Digital Removable Dentures

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Digital dentistry, an offspring of digital technology and robotics that emerged in the 1980s, has revolutionized various aspects of dental practice, including the creation of CDs. Computer-aided design and computer-aided manufacturing (CAD/CAM) techniques have been used for crafting CDs. The application of CAD/CAM methods in CD fabrication has attracted considerable attention, driving advancements in both design and production, promising quicker and higher-quality outcomes

Keywords: complete dentures (CDs) ; CAD/CAM ; 3D printing ; digital removable dentures

1. Introduction

While modern dentistry primarily aims to preserve natural teeth, the probability of losing teeth increases with age [1]. This, coupled with longer lifespans, has resulted in a growing demand for partial and complete dentures (CDs) [2]. Digital dentistry, an offspring of digital technology and robotics that emerged in the 1980s, has revolutionized various aspects of dental practice, including the creation of CDs [3]. Over the past 25 years, computer-aided design and computer-aided manufacturing (CAD/CAM) techniques have been used for crafting CDs [4]. Presently, the application of CAD/CAM methods in CD fabrication has attracted considerable attention, driving advancements in both design and production [5], promising quicker and higher-quality outcomes [6].

Multiple approaches yield satisfactory results in digitally produced CDs. The initial hurdle involves accurately capturing the dimensions of alveolar ridges, the hard palate, the functional depth and width of the border seal, and the post-palatal seal [7]. Subsequent steps encompass precise measurement of dimensions and relationships, establishing the appropriate vertical occlusion dimension, and meeting aesthetic criteria. These data guide surface design, placement of artificial teeth, and functional and aesthetic tooth arrangement, ultimately leading to successful denture creation [8]. The protocols for digitizing denture tissue surfaces are still evolving and depend on the system used. Two general options exist [9]: direct scanning of supporting tissues using an intraoral scanner, and indirect scanning of a stone cast or impression using a laboratory desktop scanner or intraoral scanner [10]. Intraoral scanning offers advantages over traditional impressions, such as enhanced patient comfort, streamlined laboratory procedures, and improved dimensional accuracy [11]. If an intraoral scanner is unavailable, scanning of physical casts or impressions becomes necessary.

Regarding computer-aided manufacturing (CAM) in the new CD production method, two main approaches currently exist: additive and subtractive [12]. The additive approach, commonly known as 3D printing, constructs objects layer by layer, and has shown potential in various domains including dentistry [13]. Existing 3D-printing systems for complete removable dental prostheses include NextDent Denture 3D+, FotoDenta Denture, and Dentca 3D Printed Denture [8]. However, current 3D printers face limitations in resolution and reproducibility, posing challenges for dental restorations [11].

There are additional reasons to embrace digital transformation [13][14]. Traditional removable prosthodontics require practitioners with progressively refined skills and experience, given the process's sensitivity to techniques, where errors can accumulate through multiple manufacturing stages [15]. Finding experienced dental technicians proficient in crafting high-quality removable dentures presents a challenge [16][17]. Additionally, conventional methods lack efficient tracking and documentation for post-process quality control and procedural improvement, which could be highly beneficial for both patients and dentists [18]. Rapid prototyping has diverse applications in engineering and medicine [4]. In the context of 3D-printed dentures, the process involves printing the denture base and teeth individually or as arches using tooth-colored materials. The products are then processed to remove excess material and bond together, resulting in high-detail and smooth-surface dentures [16]. Subtractive methods involve milling the denture base using industrially manufactured resin disks [19], and the fabricated teeth can be milled or chosen from a pre-made series [10].

The concluding phases involve carefully eliminating supports and refining the denture's surface. Alternatively, individuals have the option to choose and affix commercially accessible denture teeth from the digital repository of the CAD software

(Exocad, Darmstadt, Germany) onto the printed base [17]. Despite the availability of various additive manufacturing systems, not all are suitable for creating complete dentures, either due to the absence of compatible materials or insufficient build volume. A market analysis disclosed several systems deemed suitable for denture manufacturing, applicable in laboratory environments and chairside applications [18]. The shift to the digital era necessitates judicious financial planning from the dentist's perspective, as they take on the role of an entrepreneur [19][20]. In busy practices, chair time is viewed as a valuable resource to maximize business revenue [21]. However, understanding and appreciating the new technology necessitates a business-minded approach. The move to the digital realm requires a different mindset, involving substantial initial investment, ongoing maintenance expenses, skill development, and the acknowledgment of new risks [5].

Furthermore, there are a multitude of possible amalgamations between traditional treatment procedures and digital approaches [22]. The choice of a CAD/CAM system for denture fabrication and the incorporation of traditional and digital processes hinge on the prosthodontic proficiency of the dentist and the specific requirements of the individual patient. Compatibility issues between CAD software, CAM systems, and materials are still being debated, given the rapid evolution of the technology [3]. The rising technology of additive manufacturing (AM) is altering the procedures involved in creating removable prostheses within both clinical and laboratory settings [23][24].

2. Workflow of Digital Removable Dentures

Presently, there exists a notably limited quantity of in vitro investigations that appraise the characteristics and precision of materials when employing 3D printing for dentures, including denture bases and denture teeth [25]. The precision of the fit between the denture base and the mucosal tissue holds paramount importance for securing the retention of complete removable dental prostheses (CDs) and ensuring the long-term efficacy of the prosthesis. Studies have demonstrated that milled CDs exhibit accurate adaptation when compared to traditionally processed dentures [14].

The pursuit of streamlining workflows in digital dentistry is strongly driven by the quest for enhanced efficiency. Just as the digitization of fixed dental prostheses has evolved, a similar transformation has taken place in the fabrication of removable prostheses within dental laboratories [26][27]. This transition encompasses various steps, including the digitization of impressions or casts, and the digital placement of teeth, followed by the milling or 3D printing of trays, record bases, and the final prostheses [28]. This digital process has significantly accelerated production timelines and offers the advantage of retaining design data in cases involving prosthesis loss or fracture. However, these advancements have had minimal impact on the clinical appointment sequence or the overall workflow [29].

The initial strides in implementing a digital denture workflow in a clinical setting involved consolidating preliminary and final impressions, along with jaw relation records and tooth selection, into a single appointment [30]. Notably, this digital approach has the potential to eliminate the need for a try-on appointment, as virtual evaluation through software becomes feasible. Moreover, the purported higher accuracy of digital dentures compared to traditional ones could potentially lead to a reduction in the number of necessary adjustments [31]. This cumulative effect has the potential to streamline the required clinical appointments, possibly reducing them from more than five (depending on the extent of adjustments) to as few as three [32][33].

Lately, there have been documented instances of employing computer-aided design and computer-aided manufacturing (CAD/CAM) methods in the production of complete removable dental prostheses (CDs), highlighting various benefits [34]. Pioneering this domain are Avadent (Avadent, Scottsdale, AZ, USA) and Dentca (DENTCA, Torrance, CA, USA), which provide commercially accessible systems for digitally fabricating complete dentures [35]. Avadent utilized laser scanning and proprietary software to arrange denture teeth and design bases, while Dentca employed computer software to virtually shape edentulous ridges in the maxilla and mandible, arrange teeth, and create bases. Avadent's dentures were milled from pre-polymerized resin pucks, whereas Dentca's initial fabrication involved conventional processing techniques [36].

The introduction of digital CDs into the dental market spurred the emergence of various CAD/CAM systems each year. Distinguishing between these denture systems often involves evaluating factors such as the number of dental visits needed, methods for determining vertical dimensions, establishing dental or facial midlines, recording maxillomandibular jaw relations, and options for try-ons [37][38].

3. Clinical Implications of Digital Removable Dentures

Following the guidelines provided by manufacturers, the number of patient visits, including try-on appointments, can vary among different digital denture systems. For instance, the Wieland digital denture system requires a total of four visits, which includes try-on appointments [39]. On the other hand, both the AvaDent digital dentures and Whole You Nexteeth systems necessitate three visits, while the Baltic Denture System mandates only two visits. Irrespective of the system employed, all systems rely on dentists to assess the esthetic height of the lower face when evaluating the occlusal vertical dimension [40]. Notably, the Wieland system provides individually milled trays to establish the correct occlusal vertical dimension for bite registration. AvaDent (AvaDent, Scottsdale, AZ, USA) utilizes an anatomical measuring device, and Whole You Nexteeth (DENTCA, Torrance, CA, USA) employs a bite registration pin. In contrast, the Baltic Denture System (Merz, Germany) utilizes individually relined Baltic denture keys [41].
All these systems are grounded in milling technology, with Dentca (DENTCA, Torrance, CA, USA) being a trailblazer by introducing the initial 3D-printed denture back in 2015. Within their workflow, dentists can submit either digital or conventional impressions along with jaw relation records to the dental laboratory [42]. CAD design software streamlines the process of designing the denture base and ensuring proper teeth alignment. There is an option to create a printed try-on denture, which can be adjusted through clinical grinding and subsequent rescanning. The final denture and teeth are printed separately and then fused [43][44].

As tabletop dental printers and open-source software become more affordable, both dental practitioners and laboratories have the potential to produce CDs (complete dentures) in-house. However, due to the relatively recent introduction of 3D-printed dentures, the existing literature primarily consists of pioneering “proof-of-concept” reports on the integration of 3D printing into removable prosthodontics. Currently, there is no established evidence available regarding recommended usage, software selection, sequence, or workflow [45][46].

As dentistry advances toward a completely digital workflow, there is an increasing inclination toward utilizing intraoral scanning to replicate soft tissues [47]. A case report, which employed intraoral scanning for initial data acquisition, showcased a two-appointment process from data collection to the ultimate delivery of the denture within a fully digital workflow. However, this approach skipped a try-on session to evaluate the final esthetic outcome. Additionally, the absence of border molding compromised the retention of the final prosthesis [48]. To address this issue, the authors introduced digital relining (DR). This process involved milling a trial denture, using it for intraoral surface relining and esthetic evaluation, and subsequently digitizing the relined trial denture for adjustments before printing the final prostheses [49]. Similarly, other authors have primarily recommended scanning existing maxillary and mandibular CDs, 3D printing them, and utilizing them as custom trays or trial dentures in conventional workflows [50].

Given these constraints, the idea of creating an in-office additively manufactured interim complete removable dental prosthesis (CRDP) through a digital workflow has been suggested [51]. The process begins with an intraoral scan and maxillo-mandibular occlusal record, which are then exported as standard tessellation language (STL) files. Subsequently, computer-aided design (CAD) software is utilized to delineate the existing mandibular plane and arrange diagnostic teeth within the same CAD software [52][53]. The virtual denture base extension on the virtual edentulous ridge is then established, resulting in the formation of a 3 mm thick virtual denture base.

The approved designs for the diagnostic tooth arrangement and denture base are exported as distinct STL files, which are then brought into support-and-build preparation software [54]. An in-office 3D printer is employed to construct the denture base using soft-tissue-colored material, and the diagnostic tooth arrangement is printed using tooth-colored photo-polymerizing resins. Following polymerization in a light-polymerizing unit, the diagnostic tooth arrangement is affixed to the denture base using a soft-tissue-colored photopolymerizing resin. Ultimately, the interim CRDP is relined with a soft reliner for easy insertion and enhanced retention [55][56]. Three-dimensional printing has extended its application to the realm of immediate complete removable dental prostheses. Neumeier et al. introduced an innovative concept wherein, through digital processes, a single digital design and definitive record could be generated. This record could serve a dual purpose: it could be used to produce an immediate digital denture and function as a surgical reduction guide for alveoloplasty procedures [57]. The relining of digital immediate dentures can be carried out using methods similar to those employed for conventional dentures. Crafting definitive digital dentures involves the use of a reline impression and a fresh centric relation record. This can be accomplished by utilizing the existing digital immediate denture, eliminating the need for additional clinical procedures. The proposal of providing 3D-printed immediate or interim dentures shows promise as a treatment option, especially when considering the current limitations of traditional methods [58][59].

Concerns may arise within the digital complete removable dental prosthesis (CRDP) workflow, particularly for individuals with limited experience, in terms of the clinical workflow and procedural steps. Challenges could manifest when addressing aspects like evaluating occlusal vertical dimension, maxillomandibular relationships, lip support, and the position of maxillary incisal edges, particularly for those new to the field [60]. Furthermore, patient involvement is minimized due to the absence of try-on sessions, and the costs associated with current materials and laboratory work are higher compared to conventional methods. Additionally, digital dentures call for specialized equipment, including trays, materials, software, and specialized training, which clinicians must align with their practice, expertise, and training when adopting new workflows [61][62]. With the expansion of various companies and techniques, considering open digital systems could be a prudent approach. This strategy empowers dental professionals to adapt evolving digital technology to their specific needs, without compromising on clinical excellence or practice efficiency [63]. Delving deeper into the realm of digital dentures, it becomes evident that the journey toward their seamless integration is not without its challenges and intricacies. These challenges often manifest themselves in the laboratory phase, where the transition from traditional methods to digital workflows can give rise to unforeseen errors. The virtual review of digitally designed tooth arrangements, although promising in its potential for precision and customization, has been met with reports of occasional discrepancies and hiccups [5]. To navigate this transition successfully, a prudent approach involves the incorporation of a comprehensive checklist, especially during the initial stages of implementation. Such a checklist would serve as a safeguard against oversight, ensuring that each step of the digital design process is meticulously examined for accuracy and alignment with clinical expectations.

In addition to the intricacies of digital design, achieving a harmonious occlusion within the digital denture workflow presents its own set of challenges. The concept of occlusion, the way the upper and lower teeth come into contact, is a fundamental aspect of denture functionality and patient comfort. Within the digital framework, attaining a balanced occlusion becomes a notable hurdle, particularly during movements beyond centric occlusion. Currently, the technology and techniques in place predominantly enable the attainment of a lingualized centric occlusion, which represents the alignment of posterior teeth in a manner that prioritizes posterior disocclusion during excursive movements. However, the achievement of a harmonious occlusion during protrusive and lateral movements remains an ongoing area of research, signifying a substantial gap in the current capabilities of digital denture fabrication [18].

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