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The Role of CAD-CAM in Prosthodontics – A Review Article

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Abstract **Review Article**

Background*:** CAD-CAM technology is widely used to improve the accuracy and comfort of the prosthesis. The study objective is to summarize some important and basic information about the use of CAD-CAM technology generally and especially in Prosthodontic dentistry. ***Materials and method*:** The review was conducted in accordance with PRISMA guidelines. A comprehensive literature search was performed in PubMed, Google Scholar, and Medline for relevant studies published in English. Scanner, Design software and Processing device are used in CAD-CAM technology. In CAD-CAM technology scanning is done firstly then respectively designing is performed in CAD machine by design software and milling is performed in processing device or CAM. Using criteria for what to include and what to leave out, we chose 15 research papers those were relevant to our review and those met the review's guidelines. According to our findings and the analysis of the chosen articles, the prospects and current advances of CAD-CAM technology and fascinating and are revolutionizing the field of dentistry. ***Results*:** Based on many researches it has been determined that the CAD-CAM methodology used in the dental field is the most advance method for quick, simple and efficient work. ***Conclusion: The CAD-CAM technology can be used to create precise and effective dental component or prosthesis that can provide high quality care for the patients.

Keywords: Scanner, Design software, processing device, milling, CAD-CAM.

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INTRODUCTION

The digital revolution has profoundly transformed modern dentistry, with prosthodontics being one of the specialties most significantly impacted by technological advancements. Among these innovations, Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology has emerged as one of the most transformative tools, redefining the planning, designing, and fabrication of dental restorations [1].

Initially introduced into dentistry during the 1980s, CAD/CAM technology has undergone continuous refinement over the past few decades, evolving into an indispensable component of modern prosthodontic practice [2]. These systems have transitioned from rudimentary applications to sophisticated, highly precise, and time-efficient workflows that have become routine in both clinical and laboratory environments.

In contemporary prosthodontics, CAD/CAM technology is employed for the digital design and fabrication of a wide spectrum of fixed and removable dental restorations. These include inlays, onlays, crowns, bridges, veneers, implant-supported prostheses, removable partial dentures, and complete dentures. The integration of intraoral scanning, virtual design software, and automated subtractive (milling) or additive (3D printing) manufacturing techniques enables clinicians and dental technicians to produce restorations with superior precision, aesthetic quality, and functional predictability [3].

One of the most significant advantages of CAD/CAM workflows is their ability to reduce clinical chairside time, minimize errors associated with conventional impression-taking and laboratory processing, and enhance patient satisfaction by delivering restorations with improved fit and longevity. Furthermore, digital workflows enable the long-term storage of patient data, facilitating easy remanufacture of restorations if needed [4].

While initial applications of CAD-CAM were predominantly in fixed prosthodontics and implant-

supported restorations, the technology was soon extended to removable prosthodontics, particularly in the fabrication of complete dentures [5]. This was primarily driven by the need to overcome inherent limitations of conventional denture fabrication methods, including inaccuracies due to polymerization shrinkage, prolonged clinical chair time, and the lack of reproducibility. [5,6]

A landmark study by Kanazawa *et al*. (2011) explored the feasibility of fabricating complete dentures using CAD-CAM workflows [7]. Their research demonstrated promising accuracy with minimal deviations—approximately 0.10 mm for the intaglio (mucosal) surface and 0.50 mm for the occlusal surface—highlighting the potential for digitally produced dentures to rival or exceed conventional dentures in fit and function.[4]

Further comparative studies by Kattadiyil *et al*. underscored the clinical advantages of CAD-CAM dentures, particularly emphasizing the reduction in the number of clinical appointments required—from five visits for conventional dentures to as few as two visits for CAD-CAM-produced dentures—without compromising quality.[8] Additionally, they reported enhanced fit and adaptation of the prostheses due to the elimination of polymerization shrinkage, reduced risk of processing distortions, and the convenience of digital data storage, which facilitates easy remanufacturing of lost or fractured dentures.[9]

As CAD-CAM denture systems continued to evolve, more comprehensive reviews were conducted to evaluate their clinical utility and availability across regions. A review by Goodacre *et al*. identified four major CAD-CAM complete denture systems available globally, with some systems restricted to specific markets (two in the United States and two in Europe) [10]. Currently, five CAD-CAM complete denture systems are prominent in the market: AvaDent Digital Dentures (Global Dental Science), Baltic Denture System (Merz Dental GmbH), Ceramill Full Denture System (Amann Girrbach AG), DENTCA/Whole You (DENTCA, Inc.; Whole You, Inc.), and Wieland Digital Denture (Ivoclar Vivadent Inc.) [10].

OBJECTIVES

The main objective of this study to review to summarize some important and basic information about the use of CAD-CAM technology generally and especially in Prosthodontic dentistry.

METHODOLOGY & MATERIALS

Study Design: This review was conducted using PRISMA guidelines. The review consisted of 5 steps: (1) problem identification; (2) literature searching; (3) data review and evaluation; (4) data synthesis and analysis; and (5) data presentation.

Search Method:

The current review conducted a comprehensive search of relevant articles in electronic databases: PubMed, Google Scholar, and Medline. The search terms included "CAD-CAM," "Prosthodontics," "Dental restorations," "Implant-supported prosthesis," and "Complete dentures." Titles and abstracts were screened for relevance to CAD-CAM applications in prosthodontics. After initial screening, full-text articles were retrieved and reviewed in detail. The inclusion criteria were original research, review articles, and systematic reviews reporting on CAD-CAM techniques, methodologies, or outcomes in prosthodontics. Exclusion criteria included case reports, letters to editors, abstracts without full text, and non-English articles. Additionally, the reference lists of selected articles were screened manually for relevant additional studies. Following this process, 15 articles were selected for final analysis based on their relevance to the aims of this review.

DATA COLLECTION

This review was collected through an analysis of relevant research articles and reviews focusing on the CAD/CAM process in prosthodontics. Special attention was given to the core components and workflow of CAD/CAM systems, which typically include three sequential phases: scanning, designing, and milling. The scanning phase involves the use of advanced scanners to convert the shape of prepared teeth and oral structures into three-dimensional (3D) digital data, generating a point cloud or 3D map of the surface. Two types of scanners are primarily used for this purpose: optical scanners and mechanical scanners. Optical scanners collect 3D data using a triangulation procedure involving either white light projections or laser beams, while mechanical scanners measure the surface mechanically using a ruby ball, providing high scanning accuracy. The collected data also included detailed descriptions of the CAD design phase, in which virtual restorations are designed using specialized software, and the CAM milling phase, where these designs are fabricated from restorative materials. By synthesizing information from the selected studies, this review systematically analyzed the technological advancements, applications, and clinical outcomes associated with CAD/CAM systems in prosthodontics.

The search resulted in 130 articles which were identified in the initial databases (Figure 1). After duplicates were removed, 80 articles remained. Of these, 40 were excluded based on titles and abstracts screened; 25 full articles were excluded for not meeting inclusion criteria. Finally, 15 publications met the criteria and were included in this review.

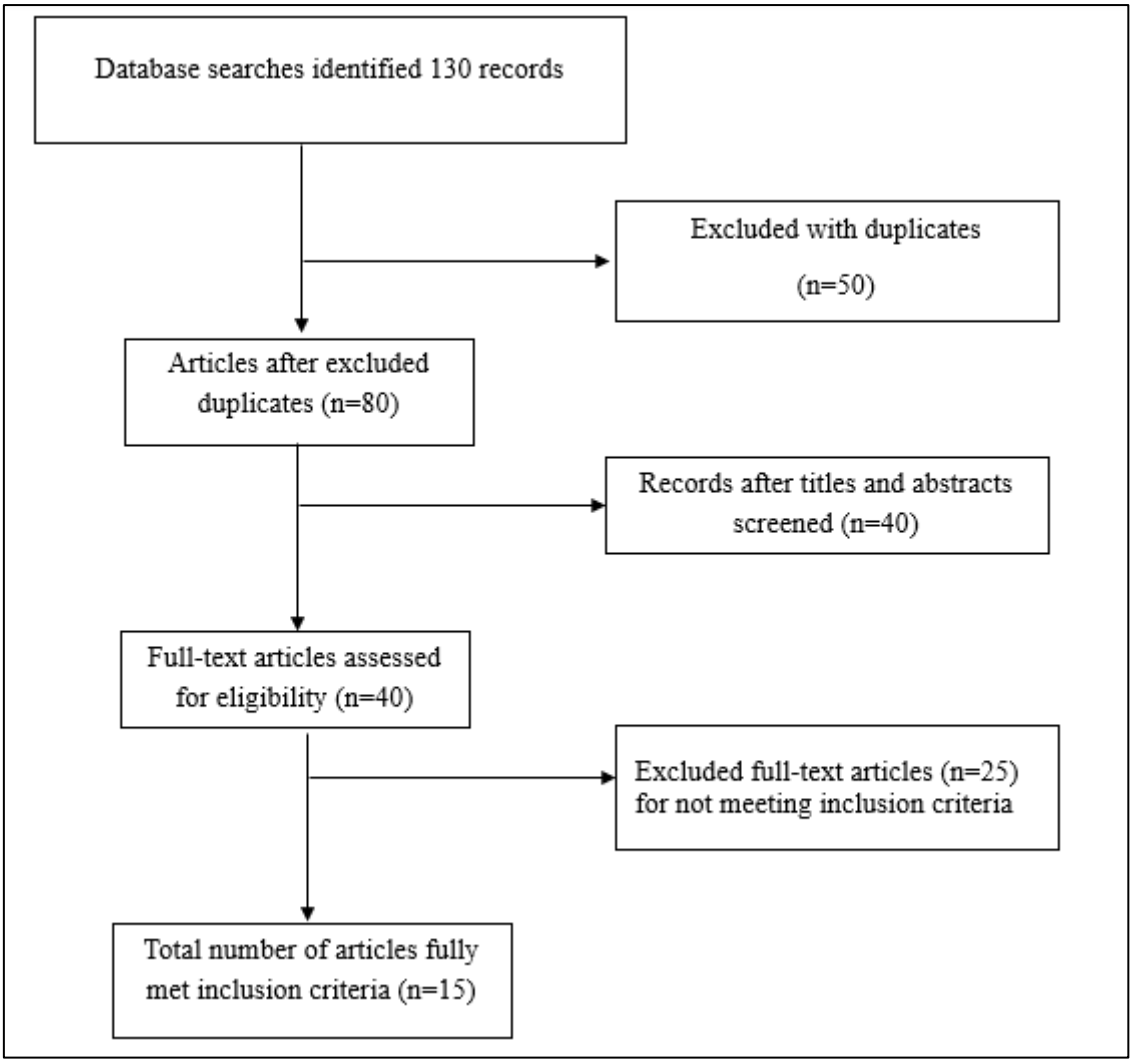

Figure 1: Flow chart of systematic review of literature selection process for the present research

RESULTS

In the present review, we included 15 papers (Table-1). Most studies do support reduced chairside time with intra-oral scanning, compared to conventional impression making, indicating a more efficient clinical approach. Besides these based on many researches it has been determined that the CAD/CAM methodology used in the dental field is the most advance method for quick, simple, precision and efficient work.

Alghazzawi (2016) [11] conducted a review focusing on all-ceramic CAD-CAM systems used chairside for crowns. The study highlighted that these CAD/CAM restorations provide highly aesthetic results with accurate color matching, superior marginal integrity, and precise fit, which in turn increased patient satisfaction.

Sulaiman (2020) [12] performed a systematic review on full-arch prostheses fabricated using complete arch CAD/CAM frameworks. The findings demonstrated excellent mechanical properties and long-term clinical success, particularly for implant-supported full-arch restorations.

Pjetursson *et al.* (2021) [13] carried out a systematic review and meta-analysis involving 49 studies (57 cohorts) investigating veneered and monolithic all-ceramic single crowns on implants made via CAD-CAM. The results showed over 96% survival rates at three years for all materials except resin-matrix-ceramic, which had a survival rate of 36.3%. Veneered crowns had a higher rate of chipping compared to monolithic crowns, and no significant difference was observed based on the anterior or posterior implant site.

Grohmann *et al.* (2015) [14] conducted a multicenter randomized controlled trial with 60 participants comparing posterior zirconia-ceramic fixed dental prostheses (FDPs) fabricated by CAD/CAM zirconia frameworks veneered with either CAD-on lithium disilicate or manually layered zirconia ceramics. Both groups had a 100% survival rate at one year. Major chipping was more frequent in the manual veneering group, while the CAD-on group mostly showed minor chipping. No biological complications occurred, and both methods yielded excellent clinical outcomes with only minor technical issues.

Al-Fouzan *et al*. (2017) [15] performed an in vitro study on 20 samples comparing CAD/CAM fabricated complete denture bases to conventional heat-polymerized acrylic resin bases. The CAD/CAM bases showed significantly lower adhesion of *Candida albicans*, suggesting a reduced risk of denture stomatitis due to smoother surface finishes and less microbial colonization.

Otto T (2017) [16] conducted a long-term follow-up study on 141 chairside CAD/CAM feldspathic ceramic inlays and onlays fabricated using the Cerec 1 system. The restorations exhibited an 87.5% survival rate over up to 27 years, with most failures due to ceramic fractures and tooth fractures. Three-surface restorations and molars showed higher failure risk. This study demonstrated excellent long-term performance of early-generation CAD/CAM ceramic restorations.

Fasbinder (2012) [17] provided a review on chairside CAD/CAM systems used for immediate ceramic restorations, emphasizing that this technology allows patients to receive definitive restorations within a single appointment with minimal need for occlusal adjustment.

Kapos & Evans (2014) [18] performed a systematic review of 18 studies focused on CAD/CAM crowns, abutments, and frameworks for implant prostheses. Survival rates were very high—98.85% for crowns, 100% for abutments, and 95.98% for frameworks—with no significant difference compared to conventional methods. They recommended a clearer classification system for CAD/CAM workflows to distinguish partial from complete CAD/CAM processes.

Abduo & Lyons (2014) [19] reviewed fixed partial dentures fabricated with CAD/CAM, consistently reporting superior marginal integrity and passive fit, which led to fewer mechanical failures and reduced biological complications.

Miyazaki *et al*. (2009) [20] conducted a systematic review on ceramic CAD-CAM restorations, highlighting excellent esthetics, mechanical strength, and long-term durability, particularly recommending ceramics for anterior prosthodontic restorations.

Reich & Schierz (2013) [21] conducted a prospective study on 41 crowns made with chairside CAD/CAM lithium disilicate (e.max CAD LT), evaluated up to 48 months using modified USPHS criteria. The failure-free rate was 96.3% after four years, with one fracture and four biological complications (pulpal necrosis and secondary caries), demonstrating overall satisfactory clinical performance.

Duqum *et al*. (2019) [22] performed an in vitro comparative study on 40 anterior all-ceramic restorations (20 lithium disilicate, 20 zirconia) fabricated using CEREC Bluecam. They compared fully digital and model-based workflows using Micro-CT to evaluate marginal fit. Marginal gaps ranged from 101.9 to 165.4 µm, with no significant differences between the two workflows, both considered clinically acceptable.

Bilgin *et al*. (2016) [23] systematically reviewed 40 articles related to milling and rapid prototyping (RP) technologies for removable dentures. CAD/CAM and RP enable fully digital planning and fabrication, showing promise to replace conventional methods, although current limitations remain for widespread clinical adoption.

Conejo *et al*. (2017) [24] reviewed 25 articles on CAD/CAM monolithic implant-supported restorations with titanium inserts and bases. Laboratory studies suggested improved fracture strength, implant connection protection, and marginal fit with titanium inserts, but clinical studies are still needed for confirmation.

Keul *et al*. (2013) [25] performed an in vitro experimental study with 600 specimens testing adhesion of PMMA- and composite-based CAD/CAM resins to various luting cements and conditioning methods. They found that conditioning methods such as MH, VL, and VP significantly increased bond strength. Composite-based CAD/CAM materials showed higher bonding values than PMMA-based. Aging through thermocycling had no significant effect, emphasizing the importance of selecting proper surface conditioning and cementation protocols for optimal bonding.

Table 1: Summary of the published articles

Authors	Study design	Sample Size	Types of CAD-CAM	Uses	Outcome
Alghazzawi (2016)[11]	Review	-	All-ceramic CAD-CAM	Chairside CAD/CAM for crowns	Provided highly aesthetic restorations with accurate color matching, superior marginal integrity, and precise fit; increased patient satisfaction.
Sulaiman (2020)[12]	Systematic Review	-	Full-arch prostheses	Complete arch CAD/CAM frameworks	Demonstrated excellent mechanical properties and long-term clinical success, especially for implant-supported full-arch restorations.

Pjetursson *et al*. (2021)[13]	Systematic Review & Meta-analysis	49 studies (57 cohorts)	Veneered & monolithic all-ceramic SCs on implants	CAD-CAM fabrication of implant-supported ceramic crowns	3-year survival rates were >96% for all materials except resin-matrix-ceramic (36.3%). Veneered SCs had higher chipping (1.65%) vs. monolithic (0.39%). Anterior/posterior site had no significant effect.
Grohmann *et al*. (2015)[14]	Multicenter Randomized Controlled Trial	60	Posterior zirconia-ceramic FDPs	CAD/CAM zirconia frameworks veneered with either CAD-on lithium disilicate or manually layered zirconia ceramics	100% survival rate at 1 year for both groups. Major chipping more frequent in manual veneering group (n=3), while CAD-on had predominantly minor chipping (n=2 minor, 1 major). No biological complications observed. Both methods provided excellent clinical outcomes with minor technical complications.
Al-Fouzan *et al*. (2017)[15]	In vitro Study	20	Complete dentures	CAD/CAM fabricated denture bases vs. conventional heat-polymerized acrylic resin bases	Significantly lower adhesion of *Candida albicans* on CAD/CAM denture bases compared to conventional bases ($P<0.05$). Clinical implication suggests reduced risk of denture stomatitis with CAD/CAM complete dentures due to smoother surface finish and reduced microbial colonization.
Otto T (2017)[16]	Long-term Follow-up Study	141 restorations (from original 200)	Chairside CAD/CAM inlays and onlays	Cerec 1 system, feldspathic ceramic (Vita Mark I), restorations fabricated chairside and adhesively cemented	87.5% survival rate after up to 27 years. Majority of failures were due to ceramic (65%) and tooth fractures (13%). Three-surface restorations had higher failure risk, premolars fared better than molars. Demonstrated excellent long-term performance of early-generation CAD/CAM feldspathic ceramic restorations.
Fasbinder (2012)[17]	Review	-	Chairside CAD/CAM	Immediate restorations	Allowed patients to receive definitive ceramic restorations within one appointment; minimal occlusal adjustment post-placement required.
Kapos & Evans (2014)[18]	Systematic Review	18 studies	CAD/CAM crowns, abutments, frameworks	Focused on restorative CAD/CAM technology for implant prostheses fabrication	CAD/CAM crowns survival rate: 98.85%, abutments: 100%, frameworks: 95.98%. Comparable survival rates to conventional methods. No significant difference in implant survival. Suggested clearer classification of CAD/CAM processes to distinguish between partial and complete CAD/CAM workflows.
Abduo & Lyons (2014)[19]	Review	-	Fixed partial dentures	Precision-fit frameworks	Consistently demonstrated superior marginal integrity and passive fit, resulting in fewer mechanical failures and lower rates of biological complications.
Miyazaki *et al*. (2009)[20]	Systematic Review	-	Ceramic CAD-CAM	Ceramic restorations	Offered excellent esthetics, mechanical strength, and long-term durability, making ceramics ideal for anterior restorations in prosthodontics.

Reich & Schierz (2013)[21]	Prospective Study	41 crowns (34 patients)	Chairside CAD/CAM lithium disilicate (e.max CAD LT)	Chairside CAD/CAM technique; evaluated using modified USPHS criteria at multiple intervals up to 48 months	Failure-free rate of 96.3% after 4 years. One failure (fracture) and four biological complications (2 pulpal necrosis, 2 secondary caries). Overall satisfactory clinical performance.
Duqum *et al*. (2019)[22]	In-vitro comparative study	40 anterior all ceramic restorations (20 lithium disilicate, 20 zirconia)	CEREC Bluecam; Lithium disilicate (e.max), Zirconia	Two digital workflows used: fully digital (model-less) and digital with printed model; Marginal fit evaluated by Micro-CT in sagittal & trans-axial views	Lithium disilicate crowns showed marginal gaps of 101.9–133.9 µm; zirconia crowns showed 126.4–165.4 µm. No significant difference between workflows. Both workflows clinically acceptable.
Bilgin *et al*. (2016)[23]	Systematic Review	40 selected articles (from an initial 78 publications)	Milling and Rapid Prototyping (RP) for removable dentures	Reviewed CAD/CAM and RP techniques for complete and partial removable denture fabrication; searched multiple databases from 1987 to 2014	CAD/CAM and RP technologies enable fully digital planning and fabrication of removable dentures. The field is rapidly evolving with potential to replace conventional methods. However, current limitations remain for widespread adoption.
Conejo *et al*. (2017)[24]	Systematic Review	25 selected articles (from an initial 505 titles)	CAD/CAM monolithic implant-supported restorations with titanium (Ti) inserts and bases	Focused on CAD/CAM monolithic ceramic restorations bonded to titanium (Ti) inserts/bases for implant-supported restorations	No clinical studies available. Laboratory studies suggest that Ti inserts increase fracture strength, protect implant connections, and improve marginal fit. Clinical studies are still needed for confirmation.
Keul *et al*. (2013)[25]	In-vitro Experimental Study	600 specimens (n=15 per test group)	Polymeric CAD/CAM resins (PMMA-based & Composite-based)	Investigated adhesion of PMMA- and composite-based CAD/CAM resins to luting cements with different conditioning methods (MH, VL, AM, VP, CG), tested with conventional (Variolink II) and self-adhesive (Clearfil SA Cement) luting cements after water storage and thermocycling.	Bond strength was significantly higher with MH, VL, and VP conditioning. Composite-based CAD/CAM materials exhibited higher bonding values than PMMA-based. Adhesive failures were common in unconditioned groups; cohesive failures seen with MH and VL. Aging (thermocycling) had no significant effect. Targeted selection of conditioning and luting cement is necessary for optimal bonding.

DISCUSSION

In Bangladesh, as awareness grows and access to technology improves, CAD/CAM is expected to become increasingly mainstream, particularly notable in the fabrication of crowns, bridges, and implant-supported fixed prostheses, thereby enhancing overall oral healthcare outcomes across the country.

CAD/CAM in Removable Prosthodontics:

Traditionally, removable partial dentures were fabricated using conventional techniques, with frameworks cast from cobalt-chromium (Co-Cr) alloys. However, the advent of CAD/CAM technology has revolutionized this approach. Now, impressions can be digitized either by scanning physical models or through direct intraoral scanning. This generates a 3D virtual design of the prosthesis that can be milled with high

precision. The accuracy of CAD/CAM-fabricated cast partial dentures is superior to that of conventional methods due to their enhanced adaptation to oral tissues and reduced human error during fabrication.

Additionally, CAD/CAM complete dentures are becoming increasingly popular. Studies have shown that digitally fabricated complete dentures demonstrate superior adaptation, uniform thickness, and reduced porosity, leading to better comfort and longevity. Al-Fouzan *et al*. (2017) demonstrated that CAD/CAM denture bases exhibited lower Candida albicans adhesion than conventional heat-cured bases, thereby reducing the risk of denture-related infections [15].

CAD/CAM in Fixed Prosthodontics:

Fixed prosthodontics has witnessed significant advancements through CAD/CAM technology. Systems like CEREC (Chairside Economical Restoration of Esthetic Ceramics) have enabled dental practitioners to produce highly accurate ceramic restorations in a single appointment. The process involves scanning the prepared tooth with a high-precision non-contact scanner, followed by milling of ceramic blocks using diamond burs. Subsequent porcelain layering and staining ensure an esthetically pleasing result [26,27].

Fasbinder (2012) highlighted that chairside CAD/CAM restorations provided better marginal integrity and reduced chair time, while Reich & Schierz (2014) reported that lithium disilicate ceramic crowns fabricated via CAD/CAM exhibited excellent long-term clinical success rates, with a four-year survival rate exceeding 95% [17,21].

Temporary (provisional) restorations can also be fabricated using CAD/CAM with materials like polymethyl methacrylate (PMMA) or bis-acryl composites. These provide improved esthetics and mechanical strength compared to conventionally fabricated provisionals, allowing clinicians to manage patient expectations and occlusion before delivering the final prosthesis.

CAD/CAM in Implant Prosthodontics:

The integration of CAD/CAM technology in implant prosthodontics has greatly simplified the design and fabrication of implant-supported restorations. The accuracy of CAD/CAM-fabricated implant components ensures excellent fit, reducing mechanical complications such as screw loosening or prosthetic misfit. Laboratory studies by Kapos & Evans (2014) confirmed the superior precision of CAD/CAM frameworks for implant restorations, attributing improved outcomes to the digital workflow and controlled milling processes.[18]

Pjetursson *et al*. (2018) further demonstrated through meta-analysis that implant-supported ceramic crowns fabricated by CAD/CAM exhibited high survival rates and fewer technical complications. Moreover, milling allows the use of durable, aesthetic materials like zirconia and high-performance polymers, further enhancing both functionality and appearance.

CAD/CAM in Surgical Guide Fabrication:

The conventional fabrication of surgical guides for implant placement involved multiple steps, including physical impressions, laboratory processing, and manual adjustments, leading to potential inaccuracies. With CAD/CAM, surgical guides are now designed directly from digital implant planning data, allowing precise transfer of virtual plans to the clinical setting.

Ahmed *et al*. (2019) demonstrated the feasibility of manufacturing surgical guides from stainless steel using CAD/CAM, ensuring improved implant positioning accuracy.[28] The reduction in logistic requirements and increased efficiency make CAD/CAM guides particularly advantageous in resource-constrained settings like Bangladesh, where centralized fabrication may not be feasible for all practices.

CAD/CAM in Maxillofacial Prosthodontics:

In maxillofacial prosthodontics, CAD/CAM has proven indispensable for fabricating facial prostheses, radiation shields, obturators, and customized implants for craniofacial reconstruction. Three-dimensional surface scanning allows precise reproduction of the patient's anatomy, leading to prostheses that are functionally superior and aesthetically indistinguishable from natural tissues.

Alghazzawi (2016) emphasized that CAD/CAM-enabled maxillofacial prostheses significantly improved patient outcomes compared to conventional methods.[11] Additionally, Ahmed *et al*. (2019) found that prostheses such as ears and noses fabricated via CAD/CAM were not only more anatomically accurate but also more predictable in terms of fit and color matching.[28] Furthermore, reconstruction of bone defects, particularly after tumor resections or trauma, can be effectively addressed through custom implants designed with CAD/CAM workflows, offering a new level of precision in maxillofacial surgery.

Expanding Applications of CAD/CAM in Dentistry:

Initially, CAD/CAM systems were primarily used to fabricate simple restorations like inlays, onlays, and single-unit crowns. However, advances in digital technology have allowed their integration across virtually every branch of dentistry, including orthodontics. The emergence of clear aligner therapy, popularized by companies like Invisalign, is one such example. These aligners, designed using CAD/CAM, offer a discreet, comfortable, and efficient method for orthodontic correction. CAD/CAM-fabricated clear aligners provided superior patient satisfaction due to

their esthetic and hygienic advantages over conventional fixed orthodontic appliances.[29]

Today, CAD/CAM technology in dentistry not only allows for faster production but also ensures the use of advanced biomaterials that possess both high strength and exceptional esthetic qualities. In Bangladesh, as awareness grows and access to technology improves, it is expected that CAD/CAM will become increasingly mainstream, improving oral healthcare outcomes across the country.[30]

Limitations

The present review has some limitations that are worth mentioning. First, the relatively small number of studies prevented. Only studies written in English were included in this analysis, and relevant literature in other languages was not considered.

CONCLUSION

The CAD/CAM system continue to improve in accuracy and versality as a part of routine dental practice in upcoming period. The CAD/CAM application can be used to facilitate the restoration of oral implants. The machined and evenly designed implant surface enhances the CAD/CAM performance. Precision of fit, durability, simplicity and aesthetic materials application are the main advantages of CAD/CAM in implant dentistry. Besides these crown, bridge and maxillofacial prostheses can be fabricated very precisely with the help of CAD/CAM technology.

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