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Digital Transformation in Complete Denture Production: CAD/CAM Complete Dentures

Tam Protez Üretiminde Dijital Dönüşüm: CAD/CAM Tam Protezler

Fulya KARADUMAN ÇİMEN
Şeyma Nur TEZCAN
Funda BAYINDIR
Atatürk University, Faculty of Dentistry, Department of Prosthetic Dentistry, Erzurum, Türkiye

ABSTRACT

The integration of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) systems into dentistry has profoundly transformed the fabrication processes of prosthetic devices. Specifically, in the context of complete denture applications, this advanced technology offers significantly greater precision, efficiency, and reproducibility compared to traditional manual methods. One of the primary advantages of CAD/CAM systems in the production of complete dentures lies in their ability to enhance the aesthetic, functional, and biomechanical properties of the prosthesis. Furthermore, CAD/CAM systems enable the standardization of production, minimizing the variability inherent in traditional techniques, which often depend on the expertise and skill level of individual technicians. This ensures that patients consistently receive high-quality and precisely manufactured prostheses. The benefits of CAD/CAM technology—such as improved accuracy, expedited workflows, and enhanced patient comfort—have facilitated its growing adoption in routine dental practice. As the technology becomes more accessible and cost-effective, its widespread implementation in dentistry is anticipated. This technological shift has also spurred an increasing number of studies investigating the use of CAD/CAM systems for complete denture fabrication. A comprehensive review of the literature was conducted using PubMed and Web of Science databases, employing search terms such as "CAD/CAM complete denture," "acrylic resin denture base," "denture base," "complete denture," "denture flasking," and "intraoral scanning." Articles and materials available in full text in both English and Turkish were included in the analysis. This review aims to provide an in-depth overview of production systems and critically examine the current literature on the use of CAD/CAM technology in the fabrication of complete dentures.

Keywords: CAD/CAM, complete denture, denture base

ÖZ

Bilgisayar Destekli Tasarım ve Bilgisayar Destekli Üretim (CAD/CAM) sistemlerinin diş hekimliğine entegrasyonu, protez cihazlarının üretim süreçlerini derinden dönüştürmüştür. Özellikle tam protez uygulamaları anlamında, bu gelişmiş teknoloji, geleneksel manuel yöntemlere kıyasla çok daha yüksek hassasiyet, verimlilik ve tekrarlanabilirlik sunmaktadır. CAD/CAM sistemlerinin tam protez üretimindeki en önemli avantajlarından biri, protezlerin estetik, fonksiyonel ve biyomekanik özelliklerini iyileştirme yetenekleridir. Ayrıca, CAD/CAM sistemleri üretim standardizasyonunu mümkün kılarak, genellikle bireysel teknisyenlerin uzmanlık ve beceri düzeyine bağlı olan geleneksel tekniklerdeki değişkenliği minimize eder. Bu, hastaların sürekli olarak yüksek kaliteli ve hassas bir şekilde üretilmiş protezler almasını sağlar. CAD/CAM teknolojisinin avantajları daha yüksek doğruluk, hızlandırılmış iş akışları ve artırılmış hasta konforu gibi günlük diş hekimliği pratiğinde giderek daha fazla kabul edilmesine olanak sağlamıştır. Teknolojinin daha erişilebilir ve maliyet etkin hale gelmesiyle, diş hekimliğinde yaygın olarak uygulanması beklenmektedir. Bu teknolojik dönüşüm, ayrıca tam protez üretiminde CAD/CAM sistemlerinin kullanımını araştıran artan sayıda çalışmaya ilham vermiştir. PubMed ve Web of Science veri tabanları kullanılarak yapılan kapsamlı bir literatür taraması, "CAD/CAM tam protez", "akrilik reçine protez kaidesi", "protez kaidesi", "tam protez" ve "ağız içi tarama" gibi arama terimleriyle gerçekleştirilmiştir. Tam metin erişimi olan İngilizce ve Türkçe makaleler ve materyaller analizde dahil edilmiştir. Bu inceleme, üretim sistemlerine dair derinlemesine bir genel bakış sunmayı ve tam protez üretiminde CAD/CAM teknolojisinin kullanımına dair mevcut literatürü eleştirel bir şekilde incelemeyi amaçlamaktadır.

Anahtar Kelimeler: CAD/CAM, tam protez, protez Kaidesi

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Sorumlu Yazar/Corresponding author: Fulya KARADUMAN ÇİMEN
E-mail: flykaradu@gmail.com

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Introduction

While complete edentulism is commonly attributed to periodontal problems or dental caries, it is actually the result of a combination of disease and non-disease factors. Individual biological structures and unique characteristics also significantly influence this process (Felton, 2009).

Despite advances in treatment options, the demand for complete dentures is expected to gradually increase due to the growing elderly population and longer life expectancy, even in developed countries where edentulism rates are declining (Polzer et al., 2010; Gökalp et al., 2007). A study of prosthetic treatment for geriatric patients showed that 2,863 people received complete dentures, representing 10.20% of all patients treated in the prosthodontic clinic. It is worth noting that this research was carried out during the COVID-19 pandemic, when there was a decrease in the need for treatment in the elderly population (Çakar Güler & Bayındır, 2023).

According to TurkStat data for 2023, the elderly population aged 65 and over increased by 21.4% in the last five years, from 7 million 186 thousand 204 people in 2018 to 8 million 722 thousand 806 people in 2023. The share of the elderly population in the total population will increase from 8.8% in 2018 to 10.2% in 2023 (TÜİK, 2024).

At the beginning of the 18th century, as a result of scientific studies led by Pierre Fauchard in France, complete prostheses began to develop in the modern sense, having previously been made using very simple and experimental methods (Çalıkkocaoğlu, 2004).

Technological innovations in the field of dentistry since the 18th century, together with today's rapid technological advances, have made dentistry a profession integrated with modern systems such as computer-aided design (CAD) and computer-aided manufacturing (CAM), while still maintaining traditional approaches (Gökalp et al., 2007).

Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) are technologies that streamline the design and production of dental restorations. CAD involves creating three-dimensional models in a virtual environment using templates, whereas CAM utilizes measured data for manufacturing (Rekow, 2006).

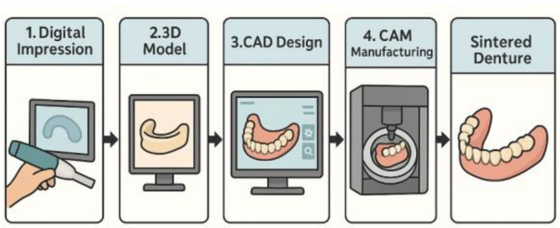

Figure 1.
CAD/CAM total denture workflow

The application of CAD/CAM technology for complete dentures began with Maeda et al. in 1994 but only gained popularity after Goodacre et al.'s clinical study two decades later. This technology is now widely used for various dental applications, including crowns, bridges, and complete /partial dentures. Complex fabrication procedures have delayed the adoption of digital technologies in complete dentures; however, ongoing advancements are expected to simplify these processes (Vozzo et al., 2023; Soegiantho et al., 2023).

Notable pioneers in dental CAD/CAM systems include Dr. Duret, who developed an early system involving optical impressions and milling; Dr. Moermann with the CEREC® system for same-day ceramic restorations; and Dr. Andersson who integrated CAD/CAM into titanium coping production (Çelik et al., 2013; Miyazaki et al., 2009; van Noort, 2012).

While CAD/CAM systems primarily focus on fixed prostheses, recent developments address challenges in producing complete dentures by introducing commercial software solutions that allow easier design processes (Inokoshi et al., 2012). Effective use of these systems typically consists of three main components: scanners (for data collection), design software (for creating digital models), and hardware (computer-controlled milling machines) (Tinschert et al., 2004). Manufacturing methods within CAM include subtractive processes like CNC machining and additive techniques such as 3D printing, which layer material to create desired shapes (Bidra et al., 2013). Generally, completing prostheses through CAD/CAM requires 2-4 sessions depending on the specific system used (Smith et al., 2021).

Minimization Methods

In the subtractive process, the base material is produced from a pre-polymerised resin disc called a 'puck'. This disc is obtained by processing under high pressure and temperature, which can result in better hygienic and mechanical properties (Steinmassl et al., 2017). Figure 2 (Ivoclar, 2025).

Figure 2.

Base milled from prepolymerized block

In complete dentures made by milling from prepolymerised PMMA discs, polymerisation shrinkage is almost non-existent and the volumetric changes that occur during milling are negligible (de Mendonça et al., 2016; Infante et al., 2014). This results in better tissue compatibility of the denture bases and a more balanced occlusion (Infante et al., 2014; Kattadiyil et al., 2015).

Increasing the number of axes on a milling machine allows for a higher capacity in prosthesis production. However, the cost of the machines increases as the number of axes increases (Abduo et al., 2014). Complex shapes such as denture bases are produced using five-axis milling systems (Kanazawa et al., 2011). Recently, systems have been developed where the denture base and artificial teeth are milled from a single disk. Examples include AvaDent Digital Dentures XCL1 and XCL-2, Baltic Denture System (Merz Dental, Germany) and Ivoclar Vivadent Ivotion (Anadioti et al., 2020). One of the major disadvantages of the subtractive method is that a large portion of the milled block is discarded unused. Another difficulty is the production of teeth that are often monochromatic and aesthetically unsatisfactory (AvaDent Digital Dentures, 2025).

The fact that the additive process produces a large amount of waste has been one of the main motivations for the development of 3D printer technology (additive manufacturing). Additive methods have reduced both cost and waste by using less material (Choi & Cheung, 2005).

3D models are stored in Standard Transformation Language (STL) format before being sent to printers. The STL format is a file format used to represent the surface of a 3D designed model. Using this format, 3D printers produce physical objects by adding material layer by layer (Beuer & Edelhoff, 2008). The thickness and orientation of each layer is critical to the properties of the final model (van Noort, 2012). For 3D printed prostheses, after the printing process is complete, a final curing step is applied to light cure the unpolymerised resins. This step can present a theoretical problem of polymerization shrinkage if the resin is not fully polymerized. A partially polymerized prosthesis is at risk of deformation when removed from the platform. Depending on the additive manufacturing process, prostheses can also develop surface distortion, often referred to as the "staircase effect" (Barazanchi et al., 2017). In 2010, One Denture, founded by Dr Tae Kim, was one of the first companies to offer a CAD/CAM workflow for complete denture fabrication. The company was later renamed Dentca (Dentures from California) (Schweiger et al., 2018). Since then, many different companies have entered the industry offering complete denture fabrication using both additive and subtractive methods (Wagner & Kreyer, 2021). Stereo lithography is used to produce resin-based structures such as prostheses and surgical guide plates, as well as wax moulds, removable prosthetic frameworks and temporary restorations (Emami et al., 2013; Astrøm et al., 2006).

The digital prosthetic manufacturing process consists of scanning the final impressions or the plaster model obtained, recording the maxillomandibular relationship, designing the prosthetic base and artificial teeth in the software program, and finally manufacturing the prosthesis using additive/subtractive methods. This digital process helps to reduce the time spent at the bedside and the duration of appointments (Wang et al., 2021).

AvaDent®

AvaDent® (Global Dental Science LLC, Scottsdale, AZ) offers advanced digital denture fabrication using milling and 3D printing for provisional dentures, with final dentures produced through a subtractive milling method. Two final denture options are available: traditional complete dentures with artificial teeth attached to a milled base or monolithic AvaDent® XCL dentures, where the base and teeth form a single unit. The monolithic option comes in two types: XCL-1 with monochromatic artificial teeth and XCL-2 with polychromatic teeth for a more natural appearance. AvaDent dentures can be completed in three appointments. In the first appointment, measurements are obtained using one of four techniques: the reference prosthesis technique, the AvaDent-Wagner EZ guide protocol, intraoral scanning, or traditional impressions (Baba et al., 2021). The second appointment involves testing provisional dentures for phonetics, aesthetics, and function, with options including Wagner EZ guides, milled white provisional prostheses, advanced try-in dentures (ATI), or printed resin monochromatic dentures. Figure 3 (AvaDent Digital Dentures, 2025).

Figure 3.

Wagner Try-In

Any adjustments made to the provisional dentures are rescanned and incorporated into the final denture (Figure 4) (AvaDent Digital Dentures, 2025).

Figure 4.

Bouma Try-In

In the third appointment, the fit of the CAD/CAM-fabricated denture is verified using tools like Fit Checker™ or pressure indicators, and any necessary occlusal or intraoral adjustments are completed to ensure optimal fit and comfort (Steinmassl et al., 2017).

The Ivoclar Digital Denture™

The Ivoclar Digital Denture™ system, developed by Ivoclar Vivadent, represents a sophisticated approach to prosthetic dentistry, integrating modern technology with established clinical practices to produce both removable and provisional dentures. Utilizing either a three- or four-appointment workflow allows for flexibility based upon individual clinical parameters and practitioner preferences. In the three-appointment protocol, the initial appointment focuses on obtaining comprehensive clinical records through various methodologies such as edge shaping of existing dentures or utilizing polyvinyl siloxane for accurate impressions and centric relationship documentation. Following this data acquisition, provisional prostheses are fabricated via additive or subtractive techniques in the laboratory.

During the second appointment, these provisional restorations undergo meticulous evaluation against critical criteria including retention, stability, phonetics, aesthetic considerations, occlusal vertical dimension (OVD), and occlusal plane alignment. Adjustments may necessitate new impressions using wash techniques to refine fit before transitioning to final denture design options. The system offers two distinct choices: one involves milling a base from prepolymerized PMMA bonded with double cross-linked artificial teeth; the other entails crafting a monolithic prosthesis from a dual-colored disc that optimizes material properties for functional efficacy (Baba et al., 2021).

In contrast, the four-appointment workflow initiates with detailed impression-taking complemented by measurements of facial landmarks using specialized tools like papilla-meters and CAD devices. Subsequent visits involve refining impressions and assessing patient-specific parameters such as lip support and incisal edge position before finalizing designs in collaboration with advanced digital modeling software. The systematic approach culminates in thorough evaluations of provisional restorations to ensure satisfactory function prior to fabricating definitive prostheses tailored to patient needs.

Ultimately, both workflows emphasize precision through digital integration while adhering closely to traditional denture fitting protocols post-fabrication—underscoring Ivoclar Vivadent's commitment to improving patient outcomes through innovative dental solutions that enhance both practice efficiency and restorative success rates in edentulous patients (Baba et al., 2021; Goodacre, & Goodacre, 2018; Çalıkkocaoğlu, 2010; Ivoclar, 2025).

Figure 5.
Tooth and gingiva material in a single monolithic disc, suitable for permanent complete dentures

Dentca™

Dentca™ (Dentca Inc., Los Angeles, CA) is the first company to produce FDA-approved 3D printable materials for teeth and gums, using additive manufacturing to create recessed denture bases to which artificial teeth are bonded prior to post-curing with the same resin material. The system supports the fabrication of complete, partial, single, and immediate dentures. During the first appointment, system-specific two-piece impression trays are used to take impressions and record the maxillomandibular relationship using conventional techniques with polyvinyl siloxane materials. The trays are separated into anterior and posterior sections to record the jaw relationship, and the EZ-Tracer™ is used for Gothic arch tracing, with adjustments made using the Dentca Jaw Gauge to determine the occlusal vertical dimension. Measurements, including lip ruler readings for incisor positioning, are sent to the manufacturer for scanning and virtual design approval. At the second appointment, provisional prostheses are tested to evaluate aesthetics, function, and phonetics. Adjustments, if required, are recorded and sent for rescanning. The final prostheses are 3D printed, with the base and teeth bonded using PMMA, followed by finishing and polishing. The third appointment involves delivering the final prosthesis, with fit adjustments and follow-up procedures performed similarly to conventional dentures (Baba et al., 2021, Steinmassl et al., 2017).

Amann Girrbach® Ag

Amann Girrbach® AG (Koblach, Austria) uses the Ceramill® full denture system (FDS), designed for laboratory technicians. Amann Girrbach has partnered with Vita (Vita Zahnfabrik, Bad Säckingen, Germany) and Merz (Merz Dental GmbH, Lütjenburg, Germany) and integrated their systems.

The Ceramill® Full Denture System

The Ceramill® Full Denture System involves a streamlined digital workflow for fabricating complete dentures. After taking maxillary and mandibular impressions, the laboratory fabricates the base and wax walls, which are sent to the clinician for fitting. During this stage, the maxillomandibular relationship is registered, the facial arch is transferred, and the smile line, midline, and canine positions are verified.

The collected data is transferred to the Amann Girrbach Artex articulator in the laboratory, where individual impressions are scanned. Using the Ceramill Transferkit, the occlusal edges and interocclusal registration are positioned on a Ceramill Map400 optical scanner, and the data is imported into Ceramill D-Flow software. Within the software, anatomical landmarks are drawn, and parameters such as tooth alignment, maxillary tooth positioning, and the occlusal plane are calculated. Artificial teeth from manufacturers like Kulzer, Vita Vionic Solutions, and Merz Dental can be used, with the software automatically applying the selected teeth set to the denture base. The technician digitally adjusts the anterior teeth to meet the patient's aesthetic preferences, and the software designs the soft tissue areas of the prosthesis.

The denture bases are milled from gum-colored wax blocks using a water-cooled 5-axis milling machine (Ceramill® Motion 2). Both the recesses for the teeth and the prosthetic surfaces of the artificial teeth are milled. The artificial teeth are placed into the wax prosthesis, and provisional dentures are tested for aesthetics, function, and phonation. Any necessary adjustments are made before final production by traditional methods. The final prosthesis delivery and follow-up procedures are similar to those used for conventional dentures (Baba et al., 2021).

Vita Vionic®

Vita has integrated its digital denture system with the Amann Girrbach® Ceramill FDS. Digital dentures are designed similarly to the FDS system, except that the artificial teeth and denture base material are manufactured by Vita. The laboratory technician can offer the clinician three options. The first is a monolithic white proof prosthesis milled from a prepolymerised PMMA block. After proofing and any necessary modifications, the final prostheses can be milled from a pink PMMA block. Another option is to mill wax walls with recesses in which the selected Vita denture teeth are positioned. The wax and teeth are used as a trial, adjustments are made and the denture is fabricated in the traditional way. The third option is the denture base, which is milled from pink prepolymerised PMMA blocks. The selected artificial teeth are cemented to the denture base with wax if a trial appointment is desired, otherwise with Vita Vionic Bonding. The dentures are then polished in the traditional manner (Baba et al., 2021).

Baltic Denture System (BDS)

Baltic Denture System (BDS) has partnered with Amann Girrbach® to integrate their digital denture system with Ceramill FDS. BDS is designed to provide patients with complete dentures in just two appointments. The clinician can start the prosthetic fabrication process with functional impressions using the components of the BDKEY set (Merz Dental GmbH). The first components of the system are the toothed upper and lower adjustable base plates. These trays are available in three different sizes (small, medium, large) and contain teeth of different shapes and sizes. The trays are placed in the mouth. A vertical ruler is attached to the upper tray to capture the midline of the face and to transfer aesthetic and functional components from the patient to the design software. The vertical bar is used to record the midline, while the facial arch is used to determine the interpupillary line and Camper's plane. A special device called the BDKEY Lock is available to record the relationship between the jaws. The teeth on the trays allow you to check aesthetics, lip support, tooth alignment and interocclusal space. Because the BDKEY trays replicate the size and shape of the artificial teeth on the milling blocks, they act as trial prostheses to verify the patient's acceptance of the final prostheses. The laboratory collects the data on an Amann Girrbach® Ceramill Map400 optical 3D scanner after scanning all the records provided by the clinician. A CAD design is created from the available data using BDCreator® software (Merz Dental GmbH). Once the design is approved, the prosthesis is milled on a 5-axis CNC machine. The milling blanks are made of cross-linked PMMA material and are available in three different sizes. They have an integrated tooth alignment with lingualised occlusion. Anterior and posterior teeth are available in different sizes and shapes. Once the complete prosthesis has been milled, it is delivered to the patient in the same way as a conventional prosthesis (Baba et al., 2021).

Denstply Dentures

Dentsply Sirona (York, Pennsylvania, USA) is the latest commercial organization to update CAD/CAM complete denture technology. They have developed a new resin for 3D printing called 'Lucitone Digital Print 3D Denture Resin'. Their system has a workflow that follows the subsequent bonding of 3D printed bases and specially designed artificial teeth (IPN 3D Digital Denture Teeth). The artificial teeth have indentations on the backs facing the base to ensure an easy fit for the prosthesis. The areas where the teeth will attach are rounded to facilitate the bonding process. The 3D printing process creates a very small gap between the artificial teeth and the base where the bonding material is applied. For bonding, the tooth is heated in a chemical bath, then the bonding material is applied, followed by light polymerization to fix the teeth to the denture base. The polishing material is then applied and the denture undergoes post-polymerization in a light polymerization unit (Baba et al., 2021).

Advantages of CAD/CAM System in Complete Prosthesis Production

Although complete dentures produced using traditional methods usually require at least five sessions to complete, CAD/CAM production systems have significantly accelerated this process. While the AvaDent and Dentca systems can complete the production of complete dentures in at least two sessions, the Ceramill system can complete the process in at least three sessions. This is a great advantage, especially for elderly patients or those who have difficulty accessing the clinic (Srinivasan et al., 2019; Bilgin et al., 2016).

The number of steps in the workflow is reduced and the software enables faster and more efficient impression analysis and tooth alignment, which is beneficial for the technician. As there is no need to mix PMMA resin as in traditional methods, monomer exposure is largely eliminated with these systems (Baba et al., 2021).

This reduction in the number of appointments relieves the dentist's workload by reducing the time spent with the patient. This saves time by reducing the amount of time the dentist spends with the patient, thus increasing the financial gain. (Srinivasan et al., 2019) Restorations made with monolithic milled prostheses and accurately obtained interocclusal records require less correction and the occlusion stabilizes more quickly (Baba et al., 2021).

With digital systems, a trial prosthesis can be fitted as with traditional methods. This stage allows the prostheses to be evaluated and, if necessary, corrections to be made so that the final prosthesis offers better fit and aesthetics (Baba, 2016). In contrast to traditional manufacturing methods, some CAD/CAM systems use prepolymerized PMMA blocks for milling. This technology prevents polymerization shrinkage and significantly improves the durability and tissue compatibility of the prosthesis (AlRumaih et al., 2018). Prepolymerized PMMA resins have superior physical properties and can be applied in thinner layers. These resins contain fewer monomer residues (Ayman, 2017), have smoother surfaces (Srinivasan et al., 2018; Arslan et al., 2018) and are more resistant to staining (Al-Qarni et al., 2020; Dayan et al., 2019). They also have a high modulus of elasticity (Steinmassl et al., 2018) and their dense structure (Ayman, 2017) provides a durable and strong prosthetic surface. The properties of prepolymerized PMMA blocks reduce the colonization of microorganisms (e.g. C. albicans) on the prosthetic surface, which minimizes the risk of infection (Raszewski, 2020; Al-Fouzan et al., 2017).

The storability of digital data associated with prosthesis fabrication facilitates the rapid duplication of prosthetic devices in the event of breakage or loss. This capability enables a rapid replacement process, ensuring that patients receive new dentures without significant delays. By using stored digital information, dental professionals can efficiently replicate a lost or damaged prosthesis, maintaining the original specifications and minimizing disruption to patient care (Baba, 2016).

The stored digital data is used to create surgical or radiographic templates for patients for future implant planning. This process helps to determine the angles at which the implants will be placed. (Baba, 2016) Compared to traditional methods, these are highly standardized systems and obtaining reliable and consistent results is important for both academic studies and clinical criteria (Bilgin et al., 2016).

Disadvantages of CAD/CAM System in Complete Denture Production

If the artificial teeth are manually attached to the milled denture base and not adjusted in the articulator, it will be difficult to achieve a balanced occlusion. In such cases, remounting may be necessary to achieve a balanced occlusion (Baba et al., 2021).

If there is a distance between the laboratory and the clinic, impression methods may be difficult for the clinician. He may prefer intraoral scanning methods, which have been shown to have limitations in edentulous patients. As another option, more reliable results can be obtained by using impression materials with high dimensional stability and heat-resistant impression materials (Baba et al., 2021).

The production of complete dentures with CAD/CAM systems still uses a combination of digital and traditional methods in clinical and laboratory processes. In particular, the impression-taking phase and the bonding of the denture base and artificial teeth with bonding agents are usually performed manually. However, in some emerging systems, the artificial teeth and prosthetic base are produced as a single block using the monolithic milling method and no bonding agent is required (Bidra et al., 2013).

When taking impressions of edentulous jaws with intraoral scanners, saliva-covered surfaces negatively affect the clarity of the impression. In addition, the lack of precise lines in their anatomical structure causes some limitations (Fang et al., 2018).

Goodacre et al. reported in a study that the margins of mandibular complete dentures could not be accurately measured, but intraoral scanners could be used for maxillary complete dentures (Goodacre et al., 2018).

The cost of materials and laboratory fees may be higher compared to conventional fabrication methods (Baba et al., 2021).

Subtractive methods produce a large amount of residual resin, which can lead to plastic pollution (Baba et al., 2021).

Disadvantages of the traditional complete denture fabrication process include the need for special equipment for filling, toxic and allergic effects due to increased monomers, fitting problems due to polymerization shrinkage, and problems such as tooth displacement (Yörükoğlu, 2020; Woelfel et al., 1960).

On the other hand, the use of CAD/CAM technologies reduces the number of appointments and makes it easier to reproduce the prosthesis thanks to digitally stored data. In addition, patient and clinician satisfaction increases with these systems, and standardization of production can be achieved at the same time (Baba, 2016).

A review of the literature on the use of CAD/CAM technology in dentistry reveals that publications to date have generally focused on fixed prostheses (Kalaycı & Bayındır, 2015). Although the incorporation of CAD/CAM technology into the production of removable dentures is a recent development, it has gained increasing popularity in recent years (Steinmassl et al., 2017).

Maeda et al. (1994) published the first scientific report on the use of computer-aided systems in the design and fabrication of complete dentures and pioneered the use of 3D laser lithography. In this study, the plastic shell of the tooth structure and the denture base were fabricated from light-polymerised resin. The teeth were then fabricated using tooth-coloured composite resin materials. By incorporating digital scans of the base plate and wax walls provided by a dentist into CAD software, Sun et al. created a prosthetic design consisting of teeth and base in a virtual environment and fabricated these prostheses using rapid prototyping techniques (Sun, 2009).

Kanazawa et al. (2011) used the subtraction method in production to speed up the CAD/CAM fabrication of complete dentures. Using 3D CAD software, new virtual dentures were designed from the acquired data. First, a rough image of the artificial teeth was extracted, followed by the shape of the denture base. Based on these images, a complete denture base was fabricated from an acrylic resin block. A bonding agent was then manually applied to the prepared base and the dentures were placed. In 2012, Goodacre et al. published the first clinical report demonstrating the ability to fabricate complete dentures from clear plastic using a 3-axis milling machine. In this study, prosthetic teeth were then manually cemented into the recesses created by milling. However, it is noteworthy that the milled denture bases in this study lacked interdental papillae and the milling lines were clearly visible. The authors also presented another clinical report in which 5-axis milling machines and finer cutters were used to fabricate complete dentures with prepolymerised PMMA. The teeth were then placed manually and this technique is still used today (Goodacre et al., 2012).

Inokoshi et al. (2012) compared traditional and additive manufacturing trial prostheses and found that both methods were adequate and accurate for their intended purpose. However, both patients and dentists rated the traditional trial prostheses higher in terms of aesthetics and stability.

Yoshidomea (2021) evaluated the realism and accuracy of fit of conventional dentures, CAD/CAM dentures, and a 3D printed prosthetic system (stereolithography and digital light processing). He concluded that milled dentures had better realism and fit accuracy compared to 3D printed and conventional dentures. In addition, 3D printed dentures had similar realism and fit to conventional dentures.

Al-Helal (2017) studied the retention of CAD/CAM prostheses and concluded that the retention of CAD/CAM prostheses was significantly better than conventional prostheses.

Emam et al. (2024) studied the fit accuracy of CAD/CAM milled, 3D printed and injection molded mandibular complete denture bases and found that the dimensional accuracy of the CAD/CAM milled group was statistically greater than the other two 3D printed groups. The injected method showed the lowest accuracy. These differences were thought to be due to polymerization shrinkage and associated internal polymerization stress. CAD/CAM milling and 3D printing technologies have shown less dimensional variation and higher accuracy compared to traditional prosthetic reproduction techniques.

This increased conformity in CAD/CAM complete dentures has been reported to reduce the incidence of oral lesions such as ulcers (de Mendonça et al., 2016).

Steinmassl et al. (2018) compared the physical properties of different CAD/CAM PMMAs with a conventional PMMA. They concluded that all CAD/CAM PMMAs have more hydrophilic surfaces than conventional PMMA.

A similar study conducted by Arslan et al. (2018) also found that CAD/CAM PMMA was more hydrophilic than conventional heat-cured PMMA. It has long been known that hydrophilicity plays a role in improving prosthesis retention (Gesser & Castaldi, 1971). Therefore, the wettability of CAD/CAM PMMA may make it the material of choice for improving the retention of complete dentures for patients with salivary dysfunction (Alammari, 2017).

Additive (3D) manufacturing methods make it possible to produce objects with complex geometries that cannot be produced by milling. In addition, the cost of these methods appears to be lower than that of subtractive methods. It is noted that there are some limitations in terms of aesthetics and stability in 3D printer fabrication. Therefore, 3D printed complete dentures have limited applications and are generally recommended for temporary or emergency dentures (Baba et al., 2015). When the physical, chemical and biological properties of acrylic resins used in CAD/CAM systems were studied, it was concluded that they have superior properties compared to conventional acrylic resins (Srinivasan et al., 2021). Echhpal UR et al. found that the highest number of Candida colonies was found in conventional, followed by 3D printed, and the lowest in milled denture base resins (Echhpal et al., 2024). In a study comparing the residual monomer content in conventional heat-activated PMMA and CAD/CAM PMMA, it was found that CAD/CAM PMMA reduced the monomer content. In CAD/CAM systems, prepolymerized acrylic resin contains less residual monomer, and porosity and Candida albicans retention are reduced (Smith et al., 2021).

The roughness of the outer surface of the prosthesis can be removed by mechanical polishing, while the inner surface of the prosthesis is not polished and retains its natural roughness. Several studies have compared the natural surface roughness of CAD/CAM prostheses with conventional prostheses. They concluded that all CAD/CAM prostheses have smoother surfaces than conventional prostheses (Kurahashi et al., 2017).

Al Qarni et al. (2020) investigated the effect of staining beverages (coffee and wine) on the color stability of acrylic resin teeth and denture bases used in CAD/CAM and conventional complete dentures. They concluded that CAD/CAM PMMA and conventionally machined dentures had similar color stability and that Avadent milled monolithic specimens were less likely to harbor stains at the tooth-prosthesis interface.

Goodacre et al. (2018) compared CAD/CAM (bonded and monolithic teeth) and conventionally fabricated prostheses (press, liquid resin, and injection) to determine which process produced the most accurate and reproducible prosthesis. They concluded that no technique could achieve perfect zero tooth loss. However, the monolithic CAD/CAM prosthesis produced the least tooth loss. They also found that the posterior teeth showed more detachment than the anterior teeth. In addition, they concluded that prosthetic processing techniques involving compression showed the greatest occlusal tooth movement.

A study by Saponaro et al. (2016) compared the clinical performance of CAD/CAM and conventional total prostheses and recorded the number and procedures for which patients returned after delivery of the prosthesis. The results showed that the average number of appointments required for prosthesis fabrication was 2.39, not 2 as claimed by the company. Since CAD/CAM techniques do not provide a balanced total prosthesis, it has been suggested that remounting may be necessary for the placement of dentures (Bidra et al., 2013). For milled denture bases, strong bonding agents must be used to bond the teeth to the base (Schwindling et al., 2016). This topic has great potential for research and development; studies on alternative bonding methods and materials are needed. In a study by Kattadiyil et al (2015), fifteen dental students at Loma Linda University School of Dentistry fabricated two sets of removable maxillary and mandibular complete dentures for fifteen edentulous patients using both digital (AvaDent) and conventional methods. The conventional and digital dentures were evaluated and scored separately by the faculty on criteria such as patient satisfaction and dental student preference. According to the evaluation results, digital dentures received significantly higher scores than conventional dentures in all areas.

There is a significant need for a greater volume of clinical case reports and well-designed scientific studies focusing on the production of complete dentures using CAD/CAM techniques (Kattadiyil et al., 2015). While this technology has shown promising advancements, the existing body of evidence is insufficient to comprehensively evaluate its clinical effectiveness and reliability in comparison to conventional methods. Moreover, the long-term performance of prepolymerized polymethyl methacrylate (PMMA) blocks, widely used in CAD/CAM denture fabrication, warrants detailed investigation. Studies assessing their biological, physical, and chemical properties over extended periods are particularly necessary to better understand their durability, biocompatibility, resistance to wear, and potential interactions with the oral environment.

Another critical area of limitation is the lack of research addressing the optimal thickness of the prosthesis base in CAD/CAM-fabricated dentures. The thickness of the denture base plays a vital role in determining its structural integrity, fit, and patient comfort. However, the literature lacks sufficient data on how variations in base thickness may influence clinical outcomes, leaving a gap in standardized guidelines for base design in digital workflows (Baba et al., 2021). Addressing these limitations through rigorous research is essential to fully realize the potential of CAD/CAM technology in complete denture fabrication and to ensure its safe and effective application in routine clinical practice.

Conclusion

Digital dental prostheses are increasingly meeting patient expectations and are becoming a preferred treatment option. They offer several advantages, including acceptable clinical outcomes, improved retention, fewer appointments, reduced reliance on human error, and the convenience of digital patient record storage. However, CAD/CAM technology for complete dentures also presents certain limitations. High costs and limited accessibility remain significant barriers, particularly in resource-constrained settings. Aesthetic customization and material options are less versatile than those of traditional methods, and some patients encounter adaptation challenges, such as speech difficulties. In complex cases, such as those involving resorbed ridges, achieving an optimal fit may be challenging due to limitations in capturing soft tissue anatomy. Additionally, reliance on digital systems introduces risks of technical issues and workflow disruptions, especially with interoperability challenges between different systems. Addressing these barriers is essential to expanding adoption and improving clinical outcomes.

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