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Advantages of Additive Manufacturing for Complete Removable Dentures

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Abstract

The purpose of this review is to examine the existing body of research regarding complete 3D-printed dentures. This examination will cover new biomaterials, methods of creation, workflow, how well they work in clinical settings, and the contentment of patients using them. The methodology involved implementing a search plan, establishing criteria for inclusion and exclusion, and picking out relevant studies. Four reviewers conducted separate searches on PubMed, Scopus, and Embase databases to collect articles released from 2002 to 2023. From the electronic database, a sum of 116 headings was acquired, and after implementing exclusion criteria, 28 articles were pinpointed relating to technology for creating full dentures through printing. Present advancements and progress in digital dentistry have effectively enabled the production of removable dental prostheses through CAD/CAM technologies.

Keywords: 3D Printing; Additive manufacturing; CAD/CAM; Removable complete dentures; Denture base materials.

Introduction

Recent advancements in digital dentistry have begun to impact the creation of this specific treatment approach. Digital dentistry has significantly transformed various aspects of dentistry since its introduction in the 1980s [1].

The initial endeavor to develop a computer-aided design/computer-aided manufacturing (CAD/CAM) system for crafting complete removable dental prostheses occurred in 1994 [2]. However, it was in 2012 that the introduction of digital denture construction gained notable attention, led by Goodacre et al. [3]. In their publication, they presented a prototype that illustrated the potential future applications of digital denture production. Presently, the continual evolution and advancement of digital technologies have led to a substantial surge in the variety of materials accessible in the market for producing digital complete removable dental prostheses [4].

Additive manufacturing (AM), also referred to as 3-dimensional (3D) printing or rapid prototyping (RP), involves methodologies that construct objects layer by layer [5]. Despite its recent introduction, 3D printing has demonstrated potential in various domains such as engineering and medical applications, including dentistry [6,7]. The existing 3D printing systems for creating complete removable dental prostheses include Next-Dent Denture 3D+ (NextDent, 3D Systems, The Netherlands), FotoDenta Denture (Dentamid, Germany), and Dentca 3D Printed Denture (Dentca, USA) [8]. However, the current printers suffer from limitations in resolution and reproducibility, and their technical constraints have thus far presented challenges in the implementation of these manufacturing techniques for dental restorations [9].

The rising technology of additive manufacturing (AM) is altering the procedures involved in creating removable prostheses within both clinical and laboratory settings [10]. The objective of this study is to assess existing literature concerning fully 3D-printed dentures, covering aspects like innovative biomaterials, manufacturing methods and processes, workflow, clinical effectiveness, and the contentment of patients [11].

Materials and methods

The approach encompassed the implementation of a search strategy, establishing criteria for inclusion and exclusion, retrieving relevant studies, selecting these studies, extracting pertinent data, and then structuring tables to succinctly present the outcomes. Searches were conducted across PubMed, Scopus, and Embase databases to amass literature published between 2002 and 2023.

The search phrases employed were "Denture" (Mesh) or "Removable Dental Prostheses" or "Removable Denture" or "Complete Denture" and "3D-printing" (Mesh) or "CAD/CAM" or "CAD-CAM" or "Computer Aided Design and Computer Aided Manufacturing" and "Milled" (Mesh) and "3D Printed" or "Printed" and "Digital Denture" (Mesh) and "Additive Manufacturing" (Mesh). Articles chosen from the database search were individually sorted by four reviewers, and any variations in selection were discussed until a consensus was established.

Results and discussion

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 [12]. 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 (CRDPs) and ensuring the long-term efficacy of the prosthesis. Studies have demonstrated that milled CRDPs exhibit accurate adaptation when compared to traditionally processed dentures [13,14].

In the context of 3D-printed dentures, an in-vitro study conducted a quantitative assessment of their tissue surface adaptation in comparison to the conventional manual approach [15]. Using high-precision 3D wax-printing technology (CAD&3DP), a wax pattern of a maxillary complete denture was crafted on a standard edentulous plaster cast, and the fit between the wax pattern and the cast was assessed quantitatively [16]. The results indicated no statistically significant disparity between the CAD&3DP group and the manually manufactured group in terms of measurements reflecting the deviation between the denture tissue surface and the plaster cast model [17]. As a result, this study concluded that the utilization of 3D printing in manufacturing CRDPs for try-in appointments during the restoration of edentulous jaws seemed to be clinically satisfactory [18].

The functional effectiveness of a prosthesis is constrained by the mechanical attributes of its constituent materials. While being chewed upon, dentures are subjected to bending stresses which lead to internal tensions [19]. Consequently, these tensions induce repetitive distortions in the polymer base, resulting in the emergence of cracks and eventual fracturing. An investigation was conducted to assess the flexural strength and surface characteristics of pre-polymerized PMMA-based polymers, utilized in CAD/CAM technology for digitally 3D printed complete dentures [20].

The research revealed that the CAD/CAM PMMA-based polymers exhibited superior flexural strength (FS) and higher hydrophobicity compared to the traditional heat-polymerized PMMA [21]. Additionally, the surface roughness of CAD/CAM PMMA-based polymers was comparable to that of conventional PMMA [22]. Recent studies have also yielded analogous outcomes, confirming the enhanced flexural strength of milled resins [23].

In the progression towards a fully digital dental workflow, there is a growing interest in utilizing intraoral scanning to replicate soft tissues [24]. A case study employing intraoral scanning for initial data capture demonstrated the swiftest route from data collection to the final denture delivery, completing the entire digital process in only two appointments [25]. Nevertheless, this approach omitted a try-in session to assess the ultimate aesthetic outcome and, more critically, due to the absence of border molding, the retention of the final prosthesis was suboptimal. The authors refined their technique by integrating digital relining (DR), wherein a trial denture was milled [26].

This milled trial denture was employed for intraoral relining and aesthetic assessment. Afterward, the relined trial denture underwent digitization, with adjustments made to the teeth arrangement based on the evaluation, culminating in the fabrication of the ultimate prostheses via printing [14].

Similarly, other researchers have primarily advocated for the scanning of existing maxillary and mandibular CRDPs, followed by 3D printing to craft custom trays or trial dentures within a conventional workflow [3].

Addressing these limitations, an alternative concept was proposed involving the in-office creation of interim CRDPs through an additive manufacturing-based digital process [27]. This approach commenced with an intraoral scan and the establishment of a maxillomandibular occlusal record, both exported as standard tessellation language (STL) files. Subsequently, a CAD software was utilized to determine the mandibular plane, followed by designing a diagnostic tooth arrangement within the same software [6].

The definition of the denture base extension on the virtual edentulous ridge was carried out, forming a 3 mm-thick virtual denture base [11]. The approved designs for the diagnostic tooth arrangement and denture base were then exported as separate STL files and fed into a support-and-build preparation software. An in-office 3D printer was employed to produce the denture base using soft-tissue-colored resin, and the diagnostic tooth arrangement using tooth-colored photopolymerizing resins [19].

After polymerization in a light-polymerizing unit, the diagnostic tooth arrangement was affixed to the denture base using a soft-tissue-colored photopolymerizing resin. Lastly, the interim CRDP was relined using a soft reliner (Coe-Soft; GC America Inc) to facilitate insertion and enhance retention [28].

Conclusion

The advent of additive manufacturing holds the promise of revolutionizing and simplifying the methods, materials, and processes involved in denture fabrication. However, certain existing constraints include the omission of try-in appointments without a dependable virtual aesthetic assessment, inadequate retention with printed polymers that necessitates relining for clinical adequacy, the inability to achieve balanced occlusion which might compromise denture stability or impact bone resorption, and the issue of long-term color instability leading to the deterioration of aesthetics.

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References

1. Gharechahi J, Asadzadeh N, Shahabian F, Gharechahi M. Dimensional Changes of Acrylic Resin Denture Bases: Conventional Versus Injection-Molding Technique. Journal of Dentistry, Tehran University of Medical Sciences. 2014; 11: 4.

2. Gao W, Zhang Y, Ramanujan D, Ramani K, Chen Y, Williams CB. The status, challenges, and future of additive manufacturing in engineering CAD/CAM. Computer-Aided Design. 2015; 14 (5): 65-89.

3. Goodacre B, Goodacre C, Baba N, Kattadiyil M. Comparison of denture base adaptation between CAD-CAM and conventional fabrication techniques. J Prosthet Dent. 2012; 116: 249-56.

4. Anusavice KJ, Shen C, Rawls RH. Phillip's Science of Dental Materials. Elsevier. 2013; 12: 99-03.

5. Al-Qarni FD, Goodacre CJ, Kattadiyili MT, Baba NZ, Paravina RD. Stainability of acrylic resin materials used in CAD-CAM and conventional complete dentures. J Prosthet. Dent. 10 06 2020, pp. 880-887.

6. Anadioti E, Musharbash L, Blatz MB, Papavasiliou G, Kamposiora P. 3D printed complete removable dental. BMC Oral Health. 2020; 343: 20.

7. Dimitrova M, Vlahova A, Kazakova R, Chuchulska B, Urumova M. Water Sorption and Water Solubility of 3D Printed and Conventional PMMA Denture Base Polymers. J of IMAB. 2023; 29(2): 4939-4942. DOI: 10.5272/jimab.2023292.4939.

8. Artopoulos A, Andrzej S, Juszczyk C, Rodriguez J, Clark R, Radford D. Three-dimensional processing deformation of three denture base materials. J. Prosthet. Dent. 2011; 110, 6.

9. Chuchulska B. Comparative study of the strength properties of injectable plastics in removable prosthetics - Doctoral dissertation., Plovdiv: MU – Plovdiv. 2021.

10. Einarsdottir RE, Geminiani A, Chochlidakis K. Dimensional stability of double-processed complete denture bases fabricated with compression molding, injection molding and CAD/CAM substraction filling. J. Prosthet. Dent. 2019.

11. Hristov Il. Contemporary analysis of soft rebasing materials and ways to deal with their shortcomings – Doctoral Dissertation., Faculty of Dental Medicine – Plovdiv. 2017.

12. Dimitrova M, Chuchulska B, Zlatev S, Kazakova R. Colour Stability of 3D-Printed and Prefabricated Denture Teeth after Immersion in Different Colouring Agents—An In Vitro Study. Polymers. 2022; 14: 3125. https://doi.org/10.3390/polym14153125.

13. Alla RK. Dental Materials Science; Jaypee Brothers Medical Publishing: New Delhi, India. 2002.

14. Keenan JP, Radford D, Clark RK. Dimensional change in complete dentures fabricated by injection molding and microwave processing. Journal of Prosthetic Dentistry. 2013; 89: 1.

15. Hada T, Suzuki T, Minakuchi S, Takahashi H. Reduction in maxillary complete denture deformation using framework material made by computer-aided design and manufacturing systems. J. Mech. Behav. Biomed. Mater. 2020; 103:103514.

16. Dimitrova M, Capodiferro S, Vlahova A, Kazakova R, Kazakov S, Barile G, Corsalini M. Spectrophotometric Analysis of 3D Printed and Conventional Denture Base Resin after Immersion in Different Colouring Agents—An In Vitro Study. Applied Sciences. 2022; 12(24): 12560. https://doi.org/10.3390/app122412560.

17. Choi JJ, Uy CE, Plaksina P, Ramani RS, Ganjigatti R, Waddell JN. Bond strength of denture teeth to heat-cured, CAD/CAM and 3D printed denture acrylics. J. Prosthodont. 2020; 29: 415-421.

18. Figuerôa S, Conterno B, Arrais G, Sugio C, Urban M, Neppelenbroek KH. Porosity, water sorption and solubility of denture base acrylic resins polymerized conventionally or in microwave. J. Appl. Oral Sci. 2018; 26: e20170383.

19. Dimitrova M, Corsalini M, Kazakova R, Vlahova A, Barile G, Dell'Olio F, Tomova Z, Kazakov S, Capodiferro S. Color Stability Determination of CAD/CAM Milled and 3D Printed Acrylic Resins for Denture Bases: A Narrative Review. Journal of Composites Science. 2022; 6(7): 201. https://doi.org/10.3390/jcs6070201.

20. Malacarne J, Carvalho RM, de Goes MF, Svizero N, Pashley DH, Tay FR, Yiu CK, Carrilho MR. Water sorption/solubility of dental adhesive resins. Dent. Mater. 2006; 22: 973-980.

21. Dimitrova M, Corsalini M, Kazakova R, Vlahova A, Chuchulska B, Barile G, Capodiferro S, Kazakov S. Comparison between Conventional PMMA and 3D Printed Resins for Denture Bases: A Narrative Review. Journal of Composites Science. 2022; 6(3): 87. https://doi.org/10.3390/jcs6030087.

22. Berli C, Thieringer F, Sharma N, Müller J, Dedem P, Fischer J, Rohr N. Comparing the mechanical properties of pressed, milled, and 3D-printed resins for occlusal devices. J. Prosthet. Dent. 2020; 124: 780-786.

23. Revilla-León M, Meyers MJ, Zandinejad A, Özcan M. A review on chemical composition, mechanical properties, and manufacturing work flow of additively manufactured current polymers for interim dental restorations. J. Esthet. Restor. Dent. 2019; 31: 51-57.

24. Arslan M, Murat S, Alp G, Zaimoglu A. Evaluation of flexural strength and surface properties of prepolymerized CAD/CAM PMMA-based polymers used for digital 3D complete dentures. Int. J. Comput. Dent. 2018; 21: 31-40.

25. Jain S, Sayed M, Ahmed W, Halawi A, Najmi, Aggarwal A, Bhandi S, Patil S. An in-vitro study to evaluate the effect of denture cleansing agents on color stability of denture bases fabricated using CAD/CAM milling, 3D-printing and conventional techniques. Coatings. 2021; 11: 962.

26. Lee DJ, Saponaro PC. Management of edentulous patients. Dent Clin North Am. 2019; 63(2): 249-61.

27. Felton DA. Complete edentulism and comorbid diseases: an update. J Prosthodont. 2016; 25(1): 5-20.

28. Thalji G, McGraw K, Cooper LF. Maxillary complete denture outcomes: a systematic review of patient-based outcomes. Int J Oral Maxillofac Implants. 2016; 31(Suppl): 169.