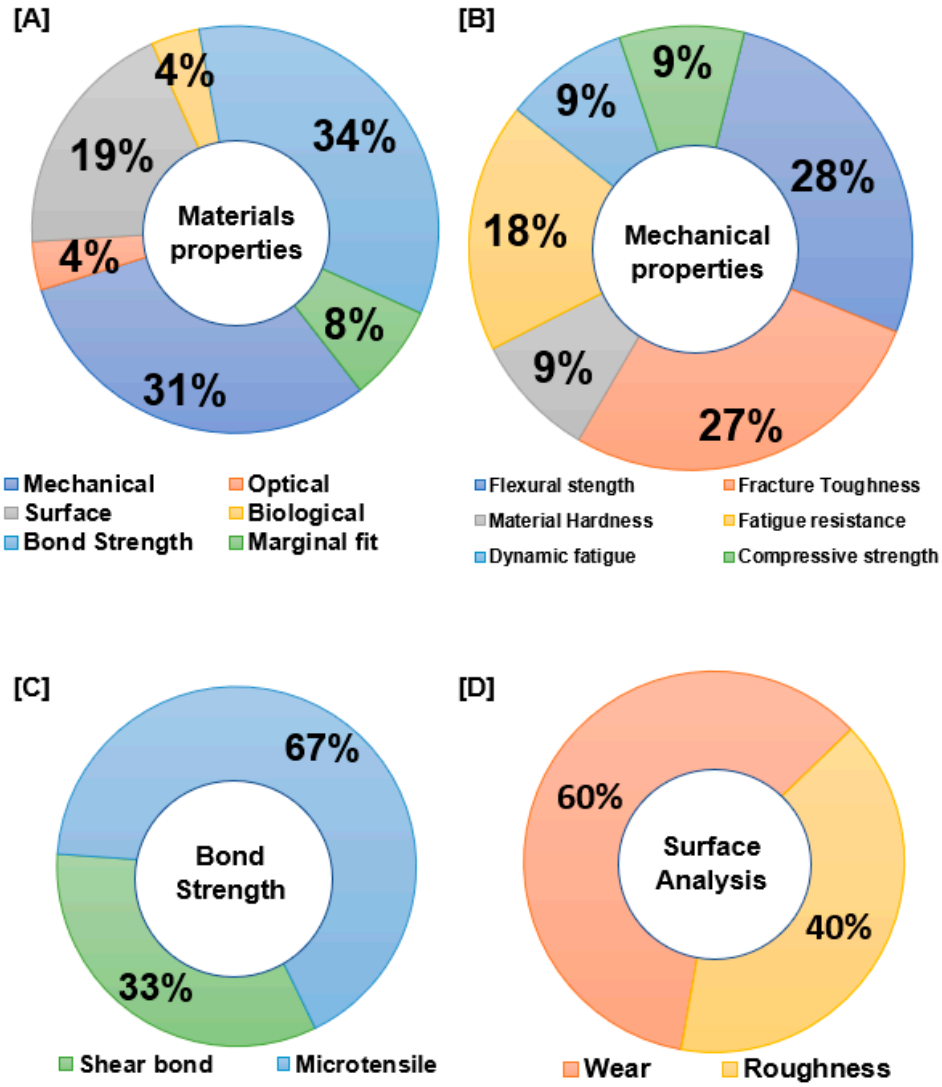


Figure 6. Schematic diagrams of the percentage of studies considering the (**A**) material properties investigated, (**B**) mechanical properties, (**C**) bond strength, (**D**) surface analysis of CAD-CAM RCBs investigated in the selected studies.

3.4.1. Mechanical Properties

The mechanical properties of dental restorative materials are vital for their long-term functionality within the oral environment. Materials must withstand various stresses, including masticatory forces, without significant degradation. Research highlights that flexural strength and fracture toughness are among the most studied mechanical properties,

crucial for materials used in posterior teeth restorations due to their need to resist bending loads [22,26–31]. Studies by Lauvahutanon et al. [30] and Okada et al. [32] demonstrate that CAD-CAM resin blocks exhibit flexural strength values similar to or better than traditional dental materials like feldspathic ceramic. However, they are affected by environmental factors like water absorption and thermocycling.

Further investigations into CAD-CAM resin blocks' mechanical robustness include assessments of their fracture toughness and fatigue behavior. Fracture toughness is essential for evaluating a material's resistance to crack propagation under stress, a critical property for dental composites used in structural components. Studies suggest that while CAD-CAM blocks show acceptable fracture toughness, they are still outperformed by newer hybrid ceramics with enhanced mechanical properties [10,33–36]. Rosentritt et al. [34] and Yamaguchi et al. [33] explored how these materials behave under dynamic loading conditions, finding significant performance variability, which suggests further refinement to improve reliability and predictability in clinical applications.

3.4.2. Bond Strength Properties

Bond strength is essential in introducing new materials that adhere to the tooth structure. The adhesion to tooth structure should provide retentive strength and marginal seal, be relatively simple to achieve, and have clinical durability, reflected in the longevity and success of the bonded restorations. Figure 6C describes the percentage distribution of studies assessing the bond strength, with microtensile (67%) and macro shear (33%) being the most applied tests.

The micro tensile bond strength test (μTBS) was the prevailing method for measuring the microscale bond strength of adhesive materials, while shear bond strength is a method for determining the bond strength by applying a shearing force parallel to the adhesive–substrate interface [37].

Most included manuscripts investigated bonding strength using micro-tensile testing (67%) instead of shear bond strength (33%). This difference could reflect that μ-TBS correlates with in vivo data, while shear bond tests are technique-sensitive when applied to large surface areas of testing [38,39].

Thirty-five percent of the studies in this review have investigated the effects of different surface treatments and adhesives on the bond strength of CAD-CAM RCBs to dentin. For example, Naruse et al. [39] found that using glass beads for air abrasion enhanced the bond. Some studies reported that air abrasion may damage the surface of CAD–CAM resin blocks [39]. Chuenjit et al. [40] stated that combining surface treatments improves bond strength between CAD-CAM materials and resin cement [41].

Various surface treatments can significantly enhance the bond strength of CAD-CAM resin materials. These treatments include air abrasion, which uses aluminum oxide particles to create a rough surface for better micromechanical retention, and hydrofluoric acid (HF) etching, which etches the surface to improve bonding [40]. Silane coupling agents also increase surface wettability and chemical bonding between the resin matrix and fillers. Combining these methods, such as HF etching followed by silane application, often yields the highest bond strength.

Sismanoglu and coworkers found that grinding the surface of hybrid ceramics and applying a universal adhesive resulted in the most robust adhesion. Regarding different CAD-CAM composite materials, Capa et al. [41] found that composite CAD-CAM RCBs were more receptive to bonding than resin nano-ceramic materials [42,43].

Shinohara and collaborators [43] have investigated the effects of three silane primers and five adhesive agents on the bond strength of CAD-CAM RCBs to dentin. The study found that combining a tributyl borane derivative and a silane primer in the SB-Dual adhesive resulted in stronger bonding between the repairing resin composite and the composite block than other agents tested.

Similarly, da Silva et al.'s work [44] examined the bond strength between a polymer-infiltrated ceramic network (PICN) and a composite for repair and the effect of several

ceramic surface treatments. The study found that the most effective way to repair hybrid ceramics was by first surface grinding and then applying universal adhesive, as this method resulted in the most robust adhesion.

3.4.3. Surface Testing Properties

Figure 6D describes the percentage distribution of surface properties. The predominant investigations involve quantifying wear loss (60%) and changes in the surface roughness (40%) of CAD-CAM RCBs.

The durability and clinical success of CAD-CAM resin blocks is significantly influenced by their resistance to wear, which is a critical aspect of material surface analysis [45,46]. Studies such as those by Zhi et al. [47] and Lauvahutanon et al. [30] have focused on comparing the wear resistance of CAD-CAM resin composite blocks to traditional ceramic materials, finding varied results in terms of durability and efficacy of surface treatments like sandblasting and silane application. Nejat et al. [48] further emphasized that the type of surface treatment and adhesive used can dramatically affect the retention strength and overall wear resistance of these materials, underlining the importance of material handling and preparatory processes in extending the longevity of dental restorations.

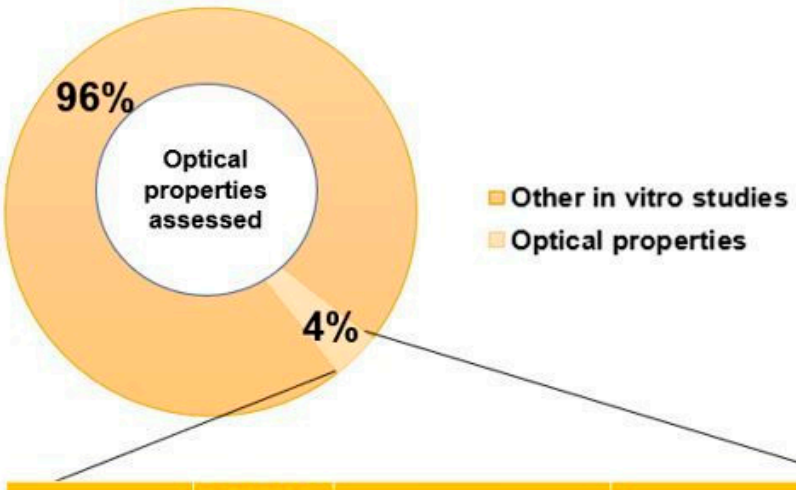
Surface roughness and biofilm formation are additional concerns with CAD-CAM resin blocks, as they can influence the material's aesthetic and hygienic properties. Studies indicate that resin composites might promote bacterial growth more than other restorative materials, leading to increased biofilm accumulation, as noted by researchers [49,50]. The choice of polishing procedures significantly affects the surface topography, with techniques like those evaluated by Kara et al. [51] and Koizumi et al. [52] showing that certain procedures can lead to smoother surfaces, thereby potentially reducing biofilm adherence and improving the material's clinical performance.

These findings collectively suggest that while CAD-CAM resin blocks present a viable option for dental restorations, their success heavily relies on the appropriate selection of materials, meticulous surface treatment, and ongoing maintenance to mitigate wear and biofilm challenges. The evolution of surface treatments and polishing methods, as explored by Kara et al. [51], and the impact of toothbrush abrasion, as studied by Koizumi et al. [52], underscore the dynamic nature of this field, highlighting the need for continuous research and adaptation of clinical practices to optimize outcomes with CAD-CAM technologies.

3.4.4. Optical Properties

When restoring teeth in an aesthetic zone, it is crucial to consider the color stability of materials used to ensure the longevity and aesthetic appeal of the restoration. Figure 7 describes the percentage distribution of investigations involving optical properties and briefly describes the only study found. According to Acar's study in 2016, CAD-CAM RCBs demonstrated more significant color change than lithium disilicate ceramic. Among the materials tested, the nanocomposite resin exhibited the most important color change, followed by the nanoceramic resin and hybrid ceramic, attributed to the hydrophilic polymer triethylene glycol dimethacrylate (TEGDMA). TEGDMA allows for the penetration of hydrophilic colorants into the resin matrix due to its increased water absorption.

Exposure to coffee and thermocycling resulted in undesirable color changes for the nanoceramic and nanocomposite resin materials. The color change of the hybrid ceramic was noticeable but still satisfactory. On the other hand, the lithium disilicate ceramic material demonstrated no noticeable color change at any thickness value, indicating superior color stability. These findings highlight the importance of carefully selecting the appropriate restorative material based on its color stability and aesthetic properties [50].



Name	Type of block	Results	Conclusion
Color stainability of CAD/CAM and nanocomposite resin materials	PICN, RNC & Lithium disilicate	The thickness of the material significantly affected the color difference caused by staining ($P<0.001$). When analyzing color differences, each tested material pair had a significant difference ($P<0.001$). The average color difference (DE00) at the mean thickness was 4.34 for the nanohybrid composite resin, 3.66 for the resin nanoceramic, 1.35 for the hybrid ceramic, and 0.43 for the lithium disilicate ceramic	The color change observed in the resin nanoceramic and nanocomposite resin materials when subjected to hot and cold coffee exceeded what is considered clinically acceptable. The average color change in the hybrid ceramic was noticeable within clinically acceptable limits across the tested range of thicknesses. On the other hand, the color change in the lithium disilicate ceramic was not perceivable within clinically acceptable limits at any of the tested thicknesses.

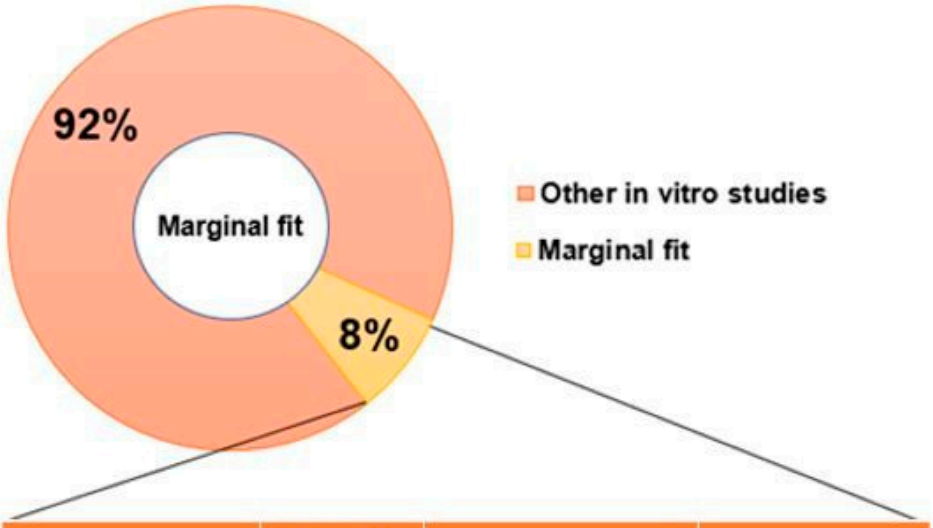
Figure 7. The percentage distribution of investigations involving optical properties and a brief description of the only study found.

3.4.5. Adaptability (Margin Fit) Properties

Figure 8 displays the percentage distribution of included studies investigating the milled restorations' adaptability.

The effect of tooth preparation design on the marginal adaptation of ceramic-reinforced CAD-CAM RCB onlays was investigated by Yang et al. [50]. The study revealed that the traditional tooth preparation design resulted in better marginal adaptation than the other designs. This outcome indicates that the conventional approach is the recommended method for clinical practice. Furthermore, the findings of this study highlight the importance of proper tooth preparation in ensuring the success of CAD-CAM restorations [53].

Similarly, De Paula Silveira et al. [53] investigated the marginal and internal fit of CAD-CAM RCBs and ceramic crowns scanned by two intraoral cameras. The study revealed that the composite resin blocks associated with the Bluecam intraoral camera demonstrated the best results for AIS (absolute marginal discrepancy) compared to the other groups. In addition, the marginal adaptation of all groups was within the clinically accepted range, indicating that both materials can be used for CAD-CAM restorations [54].

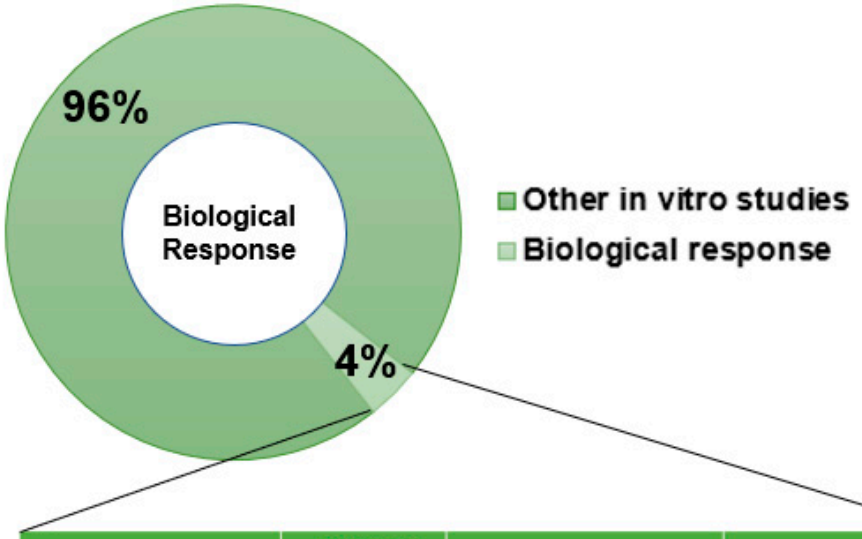


Name	Type of block	Measurements	Conclusion
Marginal and internal fit of CAD-CAM-fabricated composite resin and ceramic crowns scanned by 2 intraoral cameras	Lava Ultimate (Bluecam vs Omnicam	"In the present study, values ranging from 118 to 137 mm were obtained for absolute marginal discrepancy (AMD), and no significant difference was found among groups."	"The marginal adaptations assessed in all groups showed values within the clinically accepted range"
Effect of tooth preparation design on marginal adaptation of composite resin CAD-CAM onlays	ceramic reinforced composite resin blocks (Hyramic; Upcera)	"Traditional preparation designs resulted in significantly smaller overall discrepancies (50.9 ±0.5 mm and 139.1 ±5.4 mm, P<.001) and smaller marginal discrepancies in the buccal (49.7 ±1.4 mm and 135.8 ±2.2 mm, P<0.001) and lingual areas (47.1 ±1.0 mm and 133.4 ±1.1 mm, P<0.001)."	"The traditional preparation design offered better marginal adaptation; therefore, it is recommended in clinical practice"

Figure 8. The percentage distribution of investigations involving optical properties and a brief description of the only two studies found.

3.4.6. Biological Properties

Figure 9 represents the studies investigating the biological response and briefly describes the only study found. Alamoush et al. [54] evaluated the response of two gingival cell lines to CAD-CAM RCBs. The study examined the cytotoxicity and effect on the proliferation of two gingival cell lines, Human gingival fibroblasts (HGFs) and Human gingival keratocytes (HGKs), exposed to RCB and PICN CAD-CAM resin blocks. The results showed that all the materials examined had a more significant cytotoxicity effect on HGK proliferation than HGF. The conventional composite, however, exhibited comparable or better proliferation and lower cytotoxicity levels than the CAD-CAM resin blocks. These findings highlight the importance of considering the biocompatibility of dental materials when selecting materials for clinical use, especially in restorations that come into contact with gingival tissues.



Name	Type of block	Results	Conclusion
Response of two gingival cell lines to CAD/CAM composite blocks	Resin composite blocks, PICN & conventional composite	"There was significant difference in cell proliferation of the HGK and HGF cells in con-tact with different composite materials but no significant differences in their cytotoxicity."	"HGK proliferation and cytotoxicity appeared to be more influenced by composite materials compared to HGF, demonstrating EN cytotoxic effects in HGK. Different manufacturing techniques of resin-composites (photo curing versus heat/pressure curing) had no significant effect on their biocompatibility."

Figure 9. The percentage distribution of investigations involving the biological response of the CAD-CAM RCB and a brief description of the only study found.

4. Perspectives and Limitations

This scoping review, while extensive, is not without its limitations. First, the inherent nature of a scoping review limits the depth of analysis typically found in systematic reviews, particularly regarding risk of bias assessments and meta-analytic pooling of data. Thus, while we provide a broad overview of the landscape, the findings should be interpreted cautiously regarding their generalizability.

Secondly, most included studies are in vitro, which, although valuable for initial material assessments, do not fully replicate the complex interactions and long-term conditions experienced in clinical environments. This restricts our ability to effectively extrapolate these findings to predict long-term clinical performance.

Another significant limitation is the methodological heterogeneity among the included studies. Variations in study design, material handling, and outcome measurements across studies make it challenging to compare results directly or to draw definitive conclusions about the superiority of one material or technique over another.

Additionally, our review was confined to articles published in English, which may have excluded relevant studies published in other languages, potentially introducing language bias. This limitation could omit significant research, especially from countries where CAD-CAM technologies are widely researched but published in non-English journals.

Lastly, the rapid evolution of CAD-CAM material technology means that some newer materials may not have been included in this review. As the field advances, new materials with potentially improved properties and performance could offer different insights than those discussed here.

5. Conclusions

In this scoping review, we thoroughly examined the existing literature on CAD-CAM resin blocks, encompassing their compositional classification, manufacturers, and a variety of essential material properties. The bulk of in vitro studies we analyzed primarily evaluated their resilience to masticatory forces and their bonding efficacy. Despite these findings, there remains a significant gap in these materials' clinical, long-term performance assessments. These insights are crucial for dentists and researchers in making informed decisions about selecting and utilizing CAD-CAM resin materials for indirect restorations.

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