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Digital Workflow in Complete Dentures: From Conventional to Fully Digital Protocols

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Abstract

The purpose of this narrative review was to examine the evolution of complete denture fabrication from conventional techniques to fully digital workflows. It compares each step of the denture process in traditional versus digital protocols – including impression making, jaw relation registration, prosthesis design, trial fitting, and final fabrication – and evaluates the outcomes, advantages, limitations, and future directions of digital denture techniques. A comprehensive literature review was conducted to gather current evidence on digital complete denture workflows. Peer-reviewed articles and clinical reports on conventional, hybrid, and fully digital denture protocols were analyzed. The key clinical and laboratory stages (impression procedures, maxillomandibular relation records, computer-aided design, try-in methods, and manufacturing techniques) were compared between traditional and digital approaches, with attention to reported clinical outcomes, efficiency, patient satisfaction, and technical

considerations. The reviewed literature indicates that most stages of complete denture fabrication can be accomplished digitally with results comparable to conventional methods.

Keywords: Computer-Aided Manufacturing, Digital Protocols, Fabrication, Handicap

Introduction

Complete edentulism has a profound impact on patients' quality of life, affecting their nutrition, speech, appearance, and psychosocial well-being[1,2]. The World Health Organization classifies edentulism as a physical impairment, disability, and handicap, underscoring its significance as a health condition[3]. Conventional complete dentures (CDs) remain a common and effective treatment for edentulous patients worldwide[4,5]. This traditional approach involves multiple clinical and laboratory steps: initial impressions, final impressions with border molding, maxillomandibular jaw relation records, trial denture try-in, and finally delivery of the finished prosthesis[6]. Typically, 5–7 clinical appointments and several laboratory phases are required to fabricate conventional CDs, and the process relies heavily on clinician technique and laboratory craftsmanship. Errors at each step can accumulate, impacting the fit and function of the prosthesis.

Over the decades, efforts have been made to streamline and simplify the conventional denture workflow. Simplified or accelerated denture techniques have been proposed to reduce the number of appointments by combining steps (e.g., one-stage impressions or eliminating a separate wax try-in). Studies have shown that such simplified protocols can still achieve patient satisfaction comparable to the traditional techniques [7–9]. For instance, randomized trials reported no significant difference in patient outcomes between dentures made with "traditional" vs. "simplified" methods, indicating that some steps can be combined without compromising denture quality [8,9]. However, even with simplification, the conventional process is time-consuming and technique-sensitive.

In recent years, digital technology has begun to transform complete denture fabrication. Advances in computer-aided design and computer-aided manufacturing (CAD/CAM) and 3D printing now allow the digital fabrication of complete dentures [10]. CAD/CAM denture workflows promise greater precision and consistency by minimizing human error and manual labor. Fabrication of dentures using milling of pre-polymerized acrylic resin blanks or printing with photopolymer resins can significantly reduce laboratory time and allow dentures to be produced in fewer clinical visits [11]. Initial reports on digital denture techniques have demonstrated outcomes such as improved fit of denture bases and reduction in chairside adjustment time, as well as high levels of patient satisfaction [10–12]. Given the growing evidence that digital dentures can streamline treatment without sacrificing quality, it is important for clinicians to understand how these fully digital protocols compare with and integrate into conventional methods. This narrative review discusses the digital workflow in complete dentures – from data capture to manufacturing – and provides a comparison of conventional versus digital protocols, along with current insights, clinical implications, and future directions.

Methods

A narrative literature review was conducted to compare conventional and digital workflows for complete denture fabrication. An electronic search of English-language articles up to 2024 was performed using databases such as PubMed and Scopus, with keywords including digital dentures, CAD/CAM complete

dentures, 3D-printed dentures, and conventional complete denture. Relevant peer-reviewed studies, review articles, and case reports were selected to outline the key clinical steps in complete denture treatment under conventional and digital protocols. The focus was on the main clinical phases – impression making, jaw relation records, trial denture assessment, and denture fabrication – and how digital techniques have been applied at each stage. Information on clinical outcomes, patient satisfaction, and laboratory evaluations was extracted to provide comparative insights. Given the narrative nature of this review, no formal meta-analysis was performed; instead, the findings from the literature are synthesized qualitatively. The following sections describe the clinical workflow for digital complete dentures and then discuss comparative insights versus the conventional approach. All sources are cited in Vancouver style and listed in order of appearance.

Clinical Workflow

Data Acquisition (Impressions): The first step in any denture fabrication is capturing the anatomy of the edentulous arches. In the conventional protocol, this involves an initial preliminary impression (often in alginate) followed by a refined final impression using custom trays and border-molding techniques to record functional peripheral extensions[6]. In a fully digital workflow, two main impression approaches exist: direct intraoral scanning of the edentulous ridges, or indirect digitization of a conventional impression or cast. Direct intraoral scanning offers potential advantages in patient comfort, as it eliminates tray impression material (no gag reflex and less mess) and can reduce chairside time [13]. It also streamlines laboratory processing by producing a digital model without the need to pour plaster casts. However, scanning an edentulous mouth is challenging. The lack of distinct reference points (teeth) and the presence of movable soft tissues make it difficult for the scanner to capture the entire functional periphery with accuracy [14]. Intraoral scanners struggle with the compressible tissues at the denture borders and the vestibular extensions, meaning that critical steps like selectively applying pressure to the border areas (as done in conventional border-molded impressions) cannot be fully replicated in a purely digital scan [14]. As a result, small errors in the peripheral fit may occur if solely relying on intraoral scans. Alternative strategies involve an indirect digital workflow, where a traditional final impression is made in the mouth and then either the impression or the resulting stone cast is scanned with a desktop laboratory scanner. This indirect approach effectively captures border details through conventional means and then brings the data into the digital realm. Many current digital denture systems employ this hybrid strategy: take conventional impressions, but then use CAD/CAM to design and manufacture the denture base and teeth arrangement. Research on the accuracy of digital impressions for edentulous arches indicates that intraoral scanning can be feasible and reasonably accurate for capturing arch form, but tends to be less precise in the peripheral tissue areas compared to conventional impressions [13]. Efforts to improve direct digital impressions include techniques like scanning with functional border movements or using adjunctive devices; for example, Unkovskiy et al. demonstrated a proof-of-concept where an intraoral scanner was used in conjunction with border molding maneuvers to capture functional denture borders [14]. Despite these advancements, at present the most reliable method to obtain an accurate digital model of an edentulous jaw often still involves a conventional impression step somewhere in the process (either initially or as a verification).

Maxillomandibular Relation Records: Establishing the correct jaw relations (vertical dimension of occlusion and centric relation) is critical for complete denture success.

Traditionally, this is achieved using record bases and wax occlusion rims that the patient uses to guide jaw positioning, sometimes supplemented by extraoral tracers or facebows in complex cases. In a fully digital workflow, recording the bite relationship remains one of the biggest challenges. There is currently no entirely digital method to record an edentulous patient's centric relation without some physical aid. In practice, clinicians must still use record bases (either conventional acrylic bases or digitally fabricated trial bases) with occlusion rims or a gothic-arch tracer device to capture the jaw relation, then transfer that information into the digital design software. For instance, a common approach is to fabricate an interim record base (either 3D printed or milled) after the digital impression and have the patient's jaw relation recorded on this base with conventional bite registration materials. The record can then be scanned or the orientation used in the software to mount the digital models in the proper relationship. Fully automated digital recording of vertical and centric relation in edentulous patients is not yet available in commercial systems, so this step is inherently a hybrid one (conventional clinical step combined with digital processing) in most workflows. Studies and reviews of computer-engineered complete dentures consistently note that capturing accurate maxillomandibular relationships still requires traditional techniques [15]. Thus, while the design and manufacturing phases can be digital, this critical clinical step has not been completely digitized.

Trial Denture Evaluation (Try-In): In the conventional process, after jaw relations are confirmed, a wax trial denture (with the prosthetic teeth set in wax) is made for the patient to try in. This appointment allows verification of fit, esthetics, occlusal vertical dimension, centric relation, speech, and overall appearance before the final denture is processed. One drawback of some digital denture workflows is the potential elimination of a traditional wax try-in, especially in an expedited "one-or two-visit" protocol. Without a try-in, errors in esthetics or occlusion might only be discovered at final delivery, requiring adjustments or remakes. To address this, digital workflows often incorporate a prototype try-in denture fabricated by rapid prototyping or milling. For example, a denture can be 3D printed in a cheaper resin as a trial appliance to test fit and appearance. Alternatively, some systems mill a monolithic polyurethane or acrylic try-in denture. These digitally produced trial dentures can be placed in the patient's mouth similar to a wax try-in. If changes are needed (to tooth position, vertical dimension, etc.), the modifications can be noted and adjusted in the software before final manufacturing. This ensures that the clinician and patient still have an opportunity to evaluate the prosthesis prior to finalization, preserving an important quality check. In fully digital protocols that aim to minimize visits, it is even possible to skip a separate try-in appointment when the situation allows (for instance, in immediate dentures or when duplicating an existing satisfactory denture), but generally a try-in step – digital or physical – is recommended for complex cases to avoid errors. Notably, if the patient has an existing well-fitting denture that they have worn, some digital techniques utilize that as a reference (a "reference denture" technique), where the old denture is scanned and used to inform the design of the new one. This can sometimes

allow a more confident transition with fewer try-in adjustments.

Digital Design and Fabrication: Once the definitive digital data for arches and jaw relations are obtained (through the above steps), the denture is designed in specialized CAD software. The software allows the placement and arrangement of artificial teeth from a digital tooth library, setting the teeth in proper alignment and occlusion. The denture base is contoured digitally, and features like festooning (gingival contouring) can be done in the virtual model. After design approval, manufacturing is carried out via either subtractive milling or additive manufacturing (3D printing). In subtractive manufacturing, the complete denture (typically the base with pre-formed tooth sockets, or sometimes a one-piece denture) is milled out of a pre-polymerized polymethyl methacrylate (PMMA) resin block using a CNC milling machine. Denture teeth may be prefabricated and bonded into the milled base, or in some systems, the teeth themselves can be milled as part of one monolithic structure. Milled dentures benefit from the material properties of highly polymerized acrylic—since the resin puck is industrially processed, the resulting denture has virtually no residual monomer and minimal polymerization shrinkage. This often translates into a very precise fit of the denture base on the tissue (because the distortion that can occur during conventional processing is eliminated) and potentially improved mechanical strength of the base [16]. In additive manufacturing, dentures are 3D printed layer by layer using a photopolymerizable resin. Current 3D printing technologies can print denture bases and teeth either separately (then bond together) or in a single build.

Printed dentures offer the advantage of speed and cost-efficiency for prototyping; however, the resin used is not as dense as milled acrylic and may exhibit slight shrinkage during post-curing. Studies have noted that while both milled and printed denture bases are within clinically acceptable accuracy, milled bases tend to have superior fit and stability due to the absence of polymerization shrinkage and porosity [16]. After manufacturing, the dentures are finished (polished and any supports removed) and then delivered to the patient.

It is important to highlight that quality control steps like occlusal adjustment and fit checking remain necessary in the digital workflow. Even with milling precision, clinicians should verify tissue adaptation (e.g., using pressure-indicating paste) and refine occlusion at insertion, just as with conventional dentures. Overall, the fully digital workflow for a complete denture can reduce the number of appointments (in an ideal scenario, impressions and jaw relations in the first visit, a digitized try-in in the second, and final delivery in the third visit). In practice, many clinicians adopt a blended approach, using digital fabrication to save time and improve fit, while still employing conventional techniques where needed (such as functional impressions or jaw relation records) to ensure accuracy. This integration of digital and analog steps can yield a predictable outcome and is currently a realistic way to implement digital dentures in daily practice.

Comparative Insights

The transition from conventional to digital complete denture protocols brings several notable advantages, as well as some limitations, when comparing the two approaches. One of the most immediate benefits of a digital workflow is the reduced number of clinical visits and chairside time required to deliver the prosthesis. A recent review concluded that CAD/CAM denture techniques significantly decrease clinical appointment frequency compared to the traditional method [15]. Fewer impression and try-in sessions are needed, and much of

the laboratory work is expedited by digital processes. In addition, all patient data (scans, bite records, designs) are stored digitally, enabling easy archiving and retrieval for future needs [15]. For example, if a denture is lost or damaged, the saved digital design can be used to quickly reproduce an exact copy, something not possible with conventional dentures unless casts were preserved.

Digital dentures also demonstrate excellent fit and retention. Because milled dentures are fabricated from pre-polymerized acrylic with no chemical curing shrinkage, clinicians often observe very intimate adaptation of the denture base to the tissue, translating to improved suction and stability [15,16]. The occlusal precision of milled or printed dentures is also high, frequently resulting in minimal adjustment of occlusion at delivery. Patient-centered outcomes with digital dentures have been favorable. In a retrospective survey of edentulous patients who received CAD/CAM fabricated dentures, about 70% of experienced denture-wearers rated their new digitally made denture as better in comfort and chewing ability than their previous conventional denture [16]. This suggests that, in practice, patients appreciate the outcome of digitally crafted prostheses, possibly due to better fit or other factors like easier adaptation.

From a materials standpoint, CAD/CAM dentures show superior mechanical properties in several aspects. The dense milling resin has higher strength and durability, and laboratory studies have found milled bases to have higher fatigue resistance and less fracture risk than conventional processed acrylic [15]. Even 3D-printed denture resins, while not yet as robust as milled ones, continue to improve and have demonstrated sufficient strength for clinical use with the advantage of quick production. Furthermore, because teeth in a CAD/CAM denture can be chemically bonded or printed as a monolithic unit, the issue of tooth debonding (a common problem in traditional denture where acrylic teeth can pop out of the base) is reduced.

Despite these advantages, there are important limitations and considerations when comparing fully digital protocols to conventional techniques. First, the initial cost of implementing a digital denture system can be high – requiring an intraoral scanner, design software, milling machine or 3D printer, etc. – which may be a barrier for some practices. However, once in place, digital fabrication can reduce per-case lab costs and time. Srinivasan et al. estimated that, although CAD/CAM denture production involves substantial laboratory machine time, it can save clinician time overall, and the reproducibility may translate to cost savings in the long run [11]. Another consideration is the learning curve: clinicians must become proficient in digital impression techniques, virtual tooth arrangement, and the nuances of CAM machines. The workflow and clinical management differ from the analog process, and early errors (like a poor scan or jaw record) can propagate unless carefully controlled.

When it comes to esthetics and occlusal refinement, many practitioners feel that the artistry of arranging denture teeth and festooning gingiva is an acquired skill in the digital realm just as in the conventional realm. While software provides templates and tools, achieving a natural look might require iterative adjustments on screen, and some clinicians prefer a wax try-in to visualize the setup in the patient's mouth. As discussed, the lack of a true functional try-in in certain one-visit digital denture protocols can be a drawback if significant changes are discovered to be needed at delivery. To mitigate this, the use of printed try-in dentures (even if not required by the digital

manufacturer's workflow) is a practical step to closely mirror the conventional check trial.

Overall, current evidence suggests that clinical outcomes of digital complete dentures are largely on par with conventional dentures, with some studies indicating equal or higher patient satisfaction for digital methods [16,17]. Two systematic reviews in 2017 examined the performance of CAD/CAM complete dentures and found that retention, stability, and occlusion achieved with digital dentures were comparable to traditional dentures, and complication rates (such as sore spots or need for post-insertion adjustments) were similar between the two approaches [17,18]. In fact, digital dentures often required fewer adjustments due to their accurate fabrication [17]. These reviews did note, however, that the available clinical studies had relatively short follow-up periods and varying protocols, meaning long-term data on prosthesis longevity and patient adaptation are still limited [18].

An important insight is that rather than completely replacing conventional techniques, digital workflows can also be used in a complementary fashion. For instance, a clinician might take conventional impressions and jaw records but then use a digital process to design and mill the dentures, combining the best of both worlds. This hybrid approach can reduce appointments and improve fit while maintaining tried-and-true clinical steps for critical aspects. In complex cases or when the clinician is still gaining confidence with digital methods, such a combined protocol can ensure the patient receives a well-fitting denture with minimal risk. On the other hand, for straightforward cases or duplicate dentures, a nearly fully digital approach can drastically cut down treatment time. The flexibility to integrate digital elements gradually is an advantage during this transitional era in prosthodontics.

Discussion

The advent of fully digital protocols for complete dentures represents a significant development in prosthodontics, yet it comes with its own set of challenges and considerations. One of the persistent challenges, as detailed above, is accurately capturing the functional periphery of the denture-bearing area with intraoral scanners. Conventional complete denture techniques evolved to use border molding and selective pressure techniques to ensure the denture borders seal and extend properly. Current intraoral scanning technology, while improving, still cannot inherently perform those tissue-conditioning maneuvers. As a result, clinicians must adopt workarounds, such as scanning a functional impression or using extraoral scans of models, to achieve comparable results. Research and development are ongoing to improve edentulous scanning—future scanner software might incorporate dynamic tissue capture or merge multiple scans (e.g., at rest and with functional movements) to better record sulcus depth and tissue displaceability. Until then, a fully digital impression of an edentulous mouth may not completely match the tissue detail of a well-crafted conventional impression, which is why many practitioners currently favor a "digital-analog hybrid" for the impression phase.

Jaw relation registration remains another critical gap in the digital workflow. There have been experimental approaches, such as using digital facebows, jaw motion trackers, or even artificial intelligence-driven alignment of existing dentures, but none are widely validated to replace the simplicity and reliability of occlusion rims and a bite registration in an edentulous patient. In the coming years, we may see innovations like virtual articulators that use scanned facial scans and CBCT data to approximate jaw relations, or pressure-sensing bite

plates that digitize the centric relation record. For now, however, the conventional record base with an occlusal rim is essentially standard even in a "digital" denture technique. Importantly, this does not detract from the overall digital process – it simply means that clinicians must be comfortable with a partially conventional step. Embracing digital denture technology does not eliminate the need for fundamental prosthodontic principles; rather, it refocuses the clinician's expertise on ensuring that the data fed into the digital design are as accurate as possible.

From a clinical standpoint, one of the most appreciated aspects of digital dentures by both patients and dentists is the predictability and consistency of the outcome. Once a workflow is mastered, the digital process yields dentures that are very consistent in quality. Adjustments at insertion are often minor, which can boost patient confidence during the delivery appointment.

Patients also tend to value the reduced number of visits and the overall modern experience of digital impressions (no messy materials). However, patient education is key – some patients may be wary of new technology or have unrealistic expectations that a computer-made denture will be "perfect" with no break-in period. Clinicians should continue to manage expectations just as with conventional dentures, reminding patients that adaptation and follow-ups (for sore spots or occlusal refining) might still be necessary.

Another consideration is the training and skill development required for dental technicians. In a conventional workflow, an experienced denture technician plays a major role in setup and processing. In a digital workflow, the technician's role shifts to operating CAD software and CAM machines. Dental laboratories have been rapidly adopting CAD/CAM for removable prosthetics, and technicians must learn tooth arrangement digitally and how to characterize dentures through milling or printing. As more dental schools and residency programs incorporate digital dentistry into their curriculum, new graduates are increasingly comfortable with these tools, which will further drive adoption. The collaboration between clinician and lab also changes; for example, its common now for a dentist to send digital impression files to a lab and receive back a finished milled denture base with teeth for try-in or delivery. This requires trust in the lab's digital process and good communication to get things right the first time. Fortunately, with digital data, modifications are easily communicated – a dentist can mark changes on a digital preview, and the lab can adjust virtually.

Current evidence base: The literature to date on digital complete dentures, while promising, is still developing. Many available studies are in the form of case reports, technique descriptions, or short-term comparative studies. As noted in systematic reviews (17,18), long-term clinical trials with larger sample sizes are needed. Outcomes such as long-term patient satisfaction, maintenance needs (relines, repairs), and cost-effectiveness over the denture lifespan remain to be fully explored. It is also worth investigating whether digital dentures improve the nutritional status or overall oral health-related quality of life of patients more than conventional dentures, or if they mainly offer efficiency gains. Initial patient surveys (e.g., Saponaro et al.'s study) suggest higher satisfaction, but these need confirmation in controlled trials. Another area of interest is the application of digital workflows to *implant-supported overdentures* or *hybrid prostheses* – essentially extending these principles to more complex prosthodontics. Some implant overdenture systems

already use digital impressions and CAD/CAM frameworks, indicating the trend is expanding.

Future directions: Looking forward, the complete denture workflow is likely to become even more integrated with digital technology. We anticipate improvements in 3D printing materials that are stronger and more wear-resistant, possibly closing the gap with milled acrylic. This could allow final dentures to be printed reliably, reducing material waste compared to milling (which carves away material). Artificial intelligence (AI) might play a role in automating parts of the design – for instance, suggesting optimal tooth arrangement or occlusion based on millions of data points from previous successful cases. This could help less experienced clinicians or technicians produce high-quality setups with minimal manual tweaking.

Augmented reality (AR) could be used during try-in or delivery, projecting a virtual image of how changes in tooth position might affect facial appearance, thus aiding clinical decision-making during patient consultations. Moreover, digital dentures open the door to mass customization: denture designs can be stored and easily modified if the patient's oral condition changes (for example, residual ridge resorption over time could be compensated by digitally relining and manufacturing a new denture).

It is also possible that fully digital one-appointment denture workflows will become more routine for certain indications, such as immediate dentures (where the teeth are extracted and denture delivered same day). In such cases, digital planning can be done in advance and the denture printed on the day of extraction, saving significant time. Early reports of such approaches exist, but widespread adoption will depend on continued improvements in efficiency and practitioner comfort with the technology.

Conclusion

Digital denture technology has evolved from an experimental concept to a practical reality in contemporary prosthodontics. A fully digital workflow for complete dentures – encompassing digital impressions, CAD design, and CAM fabrication – can produce dentures with excellent fit, strength, and patient satisfaction. Compared to the conventional analog process, digital protocols offer reduced appointment numbers, faster turnaround, and the ability to easily duplicate or modify prostheses thanks to digital data archiving. However, certain fundamental steps, particularly the recording of jaw relations and functional impressions, still benefit from conventional techniques or a hybrid approach, as truly digital solutions for these aspects are still maturing. Within the current state of technology, the optimal approach may combine digital and conventional methods: leveraging digital fabrication for its precision and efficiency, while using traditional clinical steps to ensure accuracy where needed.

In summary, digital complete denture protocols have proven to be a viable and often advantageous alternative to conventional methods, without compromising clinical outcomes[17,18]. Patients can receive well-fitting, esthetic dentures in fewer visits, and clinicians can deliver these prostheses with confidence in their reproducibility and fit. As more evidence emerges and technology continues to advance – potentially overcoming the remaining challenges – fully digital workflows are poised to become the new standard for complete denture fabrication. Prosthodontists and general dentists should stay abreast of these developments, as integrating digital denture techniques can enhance practice efficiency and improve the overall patient experience. The transition from conventional to digital is not an abrupt replacement

but a progressive enhancement of denture prosthodontics, one that ultimately aims to deliver better outcomes with greater convenience. By embracing digital workflows while maintaining sound clinical judgment, practitioners can successfully navigate the modern era of complete denture rehabilitation and provide edentulous patients with the benefits of both worlds.

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