THE USE OF CAD/CAM TECHNOLOGIES IN MINIMALLY INVASIVE DENTAL RESTORATIONS: A SYSTEMATIC REVIEW

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ABSTRACT

Aim of the study The study reviews dental treatment effectiveness, CAD/CAM technology compatibility, and restorative materials' clinical performance, focusing on demographics, criteria, interventions, methodologies, and outcomes across countries and follow-up durations. **Materials and methods** This systematic review evaluates CAD/CAM technologies in minimally invasive dental restorations, analyzing 10 relevant studies from the PubMed database published between 2019 and 2024 using specific keywords: “CAD/CAM” OR “computer-aided design” OR “computer-aided manufacturing” OR “digital dentistry” AND “minimally invasive” OR “conservative dentistry” AND “dental restoration” OR “dental crowns” OR “inlays” OR “onlays” OR “veneers” to assess their effectiveness in enhancing precision, reducing chair time, and improving materials for crowns, inlays, onlays, and veneers, while acknowledging limitations in inclusion criteria and study types. **Results** The systematic review on CAD/CAM technologies in minimally invasive dental restoration highlights studies from various countries, mostly randomized controlled trials, with sample sizes ranging from 20 to 90 patients. Follow-up durations span from 1 to 7.7 years. The studies cover diverse demographics, targeting different tooth types and dental conditions. CAD/CAM systems like CEREC and TRIOS, alongside materials such as nano-ceramics, zirconia, and composites, were used for various restoration types. Clinical outcomes revealed differences in survival rates, failure rates, and complications, emphasizing the importance of material and technique selection for optimal CAD/CAM restoration results. **Conclusions** The systematic review demonstrates CAD/CAM technology's global adoption, versatility in dental restorations, and varied performance outcomes, emphasizing the importance of material and technique selection for optimal long-term results.

Key words: CAD/CAM; computer-aided design; computer-aided manufacturing; digital dentistry; conservative dentistry; dental restoration

INTRODUCTION

Restoring damaged teeth is one of the procedures that has seen modification by integrating computer-aided design and CAM systems in dentistry [1]. CAD and cam systems integration facilitates accurate, highly aesthetic restorations while also being conservative in the natural tooth structure. CAD-CAM systems allow maximal optimizations to be adopted in accomplishing restoration with minimal standing of edges of the teeth to be prepared [2]. This paradigm shift is possible through CAD/CAM technologies that allow accurate scanning such that there is no or very minimal margin of error in the placement of the restorations [3].

For the past 20 years, computer-aided design (CAD)/computer-aided manufacturing

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(CAM) has witnessed an escalation in applicability across all medical disciplines, including dentistry [4,5]. It has been mentioned in the literature that artificial intelligence models are proposed for several applications: the automated method for tooth shade selection, the automated restoration design, the automated finishing line mapping, the optimization of the casting process, the prediction of facial changes due to the presence of removable prostheses, designing partial removable dentures, however in all cited situations, the models are being developed [6,7]. CAD/CAM technology produces inlays, onlays, veneers, crowns, fixed partial dentures, implant abutments, orthodontics, and various complicated oral rehabilitation [8]. The modern dental practice is witnessing not only the aspects that relate to the practice itself but also the application of remarkable and advanced technologies that clearly change the way dentists work and also respond to the demands of the patients, which are more focused on aesthetics and do not wish to spend long hours at the dental clinic [9].

In earlier times, dental restorations used to be accompanied by aggressive tooth preparations to fit different restoratives. This resulted in increased discomfort for the patient and the potential risk of developing sensitivity and failure of the restoration [10]. With CAD/CAM systems, providing more efficient treatment methods with less invasiveness is now possible. Mould impressions are now taken digitally with great precision and help create custom-designed prosthetics that match an individual's oral cavity [11]. There has also been a dramatic development in material science from the conversion of analogue into digital processes. Present-day CAD/CAM systems have several materials, such as glass-ceramics and polymer-infiltrated ceramic networks, from which aesthetic and strong restorations can be developed [12].

They are designed to replicate the refractive index of healthy teeth, thus improving the aesthetics of the restorations and enhancing their resistance [13].

Minimally invasive dentistry relies on the early prevention and treatment of dental caries and employs effective diagnostic methods like laser technology for caries detection [14,15]. It enables the dentist to detect the caries disease process well before it can be seen on the x-ray or even if it is not clinically evident [16]. Techniques involving minimal tooth removal, such as ultra-thin veneers and partial coverage restoration, can preserve sound tooth structure and restore function and aesthetics [17]. This practice paradigm is more comfortable for the patients and enhances clinical effectiveness. Restoration prostheses produced using CAD/CAM have been reported to perform consistently well due to their accurate fitting and improved bonding. These technologies can help with workflow standardization and provide predictable results while increasing productivity and reducing time spent in the dental chair [18].

CAD/CAM technologies are beneficial in many clinical situations. Overcoming obstacles like severely worn dentition, for example, is quite a challenge [19]. In this regard, several CAD/CAM veneers for patients with pronounced occlusal wear without bulky tooth preparation become feasible. This is made possible through digital workflows, which facilitate accurate construction based on the digital impressions of the remaining dentition [20, 21].

In addition, patient-specific three-dimensional printed guides can be used during the cementation procedures to enhance their accuracy and dependability. CAD/CAM applications also fit well for the inlays, onlays, and crowns [22]. These defect-focused restorations address specific defects while keeping the other healthy tissues intact. The introduction of high-strength monolithic zirconia restorations also favours the

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minimally invasive approach by eliminating the need for layering procedures, which demand more tooth reduction [23].

With the advancement of technology, the applications of CAD/CAM in minimally invasive dentistry will also advance [24]. The evolution of materials and bonding protocols ensures further changes, which can expand the scope and lifetime of restorations even more [25]. Moreover, digital imaging and AI improvements simplify diagnosis and treatment planning and minimize the outreach of invasive procedures'ocedures [26, 27].

To conclude, the advancements in dentistry regarding CAD/CAM technologies in minimally invasive dental restoration procedures are remarkable. Not only does the technology employ more effective restoration approaches while maintaining and ensuring the tooth's natural structure is preserved, but the use of CAD/CAM technologies also increases the predictability and efficiency of dental treatment. Moving forward, improvements will likely be made in this area, benefiting the practitioners and the patients.

Objectives

To systematically review and analyze the characteristics of studies investigating the effectiveness of various dental treatments on specific types of teeth, focusing on participant demographics, inclusion and exclusion criteria, and treatment outcomes across different countries and follow-up durations.

To evaluate the effectiveness of various CAD/CAM technologies in dental restoration by examining their compatibility with different restorative materials, restorations, and restoration techniques.

The **purpose of this study** is to evaluate and compare the clinical performance and complications associated with different restorative materials by analyzing interventions, methodologies, and outcomes in a specified comparator group.

MATHERIALS AND METHODS

Study Design

The current systematic review considers CAD/CAM technology's role in minimally invasive teeth restoration and CAD/CAM-aided dental works. In this context, the objective of this paper is to systematically search and compare relevant academic resources which concern the role of CAD/CAM - Computer Aided Design and Computer Aided Manufacturing for dental restorations, with emphasis given to minimally invasive crown, inlay, onlay and veneer techniques. According to the PRISMA guidelines, the review process commenced with retrieving 9,949 records from searches within the databases, as shown in Figure 1.

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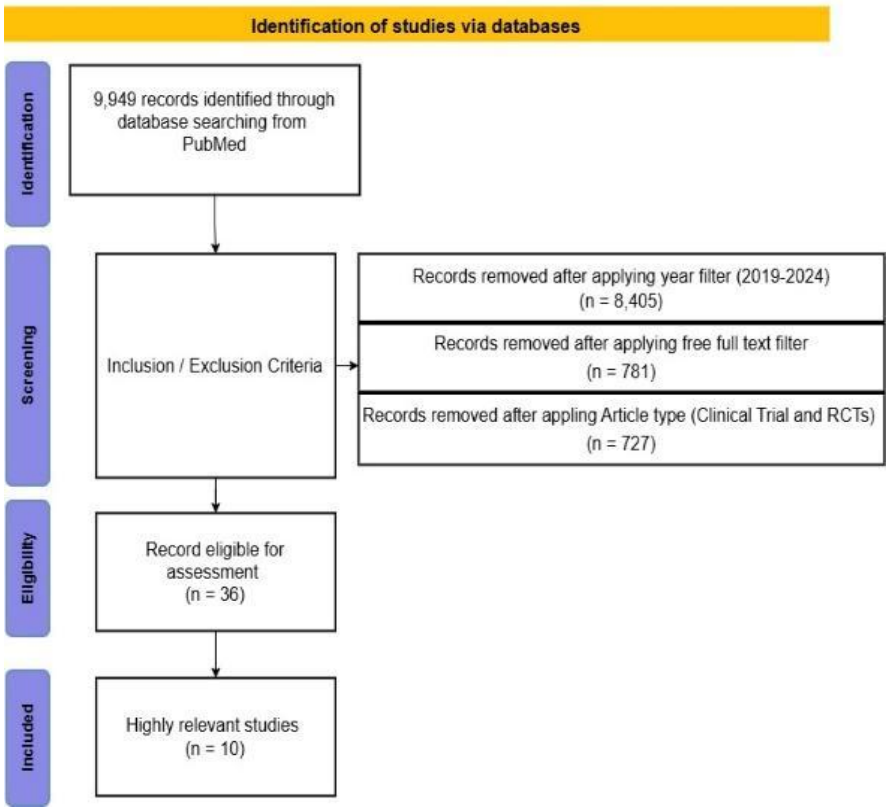

Figure 1. PRISMA flow diagram

Search Strategy

The search was conducted using specific keywords: "CAD/CAM" OR "computer-aided design" OR "computer-aided manufacturing" OR "digital dentistry" AND "minimally invasive" OR "conservative dentistry" AND "dental restoration" OR "dental crowns" OR "inlays" OR "onlays" OR "veneers." These terms were utilized to encompass investigations concerned with using CAD/CAM in restoring teeth, emphasizing the preservation of tooth structure. The searches encompassed the literature published from 2019 to 2024, specifically, the PubMed database.

Inclusion and Exclusion Criteria

The screening process was structured in a way that made it possible to hone the initial subset of studies. In the beginning, 8,405 records were eliminated since they were published before or after the stipulated timelines of 2019-2024, thus making sure that the latest innovations in the area are brought. 781 more records were denied access because they were not in the full-text available for free, restricting the review to those with free studies. Additionally, 727 records were excluded since they were not identified as Clinical Trials or Randomized Clinical Trials (RCTs). The combination of nutrients leaves 36 records that have been screened before. Out of the 36, 26 were excluded based on irrelevance, thus making it to the last 10 studies which are found to be most relevant.

Data Extraction

The data extraction process tried to apply critical aspects of CAD/CAM technology in minimally invasive dental restorations. Each article was analyzed by considering the presence of digitalization and how its use influenced the course of operations on dental crowns, inlays, onlays, and veneers. The extraction aimed to evaluate the effectiveness of CAD/CAM technologies in increasing the efficiency and effectiveness of interventions in

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conservative dentistry.

Data Synthesis

The synthesis included 10 studies using CAD/CAM technologies in minimal invasive restoration techniques. These studies underlined the CAD/CAM system's effectiveness in increasing the precision of dental restorations, reducing chair time, and enhancing the materials used for inlays, onlays, crowns, and veneers. The review integrates the results to illustrate how minimally invasive procedures, including CAD, CAM, and digital technologies, have become the mainstay of dental practice.

Limitations

The review, however, is not free of various limitations. Narrowing the inclusion criteria only to research published between 2019 and 2024 may have precluded older studies which offered additional information regarding the application of CAD/CAM technologies. Likewise, the study's criteria further restricted the search to studies with free full-text available. Also, they limited the number of studies that could be included in the analysis, possibly missing essential information. Finally, constraining the types of studies to Clinical Trials and RCTs, which to some degree guarantees that the hardest of all evidence is included, might also have their drawbacks in that they screened out other essential studies on the subject, such as other types of non-interventional studies or case studies which may give more depth to the topic being studied. These factors may have hindered the comprehensiveness of the review.

RESULTS AND DISCUSSIONS

Table 1 presents vital study information related to the systematic literature review on using CAD/CAM technologies in minimally invasive dental restoration. It summarizes various studies investigating different aspects of CAD/CAM systems and their application in dental care. Most of the studies listed are randomized controlled trials (RCTs), with one prospective study and an in vitro study, highlighting a focus on rigorous testing under controlled conditions. The studies are conducted in diverse countries such as Germany, the Netherlands, the USA, Thailand, Egypt, and Spain, indicating a global interest in these technologies. In terms of sample size, there seems to be some heterogeneity as some studies used samples as small as twenty patients whilst others relied on ninety patients, which may affect the overall statistical power and the scope of applicability of the results.

The follow-up duration varies equally, as some could be a year while others might go as far as 7.7 years. In so doing, they can provide information about the reliability and longevity of CAD/CAM restorations, while those with shorter durations focus on immediate results. It is correct to assume that these studies investigated other problems as well; the differences in design and follow-up periods lead to the conclusion that these studies aimed to study the short-term and long-term effects of CAD/CAM technologies, including the clinical and aesthetic performance of the restorations, and the survival rate of the restorations as well. This perspective highlights the need for methodological rigour and measuring effects over a prolonged period in determining the efficacy of CAD/CAM systems in dental restorative procedures.

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Table 1. Study Characteristics

Source (Author, Year)	Study Design	Country	Sample Size	Follow-up Duration
Lührs et al. 2020 [28]	RCT	Germany	24 patients	7.7 years
Crins et al. 2021 [29]	RCT	Netherlands	41 patients	3.5 years
Fasbinder et al. 2020 [30]	RCT	USA	86 patients	5 years
Suksawat et al. 2023 [31]	In vitro	Thailand	60 participants	-
Elmoselhy et al. 2024 [32]	RCT	Egypt	50 participants	2 years
Abbassy et al. 2023 [33]	RCT	Egypt	72 patients	1 year
Pontevedra et al. 2024 [34]	RCT	Spain	90 patients	5 years
Pontevedra et al. 2022 [35]	RCT	Spain	60 patients	3 years
Hassan et al. 2024 [36]	RCT	Egypt	20 patients	2 years
Abdelaziz et al. 2024 [37]	RCT	Egypt	30 patients	12 months

Table 2 describes the characteristics of the participants, inclusion and exclusion criteria, and the types of teeth treated in the studies included in the review on the application of CAD/CAM technologies in minimally invasive teeth restoration. The participant demographics are different in the studies, with the youngest ages being the 16 years level and up to 50 years. Gender proportions have been provided in some of the studies, but some are only age-focused. The studies also outlined inclusion and exclusion criteria and other factors, such as lesions due to depth, wearing out of teeth, and general well-being, to narrow down the best candidates for the relevant procedures. In terms of study procedures, the studies examined different types of teeth, justifying the application of CAD/CAM technology in dental treatment. For instance, some studies involved the treatment of anterior and posterior teeth, but others involved using first molars only, maxillary anterior teeth only or endodontic teeth. In addition, several studies have focused on posterior teeth, such as molars and premolars. Such diversity in the places of treatment enhances the profiles of CAD/CAM applications with various tooth types and dental conditions.

Table 2. Participant and Treatment Characteristics

Source (Author, Year)	Participant Demographics	Type of Teeth Treated
Lührs et al. 2020 [28]	10 males, 14 females	Anterior and posterior teeth
Crins et al. 2021 [29]	36.6 ± 6.6 years	First molars and maxillary anterior teeth
Fasbinder et al. 2020 [30]	30 males, 56 females	Premolars and molars
Suksawat et al. 2023 [31]	-	Endodontically treated maxillary premolars
Elmoselhy et al. 2024 [32]	Males and females, aged 16–45	Mutilated vital molars
Abbassy et al. 2023 [33]	Age range: 18-40 years	First permanent molars (mesial)
Pontevedra et al. 2024 [34]	52 females, 38 males	Molar and premolar
Pontevedra et al. 2022 [35]	38 women, 22 men	Posterior teeth (molars and premolars)
Hassan et al. 2024 [36]	25-40 years	Posterior teeth (molars/premolars)
Abdelaziz et al. 2024 [37]	18-50 years	Posterior teeth (molars/premolars)

Table 3 assists in finding information about the technology and materials which were used in the CAD/CAM studies for dental restorations: specific CAD/CAM

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technologies and materials, types of restorations and applied techniques. To assimilate different types of restorations different systems of CAD/CAM were used such as CEREC 3D BlueCam system, TRIOS 3 Oral Scanner, and imes-icore CORiTEC 350i milling machine. Some authors made a full digital workflow in creating restorations, such as onlays and FPDs, which encompassed IOD, CAD/CAM, CT scan, and cementation. The restorative material on the other hand differs in the series of studies which are performed, these include the use of nanoceramics (Lava Ultimate, IPS e max CAD), hybrid resin composites and zirconia (monolithic zirconia, veneered zirconia) materials. The types of restoration done including but not limited to direct and indirect composite restorations, full coronal, and onlays among others. While undertaking the rest restorations, different approaches or techniques are used based on the type and material of restoration including but not limited to adhesive cementation, selective enamel etching and the sectional matrix systems during Class II restorations. This variety emphasizes the diversification in technology, materials and methods that CAD/CAM systems can offer in their work in dentistry and coping with different reproductive tasks.

Table 3. Technology and Restoration Details

Source (Author, Year)	Type of CAD/CAM Technology Used	Type of Restorative Material	Restoration Type
Lührs et al. 2020 [28]	-	Tetric EvoCeram (composite), flowable composite	Class V restorations
Crins et al. 2021 [29]	-	Micro-hybrid and nano-hybrid composites; Clearfil Estenia C&B (indirect)	Direct and indirect composite restorations
Fasbinder et al. 2020 [30]	CEREC 3D BlueCam system	Lava Ultimate (nano-ceramic), IPS EmpressCAD (leucite-reinforced ceramic)	Chairside CAD/CAM onlays
Suksawat et al. 2023 [31]	TRIOS 3 Oral Scanner (3Shape)	Cerasmart, Vita Enamic, IPS e.max CAD, Katana Zirconia UTML	Onlays
Elmoselhy et al. 2024 [32]	Omnicam intraoral scanner, CEREC milling machine	IPS e.max CAD (Lithium disilicate), Brilliant Crios (nano-hybrid composite)	Partial indirect restorations (onlays)
Abbassy et al. 2023 [33]	-	Composite resin (Filtek P60 Posterior Restorative)	Class II composite restorations
Pontevedra et al. 2024 [34]	Trios 3 intraoral scanner, Zenostar T system	Monolithic zirconia, veneered zirconia, metal-ceramic	Three-unit posterior fixed partial dentures (FPDs)
Pontevedra et al. 2022 [35]	Trios 3 intraoral scanner, Zenotec CAM	Monolithic zirconia, veneered zirconia	Three-unit posterior fixed partial

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	system		dentures (FPDs)
Hassan et al. 2024 [36]	imes-icore CORiTEC 350i milling machine	Lithium disilicate, hybrid resin nano-ceramic	CAD/CAM onlays
Abdelaziz et al. 2024 [37]	-	Composite resin (X-tra Fil, Voco)	Class II composite restorations

Table 4 contains information about the different approaches and clinical outcomes of other studies concerning CAD/CAM dental restorations regarding particular materials and their techniques. A few purposes of such investigations were to compare different restorative methods, such as direct and indirect, composite resins and disilicate ceramics, and monolithic and veneered zirconium oxide. It was found out, for instance, that indirect restorations were associated with higher failure rates than direct ones. Moreover, it has been shown that composites performed better compared to ceramics. In many CAD/CAM materials comparisons, it was established that Katana Zirconia had the best fracture resistance, although the material demonstrated more unrestorable fractures. The results also differed depending on the study, with some indicating that clinical performance and complication rates varied between the two studies. A few ways the factors were studied were on survival rates, with one study indicating that metal-ceramic fixed partial dentures (FPDs) had a survival rate of 100%.

In contrast, for monolithic zirconia, it was 87%. Other complications included the rates of fractures, sensitivity, marginal discolouration, and restoration debonding. For example, concerning postoperative sensitivity and the amount of margin staining, nano ceramic onlays performed the best. At the same time, veneered zirconia restorations were more aesthetically appealing but suffered from more veneer fractures than the completely monolithic units. As for the technique, bulk-fill composite restorations were quick but associated with high levels of MMP-9, which predicted the risk of caries recurrence in the early stages. This emphasizes selecting suitable materials and methods for CAD/CAM dental restorations to achieve the best results.

Table 4. Comparator and Outcomes

Source (Author, Year)	**Comparator Intervention**	**Restorative Material Used in Comparator**	**Clinical Performance**	**Complications**
Lührs et al. 2020 [28]	Four groups: CLEAN, PREP_FLOW, GROOVE, GROOVE_FLOW	Tetric EvoCeram (composite)	Total retention rate: 82.8%; highest loss in CLEAN group (27.8%)	No secondary caries, minor marginal discoloration
Crins et al. 2021 [29]	Direct vs. indirect composite restorations	Direct: Micro-hybrid; Indirect: Clearfil Estenia C&B	Lower failure rates for direct restorations (3.2–5.4%) vs. indirect (8.5–15.5%)	Higher fracture rates for indirect restorations
Fasbinder et al. 2020	Lava Ultimate vs.	Leucite-	Nano-ceramic	Minimal

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[30]	IPS EmpressCAD	reinforced ceramic	onlays showed lower fracture rates than leucite-reinforced	postoperative sensitivity, low margin staining
Suksawat et al. 2023 [31]	-	-	Katana Zirconia had highest fracture resistance; others comparable	Katana Zirconia had 70% unrestorable fractures
Elmoselhy et al. 2024 [32]	Comparison between nano-hybrid composite and lithium disilicate restorations	-	Acceptable performance; better marginal integrity in nano-hybrid at 6 months	-
Abbassy et al. 2023 [33]	Different contact forming instruments with Palodent Plus sectional matrix system	Composite resin	Trimax resulted in tightest proximal contacts; PCT decreased over time	No food impaction or periodontal inflammation
Pontevedra et al. 2024 [34]	Monolithic vs. veneered zirconia vs. metal-ceramic FPDs	Zirconia and metal-ceramic	Survival rates: MC (100%), VZ (97%), MZ (87%); MZ higher failure rate	MZ had higher fracture rate; minor chipping in VZ and MC
Pontevedra et al. 2022 [35]	Monolithic vs. veneered zirconia FPDs	Veneered zirconia (IPS e.max ZirCAD)	Survival rates: 90% monolithic, 100% veneered; biological complications in monolithic group	Veneered zirconia had veneer fractures; monolithic had biological complications
Hassan et al. 2024 [36]	Lithium disilicate vs. hybrid resin nano-ceramic onlays	Lithium disilicate (IPS e.max CAD)	Both materials had a 90% survival rate over 2 years	Two debonded restorations for IPS; hypersensitivity in Voco Grandio group
Abdelaziz et al. 2024 [37]	Incremental vs. bulk-fill packing techniques	Same material (X-tra Fil)	No significant difference; bulk-fill is time-saving with fewer voids	Increased MMP-9 levels with recurrence of caries

DISCUSSIONS

The emphasis in this present systematic review on using CAD/CAM technologies in minimally invasive dental restoration rests on the prevalence of RCTs, highlighting the strict protocols followed to assess the described technologies. It is worth emphasizing that this type of research is significant since it validates the results and shows that they are applicable in daily clinical practice. Bear in mind, however, that the sample size limits of between 20 and 90 participants reflect a compromise between achieving sufficient

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statistical power on the one hand and the practicalities of clinical practice on the other hand. The statement that more emphasis is placed on RCTs in most of these studies nowadays is that there are more efforts directed towards generating CAD/CAM technologies with reliable evidence. It was also noted that such trials certainly provide information about the effectiveness and efficiency of CAD/CAM systems in practice as opposed to conventional techniques, and this information is more valuable from the perspective of effective patient care and ease of the procedure [38]. The tendency to undergo both qualitative harsh conditions permits to minimize biases in the study, and reliability towards the outcomes is elevated.

From the current systematic review, the sample sizes ranging from 20 to 90 participants tend to reflect a more realistic view of research. It was pointed out that smaller studies allow for more controlled settings, whereas more extensive studies improve the external validity of the results. The two extremes of these two are essential in applying research to clinical practice as one can ensure that the findings obtained would apply to various categories of patients [39]. Besides, it was recognized in some reviews that CAD/CAM technologies can successfully be used for children who develop dental problems and adults who need complicated restorative treatment [40]. In addition, such practices of introducing some inclusion and exclusion criteria in the studies are important in considering the populations that such results will be helpful. This way, less confounding factors like age, dental morbidities and treatment histories will enhance the quality of evidence on the efficacy of CAD/CAM technologies [41].

The present systematic review covered a variety of tooth types, including anterior teeth and both primary and permanent posterior teeth, thus showing that CAD/CAM restorations can be effectively used in both adult and pediatric dentistry. Such flexibility may diversify treatment modalities for the practitioners and improve patient outcomes in various age groups and clinical conditions. Correspondingly, a study compares the fracture strength of four types of pediatric crowns, showing CAD–CM–crowned zirconia crowns were more fracture resistant; therefore, it is concluded that CAD–CM construction processes may contribute to the pediatric crown's durability [42]. Likewise, A paper published in 2020 highlighted the successful uptake of CAD/CAM technology in pediatric dentistry. It was noted that such technologies have enhanced adhesive, aesthetic, and functional restorations for children who have different demands relative to adults [43]. The reversibility of the disability after surgery with a high level of prosthesis retention can be particularly beneficial for children who have difficulty keeping up with prolonged treatment periods. In the meantime, research reported a success rate of 92% for CAD/CAM chairside all-ceramic restorations on endodontically treated posterior teeth in the period of 1-3 years range, with oral parafunction as a risk factor of failure [44]. In addition, a severe tooth wear case digital workflow helps achieve accurate transfer of jaw relation and restorative space from provisional to final restorations employing stereolithographic templates and computerized articulation for accurate occlusal reconstruction [45]. The fact that the patient makes a rapid recovery into active life with considerable artificial intelligence is of particular advantage for children who have problems maintaining their commitment to long treatment sessions. Meanwhile, the trial against conventional restorative techniques involving CAD/CAM processes concluded that CAD/CAM restoration diminished the overall duration of the treatment sequence and increased patient comfort as well as

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satisfaction through their exact adjustment with a lesser number of alterations after placement [46,47]. A case report demonstrates a satisfactory clinical result in tooth fracture treatment where the maxillary incisors were completely broken off, and a digital mock-up was used to fabricate the 3D-printed guides, enabling aesthetic restoration and patient contentment without any negative impact on tissues after 6 months [48]. The use of CAD/CAM restorations over a period of five years was examined in another survey, and the conducted research indicated that such restorations performed well in terms of structural stability as well as aesthetic appearance, thereby reinforcing their use in adults and children alike [49]. Similarly, a randomized, double-blinded trial evaluating the performance of CAD/CAM nanohybrid composite and Lithium Disilicate restorations over a period of two years reported both materials were effective but noted significant differences in marginal integrity at 6 months [50]. In addition, there are studies which confirm the safety of CAD/CAM technology in various patients, including toddlers and the elderly, making it easier for dentists to formulate an age-based treatment approach [51].

The present systematic review focused on the application of numerous CAD/CAM systems and materials, including CEREC, TRIOS, etc., in a more precise manner and brought to light the advances in the field of digital dentistry quite appreciably. Another research provides an overview of studies about post and core restorations related to composition, methods, and CAD/CAM technology, noting a gap in new studies on long-term survival and clinical effectiveness [52]. It can be envisaged that the application of such contemporary strategies as adhesive cementation and digital workflows promotes not only the efficiency of restorations but also their effectiveness and durability. Similarly, Digitized frameworks make procedures such as diagnosis and treatment more efficient every time. This consequently reduces the time needed for all operations. For instance, it has been demonstrated that the full digital workflow enabled faster and clinically acceptable prosthetic resolutions compared with conventional approaches [53]. Moreover, the trend of digitization in dentistry, especially prosthodontics with fixed dentures, has already revolutionized clinical protocols with the improvement of CAD/CAM systems and the appearance of intra-oral scanners (IOS). Such advances make complete digital workflows possible, allowing for effective single-visit treatment of both tooth- and implant-supported monolithic fixed dental prostheses [54]. Another study examined the accuracy of CAD trial restorations produced with different digital workflows and observed deviations, where significant differences were noted, with subtractive manufacturing being the most accurate process as compared to the additive processes [55].

The current systematic review provides a critical comparison of the studies under consideration and draws conclusions regarding the restorative techniques employed. It was found that direct composite restorations had lower failure rates as opposed to indirect methods, which highlights the advantage of trying out less invasive approaches from an end-user perspective. Similarly, a case report shows a multidisciplinary strategy for the management of a case of acute amelogenesis imperfecta in a child, with a marked enhancement of oral health-related quality of life, and achieved rehabilitation of the whole mouth in this case [56]. With regards to the evaluation of clinical parameters such as survival rates and fracture rates, it can be said that they substantially contribute to the forming of evidence-based recommendations in clinical practice. In the same vein, a prospective study evaluated CAD/CAM nano-

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ceramic composite restorations on patients suffering from severe abrasion of teeth. No restorations were lost after 1 year, with success rates between 100 % to 97.2 %. There was a significant improvement in the oral health-related quality of life following treatment ($p < 0.001$). The presence of mechanical lesions did not influence the risk of failure, while the presence of chemical lesions was associated with a lower risk ($p=0.002$) [57].

The complications described in this systematic review, relating to postoperative sensitivity and marginal discolouration, are of great significance to practitioners when choosing materials and techniques. The studies' conclusions made it possible to collect some recommendations for the perfection of restoration strategies regarding available specific materials (e.g. nano-hybrid composites) and techniques (e.g. bulk-fill). Also, anticipating complications may assist clinicians in making decisions that would improve overall satisfaction with the outcomes of treatment. Similarly, an observation is provided regarding a clinical case showing the positive impact of CAD/CAM technology and the Medit i700 scanner in clinical dentistry in terms of acquiring high precision, efficiency and far better patient experience in the design and fabrication of customized dental appliances [58]. A systematic review and a meta-analysis were also conducted to assess the survival of tooth-supported ceramic prostheses made by the conventional and CAD/CAM techniques. Using data from fourteen studies with one thousand two hundred and nine restorations, the authors found that the CAD/CAM group had a 1.84 times greater risk of failure compared to the conventional restorations. CAD/CAM groups had lower survival statistics, which suggests that CAD/CAM may not be as effective as conventional methods [59]. Additionally, a study also provides survival analyses of single tooth restorations, showing that the failure rate of pressed lithium disilicate ceramics is significantly lower than that of CAD/CAM resin composites [60]. Finally, a 32-year-old woman received minimally invasive CAD/CAM occlusal veneers, which increased her jaw by 2.5 mm, which increased comfort and aesthetics without intensive wear on the teeth or joint pains [61].

The studies reviewed are supportive of CAD/CAM technologies as an effective solution within a minimally invasive approach to dental restorations, as they discuss both the strengths of the techniques and directions for further studies. Studies aimed at exploring long-term effects, cost-effectiveness of CAD/CAM technologies and recommendations on uniform protocols usage in practice are needed. Given the constant technological advancement within the digital dentistry field, learning how to navigate future emerging trends will be a priority for research.

CONCLUSIONS

1. The review of CAD/CAM technology in the context of dental restoration illustrates the dramatic improvement such CAD systems add to the current practice of Dentistry. All studies reviewed showed that CAD/CAM systems, which comprise different types of scanners, milling machines of different sizes, and various restorative materials, are accurate and reliable in dental restorations. Their use covers a wide range of tooth types and conditions, including both the anterior teeth restorations and the posterior ones, which indicates their applicability in clinical practice.

2. The types of material and the technology used in making the restorations, including nanoceramics, hybrid composites, and zirconia, suggest that material selection is a major determinant of restoration outcome. Evidence from various studies reviewed allows us to conclude that, while CAD/CAM

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systems tend to enhance the speed and quality of restorations, material and procedure selection is vital for durability, fracture toughness and aesthetics of clinical results. For example, zirconia materials may provide support for restoring teeth but may also have high rates of un-restorable fractures compared to other materials.

3. Furthermore, the review also stresses the need for long-term analysis in assessing the actual utility of CAD/CAM restorations. While improved short-term.

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