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# Evolution of CAD/CAM Systems in Implant-Supported Full-Arch Prostheses

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**ABSTRACT**

Digital workflows using CAD/CAM technology have revolutionized the fabrication of implant-supported full-arch prostheses. This review traces the evolution of digital dentistry from conventional impressions to fully guided surgery and prosthesis manufacturing. Comparisons between subtractive and additive manufacturing methods are discussed in terms of precision, time efficiency, and clinical outcomes. Key metrics for evaluating accuracy, such as trueness, fit, and passive adaptation, are critically analyzed based on recent clinical studies. Challenges such as cost, learning curve, and integration with existing clinical systems are acknowledged. The review emphasizes the growing evidence that digital workflows can improve patient satisfaction and reduce chair side time.

***Keywords:*** CAD/CAM, digital dentistry, implant prostheses, full-arch restoration, workflow accuracy

## 1 Introduction

The increasing popularity of dental implant rehabilitation has increased the demand for dental implant treatments. This has driven the development of technologies aimed at improving the efficiency, simplicity, and predictability of the prosthetic rehabilitation procedure. The efficient transfer of the three-dimensional (3D) position of implants from the planning phase to the surgical phase has always been a considerable challenge [1]. Computer-aided design and manufacturing (CAD-CAM) technologies have emerged to facilitate this and change the traditional workflow of dental implant rehabilitation. Optical scanning and 3D printing technologies have revolutionized the way that the prosthetic components are fabricated [2].

CAD-CAM technology is a computer implementation of machine-aided design and manufacturing. In the field of prosthodontics, the advantages of CAD-CAM technology have been tremendously recognized and embraced by the mass, PLA and pro-vide a greater advantage through their ability to customize private designs. The increased availability of CAD-CAM technologies has expanded 3D dental visualization data from mainly descriptive data of 3D volume to designing data that describes complex assembly geometry [3].

As CAD-CAM technology further evolves, the design capability and digital data utilization for surgical implant planning tasks are expected to become more sophisticated and widely used, The advocacy of surgical implant planning software has opened a new chapter in the computerization of implant surgery [4]. Multiple vendors have marketed their software packages to the dental implant community, the emergence of these planning software packages has basically followed a "user-friendly" graphic interface philosophy akin to some of the widely adopted software of video games and schematic graphics [5]. Some dental implant manufacturers have established a digital workflow with a significant level of integration to facilitate the transferability of data among different components of computer-aided surgical implant planning and production [6]. With the advantage of "total solution," the digital workflow is thought to be the most efficient system, However, some dental implant manufacturers perceive the need to maintain a certain level of "openness." They believe that the market is vast and cannot be monopolized by a single vendor or implant house. The utilization of surgical planning software compatible with implants from a variety of manufacturers is considered a foremost criterion [7].

The aforementioned evolution of CAD-CAM technologies is remarkable, but it still remains less documented in dental literature, especially for full-arch rehabilitation. Nevertheless, the past decade has witnessed a dramatic evolution of technologies for the planning and placement of full-arch implant-supported prostheses in the field of prosthodontics. Today, prosthodontist can choose from among a variety of surgical systems, and each system has its own advantages and drawbacks [8].

## 2 Role of CAD/CAM in Dentistry

The CAD/CAM Chairside System is a special system in which the whole CAD and CAM system, including various machines, is installed in a dental office, hence, the dental office is considered a one-stop shop, the significance of the CAD/CAM chairside system is its ability to provide immediate restorations during the first appointment [9]. The CAD CAM chairside system was classified into two types according to its milling method: the wet type and the dry type, Wet-type systems use one diamond or carbide cutter and a water coolant to minimize the temperature in the grinding process [10]. Long-span bridges are difficult to fabricate with this approach because milling time increases drastically, conversely, the dry-type CAD/CAM milling system was developed in which final molds were fabricated using a diamond-cutting tool after the sample was pasted into a resin disc, full-arch implant-supported restorations can now be fabricated on-site in a relatively short period of time [11].

The use of CAD/CAM digital systems for prosthodontics has been widely introduced and practiced, a digital method was developed for the fabrication of complete-arch models and prostheses using CAD/CAM systems [12]. The implant position was scanned and matched to that of the existing case for simulating the new restoration, the model and prosthesis were then designed to be fit-perfectly with each other based on the modified guided bone regeneration technique [13]. CAD software for dental imaging was recently developed to facilitate a measurement of tooth surfaces using digital models obtained by optical scanning, integration of CAD software into prosthetic restoration design is useful for fabricating casts of a dental arch with teeth or dental implants [14]. To aggregate individualized parameters based on computer tomography imaging, model-based restoration design and STL conversion, CAD/CAM was utilized to model and manufacture a dental prosthesis for replacing a missing tooth. Combining 3D printing and CAD/CAM systems simplifies the manufacturing of patient-specific surgical templates, but only has limited applications [15].

CAD and CAM technologies have been used in dentistry for about four decades. Various CAD and CAM systems have been introduced and have matured. Digital workflows have been developed and concepts that use the technologies have expanded [16]. CAD/CAM systems are widely used in chairside systems for intraoral scanning, block cutting systems, and processing of other materials. Indirect restorations such as laminate veneers, inlays, and crowns can be designed with the systems, and blocks of ceramics, resin, hybrid, gold, and metal are milled or cut. Intraoral scanners have become widely used in many clinics, and various ways of lecturing and communicating with dental laboratories have been developed [17].

## 3 Impact on Prosthodontics

The applied technologies allow for a more efficient workflow, in addition to greater precision and accuracy in the fabrication of the prostheses and final restorations, the appeal has spurred increased interest in these technologies from different stakeholders, including clinicians, dental laboratories, and dental schooling.[18]. CAD/CAM technology has enabled complete digital flow management using a combination of cone beam computed tomography (CBCT), CAD software, CAD/CAM milling and 3D printing devices, and CAM programming solutions [19].

CBCT is used for the diagnosis and decision-making of implant treatment, with the digital studies containing the virtual treatment plan of the prosthesis, together with the related implant and surgical guide considerations [20]. A detailed step-by-step description of the protocols for a digital flow using CAD/CAM systems in preset and fully adjustable jaw registrations is presented. Difficult partial, segmental, and full-arch rehabilitation treatment using dental implants, performed on totally edentulous maxillae and mandibles, is illustrated in a clinical case documented [21]. Pre- and post-operative clinical images, clinical photographs, and final long-term follow-up clinical radiographs of the restorations, and their peri-implant soft and hard tissue changes are presented, fully digital and CAD/CAM-based rehabilitation protocols with good esthetic and functional results were obtained [22].

## 4 Advancements in Digital Imaging

As the first step, radiograph and 3D CT images of maxilla or mandible are taken by applying occlusion plates and special transfer jig during the impression-taking procedure. Then, the occlusion jig is scanned using a laboratory scanner for matching the record bases of the upper and lower arches or the maxilla and mandible [23]. The 3D mandible and maxilla scans are imported into imaging software to select implant locations, initiate guide design, and assess the feasibility of implant placement, The guide design, containing pathways and key holes, is exported as a standard triangulated language file, which is later converted into stereo lithography file and 3D printed [24].

In the first stage, the printed guide is converted into an artificial bone model by double casting with polycaprolactone copolymer and polysulfone. For the implant installation, drilling is performed using drill sleeves mounted at the desired angulation by the guide to support the reference edge, these steps are performed using an industrial robot in conjunction with smart software that guides and adjusts the drilling angle and path in real time so that the axial drilling angles are minimized [25].

CAD-CAM technology has contributed tremendously to the preliminary stages of dental implant treatment in some dental and implant companies since the late 1980s, in recent years, the performance of CAD-CAM surgical guide design software has been further enhanced to fabricate an individual stereolithographic surgical guide for implant placement [26]. The development of CAD-CAM technology has overcome many of the drawbacks of existing implant treatment modalities (rapid, high-accuracy, and easy production), integration of CAD-CAM technologies with rapid prototyping methods has made surgical guide fabrication possible for dental implant placement[27]. CAD-CAM surgical guides are popular because they provide the advantages of implant treatment such as patient comfort, ease of use, rapid surgery, minimized healing time, and greater accuracy in implant position and orientation[28].

The aim of this article is to present the importance of CAD-CAM systems applied for implant rehabilitation and the clinical details of the investigation of CAD-CAM systems. In 1989, a fully automated and computer-controlled wax pattern manufacturing method for casting gold dental restorations was first applied to CAD-CAM technology. Various mechanical devices have also been developed to mill dental prostheses. Using the milling technique, implant support custom abutments were introduced to the clinical realm. CAD-CAM technology, which has widely replaced conventional laboratory techniques for developing implant-support custom abutments, was investigated.

## 5. Clinical Applications

CAD-CAM is a rapid engineering technology that can fabricate intelligent structures and processes using computerized systems. CAD-CAM products and systems are manufactured and processed in such a manner as to acquire the data by computerized systems [29].

New CAD-CAM systems are developed and marketed on a regular basis for a variety of applications, a range of procedures can also be conducted with devices that were manufactured and designed for other purposes, for example, in orthodontics and implantology, computerized very high-speed industrial machining systems are used for the fabrication and processing of orthodontic aligners and surgical templates, respectively[30].

In the situation of the edentulous arches replacing a full dentition with a CAD-CAM-milled prosthesis, the primary goals in treatment planning are to determine the ideal arch position, facilitate tooth selection, and ideally also aid in the clinical verification of achieved position [31]. To achieve these treatment-planning goals, it is paramount to build an accurate record base for the edentulous arches being rehabilitated, complete-arch records of the first visit are obtained using a modified impression tray to capture bone markings from the previous denture, followed by accurate mounting in a semi-adjustable articulator. From this located and articulated record, tooth position and selection are determined [32].

## 6. Accuracy in Digital Workflows

Digital implant impression involves the identification of the scan body implant position using an intraoral scan (IOS), IOS accuracy depends on many variables: scan body diagnosis and geometry, intraoral scanner device, total scan time, scanning strategy, and the performance of CAD software[33]. For open cap dental implant impressions, IOSs would improve the precision of digital impressions compared to polyether impressions, for CNC techniques, scan bodies should be manufactured with non-light-diffusing materials such as titanium and with a specific number of orientation holes to improve and stabilize accuracy[34].

## 7. Factors Affecting Accuracy

In addition to the prosthesis design, the accuracy of the CAD/CAM system is based on multiple factors including the accuracy of scan body assemblies and geometry, software, and STL data processing 8; 7, on the scan body assembly side, the screw-retained metal scan body had lower accuracy than a 3D printed design with one or 3D printed scan bodies assembly types but can be combined with single-unit prostheses, whereas cylindrical and triangular scan body designs had better results than a spherical design, due to the higher stability and repeatability[35]. The CAD system also contributes to the accuracy outcome. So the choice of the CAD software is important with Dunn software but Bevery gelatinous demonstrated better performance compared to other abnormal or head forms baseball geometries as well [36].

Moreover, the STL data including tesseral precision, decimation, errors/overlap in subareas and curves/surfaces processing during STL slicing had an impact on prosthesis accuracy, the processing data are crucial because even two STL files from the same scanner with the same processing settings produce different accuracy outcomes [37].

## 8. Comparative Analysis of Traditional vs. Digital Techniques

Implant-supported full-arch prostheses (FAP) have become a standard rehabilitative treatment modality in the edentulous arch, especially due to their high survival rates. This gold-standard workflow for FAP fabrication combines established techniques of conventional transfer and mechanical index fabrication that have been employed in various approaches, including bone-anchored, anterior, and complete-arch hybrid dentures [38]. The major goal of the iterative CAD/CAM systems and processes is to develop a control system that leads to minimized processing time, suits open-architecture workstations commonly adapted in other digital workflows, and simplifies operability [39].

Despite the insignificant overall differences in the clinical outcomes between the groups, present evidence indicates that the entirety based on CAD/CAM technique would still increase the anomaly of denture base lab occlusion more than the implant-supported FAP. Though the clinical outcomes were assessed for a short-term (1 week after the denture delivery), manual smoothing of hyperocclusion regions would be settled down as a maintenance procedure [40].

The values of better digitized and relatively tightened design of provisional prosthesis were proven in trade-off with the necessity of mechanical adjustments and times with conclusion applicability, the second aims to investigate the effect of dentist-independent factors on CAD/CAM denture delivery procedure duration [41]. It would thus consider important factors on the procedure duration as elapsed processing time, denture delivery and opening, and FAP recovery estimate times on their times delivered wrench outputs or expected/reduced quality levels, if machine-dependent outputs, which are quantitative, would always affect the maximum time of the delivery procedure, the aforementioned quality-affected indirect factors would exhibit different paces on the procedure times within distinct time ranges [42].

## 9. Time Efficiency

The precise timing of restorative treatment conditions is important for patients who need implant-supported full-arch prosthodontics. Usually, the majority of patients need to manage professional, vocational, and personal affairs during treatment after tooth extraction. It often takes three to nine months before the final restoration is delivered. Newly developed digital treatment conditions have prioritized sending patient data to the external dental laboratory right after screening and surgery [43]. This transformation in workflow essentially shortens the treatment time for fabricating restorations after screening/surgery, thus, this workflow is widely used in practices as online order systems are now easy and convenient to use, however, there is still a dilemma that implant-based fast-track treatment methods use an alternative workflow where artificial intelligence software is designed to replicate all procedures for fixed-edentulous prostheses, which require digital equipment and only a specific dental laboratory for data transfer[44]. The denture pose modeling and design fabrication are automated and sealed in only a compatible file format before communicating the data with the external dentist[43].

Time consumption, which is now well-established for assessing the CAD/CAM system workflow, is determined by the actions of the procedure, most procedures are post-processing, and design or modeling processes are the most time-consuming steps in the 11 procedures considered in the CAD/CAM systems [45].

### *9.1 Case Studies*

Dental implant treatment aims to restore aesthetic and functional harmony by replacing missing teeth with osseointegrated implants. It is a technique-sensitive procedure that has undergone remarkable technological evolution over the years. Clinical applications have also transformed, leading to predictable and straightforward therapeutic approaches. This article's aim is to document the technological evolution of computer-aided design/computer-aided manufacturing (CAD/CAM) system application for the rehabilitation of edentulous jaws with implant-supported full-arch prostheses.

The CAD/CAM process begins when a patient is referred to a specialist after initial clinical examination and radiological investigation. Before the workflow's initiation, conventional components such as fixtures and abutments are selected, and a prosthetic record with jaw relations is performed. Afterward, prosthetic setup is accomplished in the CAD software, generating the anatomical reference and the guidance and visualization planes required for the following steps. Once designed, a pre-surgical template for the bone preparation and an initial position template for the fixtures are printed. The pre-surgical template has designed sleeves, which can be covered with a surgical guide resin or fixed to a surgical plate with holes for anchoring screws.

Surgical navigation based on post-processed Cone-Beam Computed Tomography (CBCT) files allows the identification of desired anatomical points of interest for fixture position definition. Using a navigation implant associated with optical CAM equipment, drill penetration at shorter or wider positions than the pre-established ones can lead to inadequate final restoration, even if it remains fixed at the desired initial position. It should also be noted that any adjustment is required in the implant to avoid over-insertion and delayed final incorporation or periapical infection, leading to restoration failure. To address these issues, the prototype must go through a new iterative step of computer-aided design (CAD) files generation, acceptance testing on the dental casts, and manufacturing, which, depending on the prototype complexity and size, can easily take several hours to multiple days.

## 10.Successful Implementations

Literature has shown varied evolution of CAD/CAM systems for full arch implant-supported prosthesis. Most publications describe potential of myriad CAD/CAM systems catering limited situational conditions, few clinical reports of successful implementation have been published in past three years, providing usefulness to clinicians and researchers, varied situations with comorbidities, such as dentate to edentulous in one stage treatment with failing upper anterior teeth, dentate to edentulous in multiple stages with failing acceptable upper anterior teeth, and partial rehabilitation with missing posterior teeth, had been demonstrated successfully[46].

Limitations for success and recommendations to overcome have been disclosed for each situation, which can aid clinicians in complex cases. Full mouth reconstruction cases wherein the condition was edentulous and treated with Four-implant supported fixed prosthesis with surgical guide produced in Erkoform 3D were recorded. Stepwise treatment would be denotation of complex case wherein existing procedure not reported for CAD/CAM scaffold fabrication or prostheses fabrication. Since the treatment involved one stage surgery with guide, full dentate cases were avoided, reporting without prior stratification of occlusion and aesthetics [47].

The guiding principle continues to keep abutments in a lingual position for aesthetics and lateral-thrust in groups at second molar area, with standard prostheses fabricated with CADCAM on a milled abutment, however, the cases were prosthesis-centric, involving non-traditional use of treatment planning and digital design and fabrication phases of CADCAM guided workflows [48].

Digital planning was conventional surgical prosthesis planning or placement over fabricated models referring impression-based occlusion with correct DentaView assessment. Inclusion of contour data improved cross-arch definition, allowing prosthesis positioning with regard to soft-tissue profile. Semi-limited abutment inclusion effectively improved transitional CADCAM output definition, with wider final-position facet and retouches minimised. Whole-arch transition as a scanned workflow was omitted to demonstrate step-wise panoramic planning from an existing prosthesis to differ from available reports [49].

Understanding the evolution of individual equipment is crucial for understanding how the system evolved. In the 1960s, the need for compromise in shape and form for production has led to the initial development of large machines to manufacture models from which molds were produced, this reduced production time and costs and brought with it enhanced accuracy and implications for identified reasons high quality restorations were produced[50]. Intra-oral scan technologies were already commercially available for Rapid Prototyping Manufacturing as early as the 1990s and the complete CAD-CAM system for digital impressions and 3D modelling was now established. With such far more rapid production the design shifted towards the work being easier for dental technicians. There were still some limitations on the process, as the units produced were enlarged and stacks of models were still produced. Realization of the potential for CAD-CAM guided Surgery had been developing. However, the reproduction of a perfect replica for planning CAD-CAM guided systems needed to be fully established as an equipment upgrade [51].

## 11. Future Directions in CAD/CAM Technology

CAD/CAM technology is widely used for the production of prostheses, from single crowns to complete dentures. The process of CAD/CAM restoration involves acquiring an optical impression of the edentulous arch, which excludes nontemporal construction [52].

Future developments of CAD/CAM implant prosthesis systems should focus on three areas: promoting technical and clinical performance, such as providing multiple restoration types; increasing ease of use, such as improving data output and software compatibility for different products; and finding new materials, such as developing biocompatible materials for abutments or 3D printer resins with similar physical properties to PMMA. Since the introduction of dental CAD/CAM systems into dentistry, their applications have been expanding rapidly [53].

With various scanning techniques based on optical and laser technology, it has become easier to acquire precise digital dental cast models. CAD has also improved significantly due to the growth of high-performance computer techniques, software, and graphic interface. Today, the use of CAD drastically reduces the working time for designing restorations. In the CAM stage, thanks to advances in high-speed spindle motors and efficient motor control systems, furnaces for sintering CGMs or ceramics are widely used, with a great reduction in finishing and fabrication time [54]. The accessibility to information processing equipment, including personal computers, is universal.

CAD/CAM systems are being used not only for single-unit prostheses but also for complex framework fabrication. Introductory systems applicable only for simple restorations have greatly diversified, with many systems able to download and process more intricate data and allow the design of three-dimensional databases. CAD/CAM technologies are actively being used in the restorative area, such as for full contour crowns to customized abutments. Recently, these technologies have been expanded to implant-supported prostheses. With the introduction of intraoral scanning devices, it is possible to obtain digital impressions of the hard and soft tissue of edentulous arches. 3D printers producing smooth and highly precise models have been developed [55].

### *11.1 Regulatory and Ethical Considerations*

The growth in popularity of CAD/CAM technology and the ethical issues of its use at the manufacturing level necessitate a similar consideration in the application of this technology in the market. Use of the Split-Face Approach by a limited number of highly trained prosthodontists and the rise of ultra-low-cost off-shores CAD/CAM prosthesis burning into the market signal a need for caution and vigilance to maintain the safety of the public and fairness for the providers of CAD/CAM prostheses.

Some CAD/CAM prostheses produced by delegated design are so low-cost that it is impossible for local lab techs to compete. This raises issues to be resolved and guidelines to lessen the problem of offshore prostheses for the public. Different dimensions of unethical offshore prostheses include the quality of scanning and capturing the geometry of the virtual cast, design and fit of the final prosthesis and their ethics regarding the laws of where they serve or they are originated. A limit on the degree of design complexity to control flip prostheses and opportunities for difficult to design intensive local cases. Several different design and fabrication functions to be developed into a select group and used to produce designs agreed upon by dentists and lab techs. Collaboration between universities on both sides to monitor design production, solve any control issues, maintain affordable option for both the public and providers. The standard of care for CAD/CAM production must be delineated for what is acceptable scanning, and design capabilities should be listed. Off-shore design companies should be aware that if something seems too good to be true, it probably isn't. Dentists and their patients should be aware that outsourcing CAD/CAM design and fabrication into low labour cost countries is not lower cost but rather a worthy case of caveat emptor.

Finally, a necessary education program should be established to tip off dentists to the problems with offshore prostheses and how to simply determine and spot if there is a problem before loose or failed fit or fracture occurs. Attention to these issues should help inform the scientific community on the impact of CAD/CAM systems on implant supported full arch prosthesis, so the profession is ready to move forward as it becomes more commonplace [56].

## 12. Compliance with Standards

With the recognition of the importance of standardizing and regulating the design and manufacture of denture bases, denture teeth, and fixed detachable prostheses by governments and nondentist professionals, international standard organizations preceded the dentistry-related standard movements. Clinical societies have published guidelines to regulate and control the design and manufacture of denture bases and denture teeth. Narrow and strict criteria on anatomies of denture bases and occlusion of denture teeth, as well as indications and specifications of blocks and designs, are required in commercial software. In this setting, the conventional denture base and denture tooth designs may have to comply with computer commands; then, patented teeth production methods may be translated into non-designed denture base and denture tooth blanks.

The blindness of hardware availability in computer controls and automatic mills has left dental designers increasing concern that implant-supported prostheses produced in this way may not comply with the original specifications, especially porous and manipulated nonmetal prostheses produced in fixed detachment chambers. Impediments to provide proof and evidence of consistency distance from denture base to supported implants in a floor denture setting ally shape, distance, and manipulation domains induce doubts of compliance to original requirements. Requirements on the compliance of denture bases, denture teeth, and fixed-detachable prostheses must be addressed to governmental organizations, general public organizations, and clinical societies for the patient's right and interests as well as public hygiene and health [57].

**TABLE 1.** Evolution of Digital Workflows in Implant-Supported Prosthodontics: Key Technologies, Milestones, and Clinical Outcomes (1980s–2020)

| Phase | Period | Key Technologies/Systems | Milestones | Clinical Outcomes |
|---|---|---|---|---|
| Analog to Early Digital | 1980s–1990s | First dental CAD/CAM (Duret, CEREC); milled alumina copings | First CAD/CAM-fabricated crown/inlay (1983–1985) | |
| Reddit.com+11pmc.ncbi.nlm.nih.gov+11pmc.ncbi.nlm.nih.gov+11 | | | | |
| en.wikipedia.org | | | | |
| pmc.ncbi.nlm.nih.gov+2link.springer.com+2cdeworld.com+2 | | | | |
| | Established feasibility in single-unit applications | | | |
| Robot-Milled Frameworks | Late 1990s–2000s | Robotically milled titanium bars; Brånemark Novum protocol | Introduction of "teeth in a day" immediate-load and prefabricated bars for full-arch | 11-year study showed 100 % implant and prosthesis survival |

| | | | | |
|---|---|---|---|---|
| | | | support | |
| Integrated CAD/CAM Workflow | 2005–2012 | Procera/DTX Studio, Atlantis, inLab MC X5, ZirkonZahn systems | Complete digital – scan, CAD, CAM – for full-arch prostheses; virtual articulator introduction | Better fit, reduced porosity vs lost-wax, improved accuracy for larger frameworks |
| Chairside & Chairside-Lab Hybrids | 2013–2016 | Affordable wet-milling systems, intraoral scanners (IOS), CBCT integration | Integration: CBCT + IOS + virtual planning + in-office provisional fabrication | Chairside titanium abutments accurate within 25–30 µm; faster turnaround, lower distortion |
| Clinical Demonstrations | 2016–2020 | Digital-planned milled frameworks, software (NobleClinician, Exocad), photogrammetry | Retrospective and prospective full-arm studies using IOS-based frameworks | 4-year implant survival 99.1 %, prosthesis success 100 %, marginal bone loss ±1.1 mm, minimal adjustments |

With the collaborative designs debated, more comprehensive clinical guidelines have to be published with respect to the matched regulations. More arduous protocols and methodologies may be required to control the situations that animate teeth engagement, lips, tongue contours, filled faces, and jaw movements are devised but are out of range due to variants in teeth location sawing angle and supported tissues. The negotiation framework, where patient-specific and viewer-specific components are computed and collaboratively refined, may be an alternative measure to guarantee the rights for both patients and dental professionals; it can design denture bodies shaped and styled in their unique way by assigning small sizes to there and changing distances, positions, and locations for removement and adjustment. Each training institution that can afford beacons may share a newly trained designer that is supplied with only the protocols, the geometry, and the viewer [58].

## 13. Conclusion

The introduction of computer-aided design and computer-aided manufacturing (CAD/CAM) technology has posed a challenge to manufacturers of analog devices. Shortening lead times is one of the difficulties facing conventional systems. CAD/CAM systems take almost an hour to scan an analog record. This doesn't even include preparations, calculations, and finishing time. The challenge is to reduce production time to several minutes so that milling can be immediately undertaken after scanning 14. These systems are machined faster than commercial products. Of the benchmarks, the fastest design time is only 627 seconds without quality degradation, while the time consumption for the longest-part lies within reasonable limits. For irregular parts, the latest algorithm and high-computing cluster have pushed the time consumption to meet expectations. With respect to fast CAD/CAM systems for irregular HM parts, limitations invariably exist. Geometric accuracy and finishing residuals are difficult to satisfy. Generating a CAM process to prevent database reading time overhead is also challenging. However, these topics are easily answered by miniaturized auxiliary modules.

Despite their speed, the fast algorithms give relatively lower geometric accuracy and periodic finishing points non-uniformly distributed on the inner wall. Due to the streamlined surface, dual-band milling endow an inner circular tool path and an outer/spherical tool path, while the former is sensitive to slanting walls. A slower and more accurate slicing algorithm would bend at high robustness. Thus, precision control is invoked with an industrial-grade benchmarking. If interiorized for industrial mass production, these systems can substantially shorten the lead time and reduce user-costs. Moreover, the customization alloy permits easy processing of multicore, single-layer, or multilayer fabrication that would be hard to fabricate with other methods. The competitiveness of CAD/CAM will be strengthened against the prevailing metal framework, as it is designed primarily for the rapid production of individual or small production series parts. Currently, it focuses more on mass-production systems than stand-alone machines for local solutions to meet individual requirements.

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