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Digital Complete Dentures- An Overview

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Review

History

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ABSTRACT

Purpose of review: This review provides insight into the current techniques and systems used for fabricating digital dentures.
Recent Findings: In the current era of digitalization, innovations in the field of digital dentistry have led to significant advancements in complete denture fabrication. Digital technologies may revolutionize the future of dentistry in terms of simplicity and treatment time. Complete dentures fabricated with the help of a computer-aided design and manufacturing have become increasingly popular as they result in better fit, high patient and dentist satisfaction while reducing the number of appointments.
Summary: This review focuses on different techniques and digital workflow for digital complete denture fabrication.

Keywords: CAD CAM dentures, Digital complete dentures, Digital denture workflow, Printed dentures, Milled dentures.

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Introduction

Advancement in the field of medical sciences has led to an increase in life expectancy, thereby increasing the number of completely edentulous patients requiring rehabilitation with complete dentures. Conventional complete dentures always remain a choice for most patients, because of anatomical, physiological, and financial restraints, although other treatment options like implant-supported dentures are proven efficient.[1] The limitations of Polymethyl methacrylate (PMMA) dentures like porosity, dimensional shrinkage, and bacterial adherence to the denture base have led to the development of newer materials with improved physical properties.[2,3] Modern denture base materials and techniques like milled and printed complete dentures have overcome the limitations associated with conventional dentures. They also have potentially reduced chairside time, fabrication time, and incurring costs for the dentist and dental clinic.[4,5]

A digital denture is defined as “a complete denture created by or through automation using computer-aided designing (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE)” by the Glossary of Digital Dental Terms.[6] First, the geometrical shape of an object is obtained using CAD software, and later, CAM software directs the fabrication process. Maed *et al.* first applied the 3-dimensional (3D) laser lithograph technique by using the computer-aided system in complete denture designing and fabrication. A plastic shell of resin was fabricated with transfer bases made with photo-polymerized resin and denture teeth were made with teeth-colored acrylic. Later, another study incorporated scanned transfer bases and occlusion rims into a CAD software program.[2,7,8] Virtual dentures were designed, and the base and teeth were printed using rapid prototyping, and additive manufacturing technology in individualized printed flasks.[2]

Complete Denture fabrication with computer-aided technology uses light scanning technology to obtain clinical information from the patient, which is digitized, and on computer software digital designing of complete dentures is done and a designed virtual denture in occlusion is obtained. An automated manufacturing technique (CAM), which can be subtractive (such as computerized numerical control milling) or additive (such as 3D printing), is then applied.[9,10]

In the subtractive method, a pre-polymerized resin blank is used to mill the denture base. Later, milled denture teeth or prefabricated teeth are bonded on the denture base. Monolithic dentures also use the same milling technique where the denture base and teeth are milled together.[6] The subtractive technology benefits dentists, patients, and laboratory personnel, as it shortens the duration of the procedure. Its drawbacks include high material waste, thickness limitation on the prosthesis, and poor recording details due to the size of the cutter used for milling and the expensive nature of the equipment.[11-13]

Additive manufacturing also known as rapid prototyping (RP) or 3-dimensional (3D) printing involves techniques that construct objects layer by layer. In additive manufacturing, the materials are generally based on liquid or powder to build a solid 3D model.[1,10] Additive manufacturing has high design flexibility and greater accuracy in recording details, and a negligible amount of material wastage.[9,14-16]

Digital denture (printed or milled) fabrication is done in two different methods – A complete digital protocol (scanning of hard and soft tissues intraorally) or a combination of conventional and digital fabrication techniques (recording impressions in the conventional technique, Jaw relation records, and designing digitally and denture fabrication). Earlier, a combination of conventional impressions and digital fabrication techniques was preferred which required procuring materials and trays, and equipment compatible with the particular digital system, and the denture was fabricated by specific manufacturers, However, recent advances have led to the development of open systems which allows the dentist to use their trays and materials for procedures which can be sent to the laboratory for scanning of the same, followed by designing and fabrication of the denture. These Open systems allow the in-house fabrication of dentures by the dentist if printers or milling machines are available in dental clinics.[17]

Applications of digital dentures include the fabrication of immediate dentures and implant-supported overdentures. The digital protocol can be applied for the fabrication of immediate dentures and implant-supported overdentures. For immediate denture fabrication, conventional steps for impression-making and jaw relation records are done, later these records are sent to the laboratory and can be scanned. The teeth can be extracted virtually on the virtual cast and prosthetic teeth placement can be planned. A try-in prosthesis can be printed for a try-in procedure. The final denture can be printed or milled, the natural teeth can be extracted and denture insertion can be done. Digital dentures have a few limitations like the need for relining. The use of intraoral scanners to record the denture-bearing areas requires relining and repeated adjustments of the tissue surface of the denture for accurate fit. It is not possible to digitally register interocclusal records without existing dentures.[18]

Advantages of Digital Complete Dentures

Digital complete dentures have numerous advantages over traditional complete dentures for dentists, patients, and dental technicians. In general, when compared to conventional complete dentures, both milled and printed dentures have the following advantages

1. Digital dentures can be fabricated within three to four appointments, thereby reducing the number of visits for patients. This is beneficial for elderly patients, as fewer visits to the dentist are required. The dentist and the technician can deliver the prosthesis in a more time-efficient manner.[2,19-22]
2. With fewer dental visits, the dentist spends less time in the chairside procedure.[2]
3. Digital systems have digital data stored in a repository, which does not require the making of new clinical records for the swift fabrication of replacement dentures. This is beneficial if dentures are lost or broken. The replacement dentures will have the exact contour of the old dentures, making patient adaptation easier.[2,23,24]

Advantages of milled dentures

1. Milled dentures exhibited superior fit and improved dimensional stability. This is due to the denture being milled from Pre-polymerized acrylic resin. The poly (methyl methacrylate) (PMMA) pucks are highly condensed resins as they are polymerized at high temperatures under pressure.[2,19]
2. Milled dentures showed enhanced physical and mechanical properties compared to conventional heat-polymerized PMMA.[2,25]
3. Milled bases and teeth show improved resistance to stain collection in comparison to traditional dentures.[2,26,27]
4. Monolithic dentures have the teeth as part of the denture as they are milled, compared to the techniques of denture processing used in conventional dentures; therefore, there is very little tooth movement.[2]
5. Denture teeth milled digitally as a part of a monolithic denture is not dislodged from the denture. The monolithic dentures' milled teeth enable the production of teeth of any size and form that precisely match the tooth morphology in the opposing natural dentitions.[2]

Advantages of printed dentures

1. Definitive dentures and trial dentures can be rapidly processed as printing of denture bases and denture teeth within in short time.[2,4]
2. 3D printing systems offer more environmentally friendly techniques by minimizing the use of denture resin.[2]
3. Printed dentures are cheaper compared to milling; it is affordable for both dentists and technicians and complex details can be obtained with high accuracy.[4]
4. Denture Duplication of existing dentures using 3D printing saves treatment time and material use and reduces the effect of the human factor.[4]

Disadvantages of digital complete dentures

Comparing digital complete dentures to traditional processed complete dentures, several disadvantages can be listed.

1. A Clinician has to have sufficient knowledge about using digital systems and making multiple complete dentures to achieve clinical skills.
2. Compared to traditional fabrication techniques, the cost of materials and lab fees is higher.[4]

Table 1. Advantages and Disadvantages of intra-oral scanning.

Advantages	Disadvantages
1. Mucostatic impressions can be recorded.	1. Inability to accurately record flabby due to the software's deletion of sections that aren't stable over time.
2. Decreased patient discomfort as impression materials need not be used to record impression.	2. Accuracy of the scan is affected by the length and distribution of the edentulous area, the skill of the operator, and the size of the scanner tip.
3. Elimination of stresses associated with impression distortion.	3. Difficulty in consistently capturing the border areas.
	4. Inability to other impression techniques such as pressure, selective pressure, or minimal pressure.
	5. Compressibility of the oral mucosa is difficult to assess.
	6. Recording the mandibular edentulous arch is difficult due to the movements of the tongue.[24-26]

Use of intraoral scanners/ Extraoral scanners in digital denture fabrication

Most of the systems use conventional impression techniques or the master cast that was scanned later extraorally using laboratory scanners. The accuracy of the extraoral scan depends on the conventional impressions or casts scanned. The impressions and models are sent to specific laboratories and are scanned with the help of laboratory scanners. Studies have suggested the use of intraoral scanners for recording the denture-bearing area of edentulous patients.[18,28,29] Studies have suggested the use of the buccal-occlusal-palatial (BOP) and "zig-zag" techniques mainly used for the intraoral scanning of edentulous jaws.[30] Intra-oral scanners have a few advantages and disadvantages explained in Table 1.

Digital Denture Fabrication

Digital dentures may be fabricated using a complete digital protocol or a combination of conventional and digital fabrication methods. However, the completed digital workflow for complete dentures is still debatable since it is difficult to digitally register the interocclusal records and the functional impressions. A combination of conventional impressions and jaw relation records with digital designing, and processing techniques helps fabricate the final prosthesis.[31] Data acquisition, data processing (designing), and prosthesis manufacturing are the three fundamental phases in the fabrication of a digital denture.

Data acquisition –Data may be collected directly intraorally in the dental clinic using an intraoral scanner and later electronically sent to the lab. The conventional impressions/ master casts and jaw relation records are then sent to the laboratory where they are scanned using extra-oral scanners.

Data processing: Data processing is accomplished using computer-aided designing (CAD) tools and reverse engineering.

Prosthesis manufacturing: The prosthesis may be manufactured through the subtractive or additive method.[32]

Milling

During milling dentures, once the prosthesis design has been approved, a milling software program receives the CAD stereolithography file and instructs the milling machine to do a series of motions. The artificial teeth can be milled either as part of the prosthesis (monolithic), separately, as an entire arch, or prefabricated set and bonded to the milled denture base.[32] A Pre-polymerized block can be used to mill the denture base, and a dual cross-linked block can be used to mill denture teeth, and later bonded to the denture base. A bicolored disc can be used to mill a monolithic denture; on one side, the denture base is made of high-impact PMMA, and on the other, the teeth are formed of strongly cross-linked PMMA and can be milled simultaneously.[7] Milling machine type also plays a significant role in determining the quality of milled dentures. Classification of type of milling machines is based on the number of milling axes a machine has, which can be three to five axes. The ability of the milling machine is improved by adding more axes. The milling procedure will ultimately guarantee the denture's durability and minimize manufacturing flaws. However, waste materials and the wearing of the milling burs wear are the major drawbacks of milling.[9,33]

3D-Printing

3D printing involves the process of creating objects designed digitally by linking materials successively, layer by layer. Once the digital design is completed, it is printed using a large number of successive layers of liquid or filament material. The thickness of each layer and orientation significantly affect the characteristics of the final prosthesis. As the layers lack resolution, producing an esthetic prosthesis is often challenging. Additive manufacturing includes several types such as stereo lithography, fused deposition modeling, digital light projection, and jet printing.[9]

Stereolithography (SLA)

This method uses an electron beam or UV light for polymerization for the initiation of the chain reaction of monomer and resin. The materials in liquid form are used which comprise photopolymers such as pure polymer resins, composite resins, and polyamides. Liquid resin is used to create rigid layers which are hardened layer by layer until the

3D model is completed. The completed model is later rinsed and cured in an ultraviolet oven. The 3D printed models by SLA have high resolution and quality. The thickness of each layer is determined by the energy of the light source and the duration of exposure.[9,10,15]

Fused depositing modeling (FDM)

The important aspect of this technology is the polymer's thermoplastic nature, which permits the layers to bond together during the process of printing and later solidify at room temperature after printing. Commonly used materials are Acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), and polycarbonates. The material should have a low melting point and sufficient viscosity after melting to allow it to exit the nozzle smoothly. However, it must be strong enough to hold up the subsequent layers.[9,10,15]

Digital light projection (DLP)

This is a photo-curing method that uses the principles of the SLA method. Using liquid photosensitive resins the 3D model is printed layer by layer, with the following layers being added on top of the previous layers. The DLP 3D printer's projected light source from within the clear resin tank across the platform cures the entire building layer assembly. The complete part is put together by moving a build platform dependent on the layer thickness using a computerized projector screen after each layer has been hardened. Beyond a laser projector, a digital micro-mirror is used to reflect lightand create several layer combinations. While DLP uses UV light from the digital lens's projection source, SLA uses a UV laser beam as its light source. In SLA compared to DLP, the curing is more exact and the quality is higher since the UV light source is static and cures each layer of resin at the same time. The DLP 3D printer has a light source with variable intensity.[9,10,15,34]

Material jetting

A photopolymer injection system creates the entire three-dimensional item layer by layer through a number of nozzles. The material is cured by UV radiation and shares a chemical foundation with vat photopolymerization.[9,10,15,34] (Table 2)

Workflow for Milled Denture

Several workflows for fabricating milled dentures depending on the commercially available system and number of dental visits are available. Many protocols use combined conventional and digital clinical steps. The conventional steps are then later digitized or used for clinical try-in procedures. There are numerous options to combine the production of the base with one of the denture teeth milled as shown in Table 3. The workflow with various commercially available systems for milled dentures is presented in Table 4.

Table 2: Common Additive Manufacturing Methods, advantages, disadvantages, and materials used

AM Techniques	Advantages	Disadvantages	Materials used
Stereolithography	High accuracy Adequate mechanical strength Accurate recording of details	Expensive The need for final processing Toxicity of Residual monomer	Acrylate photopolymer Plastic
Fused depositing modeling	Low cost, High speed, Easy processing	Reduced mechanical strength, low surface quality Poor variety of thermoplastic materials	Acrylonitrile butadiene Polylactic acid (PLA) Styrene (ABS) Polycarbonate Composites
Digital light Projection	Quick Production Low cost Excellent surface finish	Limited material selection Skin sensitization	Resins Photopolymers Plastic
Material Jetting	High Precision Fast build process Thin layer with high resolution	Irritant to the body	Photopolymers

Table 3. Various options for the fabrication of milled dentures

Milled Denture base	Denture teeth bonded in the milled recess of the denture base or on milled abutments	Printed Denture base
with Prefabricated Denture Teeth Set With Milled Denture Teeth set With Milled individual Denture Teeth Monolithic denture base and denture teeth	Hybrid combination of milling and printing	With Milled Denture Teeth Set With printed individual Denture Teeth With prefabricated Denture Teeth With printed individual teeth set

Table 4. Overview of Commercially Available Milled Denture System for Complete Dentures

Clinical Steps	AvaDent® Digital Dentures	Ivoclar digital denture TM	Ceramill® full denture system	Baltic denture system
1st appointment	Intra-oral scanning the edentulous jaws using an intraoral scanner Final impression, Recording vertical and horizontal jaw relation	Primary impression Recording vertical and horizontal jaw relation occlusal plane determination Papillometer upperlip length+lip closure line	Final impression Recording vertical and horizontal jaw relation (Ceramill Transferkit)	Final impression using specific trays(upper and lower KEY, 3 sizes)
2nd appointment	Try in, checking aesthetics and functional aspects.	Final impressions with milled customized trays Recording vertical and horizontal jaw relation(gothic arch tracing)	Try in, checking aesthetics and functional aspects.	Determination of vertical and horizontal jaw relation(gothic arch tracing)
3rd appointment	Denture insertion Checking for fit of the tissue surface and correction of occlusal errors.	Try-in of milled monolithic trial dentures (Ivobase CAD+individual manufactured or milled denture eeth	Denture insertion Checking for fit of the tissue surface and correction of occlusal errors.	Denture insertion Checking for fit of the tissue surface and correction of occlusal errors.
4th appointment		Denture insertion Checking for fit of the tissue surface and correction of occlusal errors.		
Method of fabrication	Milled bases with bonded teeth or the teeth and denture bases milled as a single unit.	Milled base with recesses for denture teeth	Milled base with recesses for denture teeth	Milled prefabricated base with denture teeth

Table 5. Overview of commercially available printed denture system for complete dentures

Clinical Steps	Dentca Digital Dentures
1st appointment	Impression with specific trays Recording vertical and horizontal jaw relation (Gothic arch tracing) upper lip length measured with lip ruler and incisal edge position Try in on demand
2nd appointment	Denture insertion Checking for fit of the tissue surface and correction of occlusal errors.
Method of fabrication	Printed base with recesses for denture teeth

Table 6. Comparison between Printed and milled dentures.

Printed Dentures	Milled dentures
The cost of equipment is less	High cost of equipment
Non-polymerized resin can cause skin reactions	Highly cross polymers used in the fabrication
Polymerization shrinkage	No polymerization shrinkage
Printed teeth lack a variety of shapes and shades	Milled teeth Have more choices
Do not exhibit surface details (root Prominence)	Enhanced esthetics

Workflow for Printed Denture

There are numerous options to combine the fabrication of the base with the one of the denture teeth milled as shown in Table 3. The workflow with various commercially available systems for printed dentures is presented in Table 5.

Physical Properties

1. Flexural strength- studies have compared the flexural strength of conventional heat-polymerized PMMA to both printed and milled denture base materials. Milled denture base materials showed higher flexural strengths in comparison to printed and conventional PMMA. Milled dentures use PMMA pucks that are processed under significantly higher temperatures and pressure resulting in dense material with lesser voids. This procedure enables the fabrication of milled dentures with thinner dimensions while maintaining acceptable strength.[35-38]
2. Fracture Toughness- studies compared the fracture toughness among conventional, milled, and printed dentures. Printed dentures showed less fracture toughness in comparison with the two other groups.[38,39]
3. Color Stability – several studies examined the color stability in milled, conventional, and printed denture materials and found that the printed resin group showed considerably larger color changes. It is attributed to increased water sorption seemed to be higher in printed denture materials. Surface deterioration, and factors relating to the mixing, polymerization, and post-processing of the printed material, could all be contributing factors to the decreased color stability.[39-41]
4. 4.Denture tooth bond strength- literature reports that the bond strength of printed denture base with printed teeth is lower than observed with conventional

processes of denture base and teeth. The printed group showed both adhesive and cohesive failures.[42,43]

5. Denture base adaptation- Milled dentures of exhibited superior denture base adaptation when compared with conventional processed dentures.[27,44] Milled dentures also showed improved retention. Printed dentures showed poor denture base adaptation when compared with milled dentures.[27,39]
6. Surface Characteristics- After polishing, milled dentures showed superior surface
7. characteristics than 3D printed and conventional dentures.[2,39,45] (Table 6).

Conclusions

Digital technology permits dentists to provide dentures that are highly esthetic, strong, and have better patient outcomes. The dentures can be fabricated in three to four clinical visits, which is beneficial to the clinician, technician, and patient. A better understanding of the indications, workflow, and limitations of the various digital systems used to fabricate complete dentures can promote simplified protocols for dentures, patient satisfaction clinical efficiency, and favorable long-term outcomes. With the aid of a fully functional laboratory, digital dentures can be largely or nearly totally incorporated into clinical practice to effectively increase clinical efficiency, communication, and outcomes.

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References

1. Anadioti E, Musharbash L, Blatz MB, Papavasiliou G, Kamposiora P. 3D printed complete removable dental prostheses: A narrative review. BMC Oral Health. 2020;27:343.
2. Marinello CP, Brugger R. Digital removable complete denture—An overview. Current Oral Health Reports. 2021;8:117-131.
3. Mert D, Kamnoedboon P, Al-Haj Husain N, Özcan M, Srinivasan M. CAD CAM complete denture resins: Effect of relining on the shear bond strength. Journal of Dentistry. 2023;131:104438.
4. Alhallak K, Hagi-Pavli E, Nankali A. A review on clinical use of CAD/CAM and 3D printed dentures. Br Dent J. 2023.
5. Schweiger J, Stumbaum J, Edelhof D, Guth JF. Systematics and concepts for the digital production of complete dentures: Risks and opportunities. Int J Comput Dent. 2018;21:41-56
6. Grant GT, Campbell SD, Masri RM: The American College of Prosthodontists Digital Dentistry Glossary Development Task Force. Glossary of digital dental terms. J Prosthodont. 2016; 25:S2–S9.
7. Baba NZ, Goodacre BJ, Goodacre CJ, Müller F, Wagner S. CAD/CAM complete denture systems and physical properties: A review of the literature. J Prosthodont. 2021;30:113-124
8. Sariga K, Harsha KK, Ravichandran R. An update on CAD/CAM removable complete dentures: A review on different techniques and available CAD/CAM denture systems. International Journal of Applied Dental Science. 2021;7:491-498.
9. Abedini A, Kazem SM, Behboodyzad SF. A literature review of 3D printing In dental prosthesis. Journal of Pharmaceutical Negative Results. 2022;13:2039-2050.
10. Schweiger J, Edelhoff D, Güth JF. 3D printing in digital prosthetic dentistry: An overview of recent developments in additive manufacturing. J Clin Med. 2021;7:2010.
11. Goodacre CJ, Goodacre BJ, Baba NZ. Should digital complete dentures Be part of a contemporary prosthodontic education? J Prosthodont. 2021;30:163-169.
12. Maragliano-Muniz P, Kukucka ED. Incorporating digital dentures into clinical practice: Flexible workflows and improved clinical outcomes. J Prosthodont. 2021;30:125-132.
13. Kim TH, Huh JB, Lee J, Bae EB, Park CJ. Retrospective comparison of postinsertion maintenances between conventional and 3D printed complete dentures fabricated in a predoctoral clinic. J Prosthodont. 2021;30:158-162.
14. Wagner SA, Kreyer R. Digitally fabricated removable complete denture clinical workflows using additive manufacturing techniques. J Prosthodont. 2021;30:133-138.
15. Tian Y, Chen C, Xu X, Wang J, Hou X, Li K, et al. A review of 3D printing in dentistry: Technologies, affecting factors, and applications. Scanning. 2021;17:9950131.
16. Charoenphol K, Peampring C. Fit accuracy of complete denture base fabricated by CAD/CAM milling and 3D-printing methods. Eur J Dent. 2022;2022:13.
17. Lo Russo L, Zhurakivska K, Guida L, Chochlidakis K, Troiano G, Ercoli C. Comparative cost analysis for removable complete dentures fabricated with conventional, partial, and complete digital workflows. J Prosthet Dent. 2022;31:S0022.
18. Rasaie V, Abduo J, Hashemi S. Accuracy of intraoral scanners for recording the denture bearing areas: A systematic review. J Prosthodont. 2021;30:520-529.
19. Srinivasan M, Schimmel M, Naharro M, O'Neill C, Mckenna G, Müller F. CAD/CAM milled removable complete dentures: Time and cost estimation study. J Dent. 2019;80:75-79.
20. Arakawa I, Al-Haj Husain N, Srinivasan M, Mankiewicz S, Abou-Ayash S, Schimmel M. Clinical outcomes and costs of conventional and digital complete dentures in a university clinic: A retrospective study. J Prosthet Dent.2022;128:390-395.
21. Chappuis Chocano AP, Venante HS, Bringel da Costa RM, Pordeus MD, Santiago Junior JF, Porto VC. Evaluation of the clinical performance of dentures manufactured by computer-aided technology and conventional techniques: A systematic review. J Prosthet Dent. 2021;129:547-553.
22. Peroz S, Peroz I, Beuer F, Sterzenbach G, von Stein-Lausnitz M. Digital versus conventional complete dentures: A randomized, controlled, blinded study. The Journal of Prosthetic Dentistry. 2022 ;128(5):956-963.
23. Ammoun R, Bencharit S. Creating a digital duplicate denture file using a desktop scanner and an open-source software program: A dental technique. J Prosthet Dent. 2021;125:402-416
24. Takeda Y, Lau J, Nouh H, Hirayama H. A 3D printing replication technique for fabricating digital dentures. J Prosthet Dent. 2020;124:251-256
25. Steinmassl O, Dumfahrt H, Grunert I, Steinmassl P-A. Influence of CAD/CAM fabrication on denture surface properties. J Oral Rehab. 2018;45:406-413
26. Al-Qarni FD, Goodacre CJ, Kattadiyil MT, Baba NZ, Paravina RD. Stainability of acrylic resin materials. J Prosthet Dent. 2020;123:880-887.
27. Kalberer N, Mehl A, Schimmel M, Müller F, Srinivasan M. CAD-CAM milled versus rapidly prototyped (3D-printed) complete dentures: An in vitro evaluation of trueness. J Prosthet Dent. 2019;121:637- 643.

28. Yoon HI, Hwang HJ, Ohkubo C, Han JS, Park EJ. Evaluation of the trueness and tissue surface adaptation of CAD-CAM mandibular denture bases manufactured using digital light processing. J Prosthet Dent. 2018;120:919-926.

29. Afrashtehfar KI, Alnakeb NA, Assery MKM. Accuracy of intraoral scanners versus traditional impressions: A rapid umbrella review. J Evid Based Dent Pract. 2022;22:101719.

30. Unkovskiy A, Wahl E, Zander AT, et al. Intraoral scanning to fabricate complete dentures with functional borders: A proof-of-concept case report. BMC Oral Health. 2019;13:46.

31. Lee H-J, Jeon J, Moon HS, Oh KC. Digital workflow to fabricate complete dentures for edentulous patients using a reversing and superimposing technique. Applied Sciences. 2021;11:5786

32. Punj A, Fisselier F. Digital dentistry for complete dentures. A review of digital dentistry versus conventional approaches to complete dentures. Decisions. Dentistry. 2020;6:12-14

33. Soeda Y, Kanazawa M, Arakida T, Iwaki M, Minakuchi S. CAD-CAM milled complete dentures with custom disks and prefabricated artificial teeth: A dental technique. J Prosthet Dent. 2022;127:55-58.

34. Nulty A. A literature review of 3D printing materials in dentistry: Part four. Clinical Dentistry. 2022;2:44-49

35. Pacquet W, Benoit A, HatègeKimana C, Wulfman C. Mechanical properties of CAD/CAM Denture Base resins. Int J Prosthodont. 2019;32:104-106.

36. Aguirre BC, Chen JH, Kontogiorgos ED, Murchison DF, Nagy WW. Flexural strength of denture base acrylic resins processed by conventional and CAD-CAM methods. J Prosthet Dent. 2020;123:641-646.

37. Prpić V, Schauperl Z, Ćatić A, Dulčić N, Čimić S. Comparison of mechanical properties of 3D-printed, CAD/CAM, and conventional denture base materials. J Prosthodont. 2020;29:524-528.

38. de Oliveira Limírio JPJ, Gomes JML, Alves Rezende MCR, Lemos CAA, Rosa CDDRD, Pellizzer EP. Mechanical properties of polymethyl methacrylate as a denture base: Conventional versus CAD-CAM resin - a systematic review and meta-analysis of in vitro studies. J Prosthet Dent. 2022;128:1221-1229.

39. Srinivasan M, Kamnoedboon P, McKenna G, Angst L, Schimmel M, Özcan M, et al. CAD-CAM removable complete dentures: A systematic review and meta-analysis of the trueness of fit, biocompatibility, mechanical properties, surface characteristics, color stability, time-cost analysis, clinical and patient-reported outcomes. Journal of Dentistry. 2021;113:103777.

40. 40. Gruber S, Kamnoedboon P, Özcan M, Srinivasan M. CAD/CAM complete denture resins: An In vitro evaluation of color stability. J Prosthodont. 2021;30:430-439.

41. Dimitrova M, Corsalini M, Kazakova R, Vlahova A, Barile G, Dell'Olio F, et al. Color stability determination of CAD/CAM milled and 3D printed acrylic resins for denture bases: A narrative review. Journal of Composite Science. 2022;6:201.

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

43. Alharbi N, Alharbi A, Osman RB. Mode of bond failure between 3D-printed denture teeth and printed resin base material: Effect of fabrication technique and dynamic loading. An in-vitro study. Int J Prosthodont. 2021 ;34(6):763–774.

44. Wang C, Shi YF, Xie PJ, Wu JH. Accuracy of digital complete dentures: A systematic review of in vitro studies. J Prosthet Dent. 2021;125:249-256.

45. Srinivasan M, Kalberer N, Kamnoedboon P, Mekki M, Durual S, Özcan M, et al. CAD-CAM complete denture resins: An evaluation of biocompatibility, mechanical properties, and surface characteristics. Journal of Dentistry. 2021;114:103785.