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Review

Future Prospects and Challenges in Additive Manufacturing for Complete Dentures: A Narrative Review

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Abstract: The utilization of computer-assisted design and computer-assisted manufacturing (CAD/CAM) techniques in the creation of complete dentures (CDs) has piqued the interest of many people. This article seeks to provide a comprehensive, critical, and objective analysis of the current knowledge of CDs and related technology. The aim of this study is to assess existing literature concerning 3D-printed complete dentures, covering aspects like innovative biomaterials, manufacturing methods and processes, workflow, and clinical effectiveness. The design of the current study included an initial review of 172 titles, an appraisal of abstracts, and finally a selection of articles for rigorous textual analysis. Inconsistencies discovered throughout the selection process were amicably resolved through discourse, culminating in the identification of 65 items. The publications retrieved from a thorough search of the PubMed, Scopus, and Embase databases spanned the years 1994 to 2023. Contemporary digital technology provides evident advantages, but its successful incorporation necessitates meticulous preparation. In the realm of dental healthcare, the digital workflow showcases versatility and a range of applications.

Keywords: 3D printing; complete removable dentures; CAD/CAM; denture base materials

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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].

The objective of this study is to examine the current body of literature on 3D-printed complete dentures, encompassing topics such as advanced biomaterials, manufacturing techniques, processes, workflow, and clinical efficacy.

2. Materials and Methods

2.1. Literature Search Strategy

A literature search was undertaken in PubMed, Scopus, and Web of Science Databases to identify English language publications from 1994 to 2023. The keywords used included "Removable Dentures" [Mesh] AND "Three-dimensional printed" [Mesh] "CAD-CAM" [Mesh], "Computer Aided Design and Computer Aided Manufacturing" [Mesh], "Milled" [Mesh], and "3D Printed" [Mesh].

2.2. Study Inclusion and Exclusion Criteria

2.2.1. Inclusion Criteria

(1) In vitro studies regarding materials for removable dentures;
(2) Clinical studies regarding digital technology and the properties of denture base materials;
(3) Studies that utilize the advantages and disadvantages of denture base materials;
(4) Studies that use mechanical and chemical testing devices for investigation of the qualities of removable dentures.

2.2.2. Exclusion Criteria

(1) Non-English articles.
(2) Studies that investigate removable partial dentures;
(3) Studies on CAD/CAM technology, used for other materials;
(4) Studies on animals;
(5) Full articles unavailable;
(6) Case reports, conference papers, book chapters, patents, and letters to the editor, which are not related to dentistry.

Following PRISMA guidelines, Figure 1 illustrates the structure of the present study.

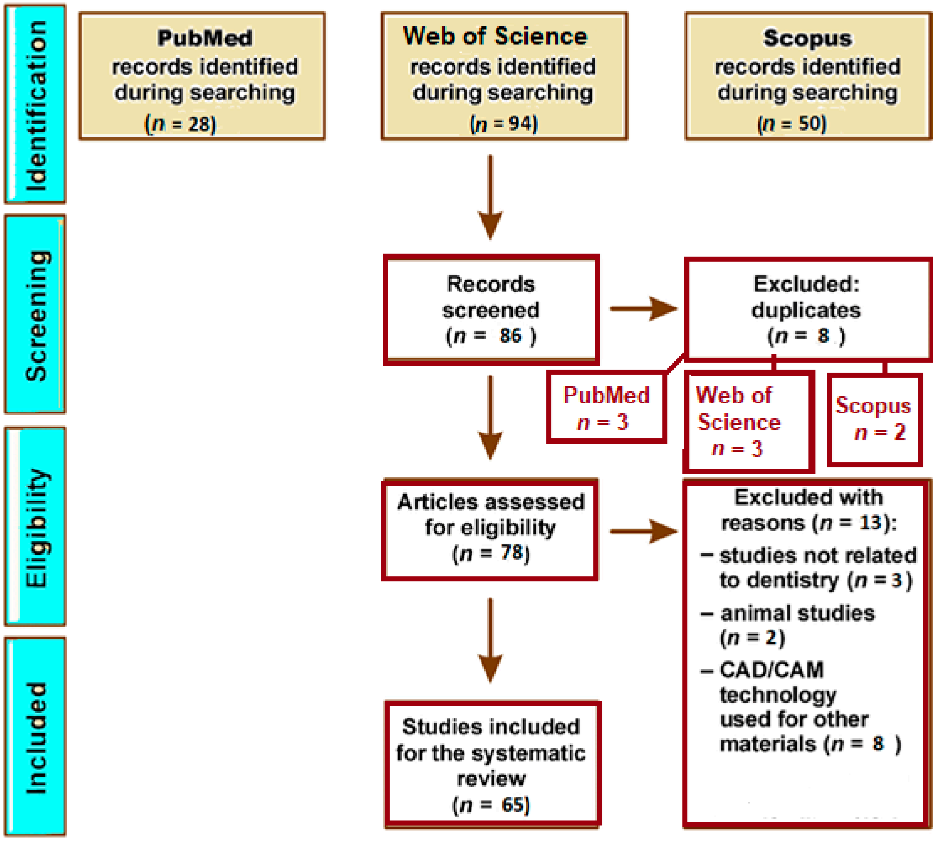

Figure 1. Flow chart of the inclusion and exclusion criteria for selecting articles.

For the current study, 65 titles were selected and obtained. The included articles are presented in Table 1.

Table 1. List of the included articles.

No.	Article	Year of Publication	Reasons for Inclusion
1.	Goodacre, B.J.; Goodacre, C.J.; Baba, N.Z.; Kattadiyil, M.T. Comparison of denture base adaptation between CAD-CAM and conventional fabrication techniques. J. Prosthet. Dent. 2016, 116, 249–256. [2]	2016	CAD/CAM technology used for complete dentures
2.	Artopoulos, A.; Andrzej, C.; Juszczyk, J.; Rodriguez, R. K.F.; Clark, D.R. Radford. Three-dimensional processing deformation of three denture base materials. J. Prosthet. Dent. 2011, Vol. 110, 6. [8]	2015	CAD/CAM technology used for complete dentures
3.	Anadioti, E.; Musharbash, L.; Blatz, G.; Papavasiliou, P.; Kamposiora. M. 3D printed complete removable denture. BMC Oral Health. 2020, Vol. 343, 20. [9]	2020	3D-printing technology used for complete removable dentures
4.	Kattadiyil, M.T.; Goodacre, C.J.; Baba, N.Z. CAD/CAM complete dentures: A review of two commercial fabrication systems. J. Calif. Dent. Assoc. 2013, 41, 407–416. [25]	2013	CAD/CAM technology used for complete removable dentures
5.	Kanazawa, M.; Inokoshi, M.; Minakuchi, S.; Ohbayashi, N. Trial of a CAD/CAM system for fabricating complete dentures. Dent. Mater. J. 2011, 30, 93–96. [26]	2011	CAD/CAM technology used for complete removable dentures
6.	Katase, H.; Kanazawa, M.; Inokoshi, M.; Minakuchi, S. Face simulation system for complete dentures by applying rapid prototyping. J. Prosthet. Dent. 2013, 109, 353–360. [27]	2013	CAD/CAM technology used for complete dentures
7.	Zhang, Y.D.; Jiang, J.G.; Liang, T.; Hu, W.P. Kinematics modeling and experimentation of the multi-manipulator tooth-arrangement robot for full denture manufacturing. J. Med. Syst. 2011, 35, 1421–1429. [28]	2011	CAD/CAM technology used for complete dentures
8.	Goodacre, C.J.; Garbacea, A.; Naylor, W.P.; Daher, T.; Marchack, C.B.; Lowry, J. CAD/CAM fabricated complete dentures: Concepts and clinical methods of obtaining required morphological data. J. Prosthet. Dent. 2012, 107, 34–46. [29]	2012	CAD/CAM technology used for complete removable dentures
9.	Srinivasan, M.; Cantin, Y.; Mehl, A.; Gjengedal, H.; Müller, F.; Schimmel, M. CAD/CAM milled removable complete dentures: An in vitro evaluation of trueness. Clin. Oral Investig. 2017, 21, 2007–2019. [30]	2017	CAD/CAM technology used for complete dentures
10.	Punj, A. Digital Dentistry for Complete Dentures a Review of Digital Dentistry Versus Conventional Approaches to Complete Dentures. Decis. Dent. 2020, 12–20. [31]	2020	3D printing of complete dentures
11.	Bilgin, M.S.; Erdem, A.; Aglarci, O.S.; Dilber, E. Fabricating Complete Dentures with CAD/CAM and RP Technologies. J. Prosthodont. 2015, 24, 576–579. [32]	2015	CAD/CAM technology used for complete dentures

3. 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 [33]. 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 [34,35]. 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 [36]. 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 [37].

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 [38]. 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 [39]. 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 [40,41].

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 [42]. 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 [25]. 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 [43].

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 [26,27].

4. 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 [28]. 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 [29]. 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 [44].

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 [30]. 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 [45,46].

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 [47,48].

As dentistry advances toward a completely digital workflow, there is an increasing inclination toward utilizing intraoral scanning to replicate soft tissues [49]. 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 [50]. 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 [51]. 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 [52].

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 [53]. 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 [54,55]. 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 [56]. 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 [57,58]. 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 [59]. 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 [60,61].

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 [62]. 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 [63,64]. 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 [65]. 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].

5. Challenges and Drawbacks of Digital Complete Dentures

5.1. Integration into Dental Laboratories and Clinics

Incorporating digital technology into dental laboratories and clinics presents a multifaceted set of challenges that extend beyond the mere introduction of new tools. The need for comprehensive workflow adjustments is paramount, as practitioners and technicians must adapt their established processes to accommodate the intricacies of digital denture fabrication. This includes redefining protocols, modifying existing procedures, and integrating novel steps into the conventional workflow.

One of the primary hurdles encountered in this transformation lies in staff training. The acquisition of digital skills and expertise is essential for the seamless integration of technology into daily practices. Resistance to change, often observed among experienced practitioners and technicians comfortable with traditional methods, can impede a smooth transition. Overcoming this resistance necessitates not only effective training programs but also fostering a culture that embraces innovation and values continuous learning.

Financial considerations further underscore the challenges associated with the adoption of digital technology. The initial investment required for acquiring and implementing state-of-the-art digital tools and equipment can be substantial. This financial commitment demands meticulous planning to ensure that the chosen technology aligns with the specific needs and goals of the dental laboratory or clinic. Careful consideration of return on investment is crucial to justify the expenditure and assess the long-term benefits of transitioning to digital denture fabrication. Beyond the upfront costs, ongoing expenses add to overall economic considerations. Maintenance of and updates to digital systems, along with continuous staff training to keep abreast of evolving technologies, contribute to operational costs over time. These recurrent expenditures must be factored into financial strateies to sustain the effective functioning of the digital workflow.

Seamless interoperability between various digital systems and software components is a pivotal aspect of successful digital integration. Achieving harmonious collaboration between different elements of the digital workflow, such as scanning, designing, and milling or printing, requires standardized protocols. Unfortunately, the current landscape often lacks universally accepted standards, hindering effective communication between disparate components. This lack of standardization not only complicates the implementation process, but also poses potential barriers to collaborative efforts within the broader dental community.

In conclusion, the challenges associated with incorporating digital technology into dental laboratories and clinics extend across multiple dimensions, ranging from the need for workflow adjustments and staff training to financial considerations and interoperability concerns. Addressing these challenges requires a strategic and holistic approach that combines effective training, careful financial planning, and collaborative efforts toward standardization within the digital dental ecosystem.

5.2. Current Limitations of the Digital Approaches

5.2.1. Material Limitations

Despite significant advancements in digital denture fabrication, the materials used in this process may still exhibit limitations, encompassing aspects such as durability, esthetics, and biocompatibility. Despite ongoing progress, achieving the ideal balance in these material properties remains an ongoing challenge. Addressing these material constraints is not only pivotal for ensuring the longevity of dentures but is also a critical factor influencing patient satisfaction. It necessitates ongoing research and development efforts to enhance the material options available for digital denture fabrication, ensuring that the final products meet both functional and aesthetic expectations.

5.2.2. Fabrication Challenges

The fabrication process, whether utilizing milling or 3D-printing technologies, is not without its challenges. Precision issues, surface finish discrepancies, and intricacies in detailing may arise during the production of digital dentures. Identifying and mitigating these challenges is essential to uphold the quality and accuracy of the final denture. Continuous refinement of fabrication processes, technological advancements, and research into innovative techniques are crucial components of addressing these challenges. As the field evolves, overcoming fabrication hurdles will contribute to the establishment of digital denture fabrication as a reliable and precise method within the dental industry.

5.2.3. Developments and Challenges between Milled and Printed Dentures

- Milled Dentures

Milling technologies stand out for their high precision in creating dentures, ensuring an accurate fit and optimal functional outcome. Additionally, milled dentures often boast a broader range of materials, providing dental professionals with increased options for customization. The precision offered by milling technology aligns with the meticulous requirements of denture fabrication, contributing to the production of prosthetics that closely match the intended specifications.

- 3D Printed Dentures

In contrast, 3D printing introduces distinct advantages, notably in terms of design flexibility. This technology allows for the creation of intricate and customizable designs that may pose challenges with traditional milling methods. Moreover, the speed of the printing process presents a potential advantage, potentially reducing turnaround times for denture fabrication. However, the adoption of 3D printing for dentures comes with its own set of challenges and considerations.

- Challenges and Considerations

Print resolution is a critical consideration in 3D printing, as achieving fine details and an optimal surface finish may present challenges that need careful attention. Additionally, the range of materials suitable for 3D printing may have specific limitations that can impact the final denture properties. Balancing the benefits and challenges of both milled and printed dentures is crucial for dental professionals seeking to leverage the advantages of digital technology while delivering high-quality prosthetics.

6. Results and Discussion

The quest for a comprehensive and flexible occlusal scheme in the digital domain requires a multidisciplinary approach, drawing expertise from prosthodontics, material science, computer engineering, and biomechanics [39]. Careful consideration is essential due to the intricacies of human masticatory movements, the interaction between artificial teeth and oral tissues, and the precise calibration of occlusal contacts during various functional tasks [9]. Both researchers and practitioners are collaboratively working to address these challenges, aiming to create digital denture workflows that accurately replicate the intricate dynamics of natural occlusion [36].

In summary, the challenges in the realm of digital dentures go beyond technical aspects. Successfully integrating digital workflows into dentistry necessitates a nuanced understanding of potential pitfalls and limitations [14]. The use of checklists as procedural safeguards and the ongoing effort to achieve a balanced occlusion during dynamic movements highlight the complexity of this transformative endeavor [47]. As technology advances and interdisciplinary collaborations thrive, there is an anticipation that these challenges will gradually be overcome, ushering in a new era of dentistry where digital dentures can confidently stand alongside their traditional counterparts [19]. This evolution signifies a shift towards a more sophisticated and integrated approach to dental care.

At present, a blend of traditional impressions and maxillomandibular relationship procedures, coupled with modern CAD/CAM production and processing techniques, appears to be a strategy that enables clinicians to harness the advantages of both approaches for optimal outcomes [31]. However, this approach could involve an additional appointment for creating custom impression trays and record bases after the initial impressions. Given the nascent stage of 3D-printing technology, finding the appropriate balance between conventional and digital workflows might be essential to maintaining high clinical standards while integrating cutting-edge techniques [32].

To ensure efficiency and gratifying outcomes in the field of dentistry, it becomes increasingly evident that the realm of digital dentures necessitates substantial investment in further research and development [54]. While the promise of these innovative solutions is captivating, their full potential and reliability are still under scrutiny. In this pursuit, a plethora of clinical investigations with extended follow-up periods are imperative before digital dentures can confidently supplant their conventional counterparts [49].

The advent of digital technology has bestowed dentistry with transformative possibilities [15]. The concept of digital dentures, which involves the integration of computer-aided design (CAD) and computer-aided manufacturing (CAM) techniques, offers the prospect of enhanced precision, customization, and overall patient satisfaction [4]. Nevertheless, this transition from traditional dentures to their digital counterparts is not a decision to be taken lightly, as the intricate interplay between oral physiology, patient comfort, and long-term durability demands thorough evaluation [33,36]. Central to the discussion of digital dentures is the emergence of 3D-printing technology [16].

Moreover, 3D-printed dentures present a promising avenue for streamlining the denture-manufacturing process. The utilization of additive manufacturing techniques can potentially reduce costs, curtail material consumption, and minimize the need for extensive equipment [26]. These factors collectively imply a more efficient and accessible method of producing dentures, particularly when compared to the resource-intensive nature of CAD/CAM dentures.

However, this innovative frontier is still in need of comprehensive exploration. The manufacturing precision of 3D printing, the biocompatibility of materials employed, and the long-term performance of these digitally fabricated dentures are factors that necessitate rigorous investigation. Clinical trials that encompass a diverse range of patients and span considerable timeframes are crucial to unveil the true potential of 3D-printed dentures. These trials should meticulously track parameters like fit, functionality, comfort, and durability, comparing them against the gold standard of conventional dentures.

In essence, while the allure of digital dentures, particularly those created through 3D printing, is undeniable, their incorporation into mainstream dental practices must be underpinned by robust scientific inquiry. The field demands a concerted effort to accumulate data, analyze outcomes, and ensure that patient well-being remains paramount throughout this technological evolution. Therefore, the path forward necessitates not just enthusiasm, but disciplined and sustained research to substantiate the claims and promises of digital dentures, ultimately elevating the standard of dental care and patient quality of life.

7. Conclusions

The utilization of digital technology in creating complete dentures demonstrates adaptability.

- It enables the incorporation of both well-established conventional methods in clinical practice and recent progress in CAD/CAM techniques in dental laboratories;
- Evolving digital technology holds promising prospects for the dental industry, potentially reaching unprecedented levels;
- However, pursuing this pathway requires careful consideration and thorough preparation.

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Abbreviations

AM	Additive manufacturing
CAD/CAM	Computer-aided design/computer-aided manufacturing
CD	Complete dentures

DR	Digital relining
ISO	International Organization of Standardization
PMMA	Polymethyl methacrylate
RPD	Removable partial denture
STL	Stereolithography, standard triangle language, standard tessellation language
3D	Three-dimensional

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