A Comprehenive Review On Digital Denture Technology

Singh A [1], Sreekumar S [2], Kumar A[3] , Thomas R B [4] Patil M P [5]

Cite this paper as: Singh A, Sreekumar S, Kumar A , Thomas R B, Patil M P (2024) A Comprehenive Review On Digital Denture Technology. *Frontiers in Health Informatics, 13* (3),8075-8088

Abstract
Advancements in science and technology have brought a revolution in health and medicine. With increasing life expectancy over coming decades, there will be a rise in demand for complete dentures. This has led to a need for improved technical quality and service. Prosthodontics has transformed with the introduction of digital technologies. Innovative digital manufacturing technologies such as 3D printing (additive manufacturing) computer-aided design/manufacturing (subtractive manufacturing) have revolutionized the speed and convenience of treatment delivery. Different manufacturers have followed various protocols in the fabrication of complete dentures. However, there is a need for better collation and comparison of these protocols. An electronic search was conducted in the PubMed/MEDLINE, ScienceDirect, Google Scholar, and Web of Science databases. Databases were searched from 1992 up to 2022 . The search was performed using a variety of keywords including CAD/CAM, complete/partial dentures, RP, rapid manufacturing, digitally designed, milled, computerized, and machined. Using a variety of keywords and aiming to find the topic, 104 publications were initially searched. For the main topic, the abstract of these 104 articles were scanned, and 64 publications were selected for reading in detail. Full text of these articles was gained and searched in detail. Totally, 34 articles that discussed the techniques (scanning and milling protocols), advantages, and disadvantages of CAD/ CAM and RP for removable denture fabrication, financial implications, patient satisfaction and the articles were incorporated in this review.

Introduction

The demand for complete dentures is projected to see a significant rise in the coming decades due to an aging population and increased awareness of oral health. Digital technologies have notably revolutionized the manufacturing process of both partial and complete dentures. Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM), which is a subtractive technology, and 3D printing, which is an additive technology, are at the forefront of this transformation. These digital manufacturing technologies are anticipated to bring substantial changes to dental treatment protocols. The integration of CAD/CAM and 3D printing in denture fabrication enhances precision, customizability, and efficiency. As a result, these advancements are likely to considerably improve the speed and simplicity of dental procedures in the near future, making high-quality dental care more accessible and efficient for patients. [1, 2].Fabricating a traditional complete denture involves multiple complex steps, which can be challenging for the dentist, technician, and the patient. As a result, there is a growing need to adopt digital technology to streamline the fabrication process. With the evolution of digital technology, the number of appointments required for creating digital dentures has been reduced to 2–4 sessions. [3]. Apart from Saving treatment time, retaining the patient data adds on to the benefits of digital dentures.

Computer-Aided Design (CAD) software renders an object's geometry by creating a detailed and accurate visual representation in a virtual 3D space. This allows designers to manipulate and refine the object's shape, size, and structure before production begins. On the other hand, Computer-Aided Manufacturing (CAM) software takes this digital model and translates it into precise instructions for manufacturing equipment. CAM software controls the fabrication process, ensuring the physical object is produced accurately according to the CAD design.[4]. Since its early inception in the 1980s, when Andersson coupled the concepts of copy milling and quick digitization of single fixed dental prosthesis, computer-aided design/computer-aided manufacturing, or CAD/CAM, has made significant contributions to the profession of dentistry. With the launch of Global Dental Science's Avadent™ digital denture in 2013, CAD/CAM technology began to revolutionize the production of complete dentures. This breakthrough marked a significant shift from traditional denture fabrication methods to more advanced, digital approaches. The Avadent™ system utilized CAD (Computer-Aided Design) software to create precise digital models of a patient's oral anatomy. These models were based on detailed scans and measurements, allowing for a highly accurate representation of the patient's mouth.

Once the digital design was finalized, CAM (Computer-Aided Manufacturing) technology took over to fabricate the dentures. The CAM process involved using computerized milling machines or 3D printers to produce the denture base and teeth with exceptional precision. This method ensured a more accurate fit and improved the overall quality of the dentures, significantly enhancing patient comfort and satisfaction The introduction of digital dentures like Avadent™ led to several key advancements in the field of prosthodontics. [5] Various companies have been introduced ever since.

The aim of this article is to compile information about the evolution of digital dentures, emphasizing scanning protocols and the compatibility of different software and systems. There is a deficiency in the existing literature on these topics

Research Question

I. How has digital dentistry evolved in terms of complete denture?

II. What differences are there between digital v/s conventional dentures?

III. What is the various scanning and milling options offered by different manufactures? (i.e. digital workflow of multiple systems)

IV. What is the available data on financial implications and patient satisfaction?

Methodology, search

This narrative review is based on preclinical and clinical studies in English without restrictions regarding year of publication. The review focused on the following questions.

An electronic search was conducted in the PubMed/MEDLINE, ScienceDirect, Google Scholar, and Web of Science databases. Databases were searched from 1992 up to 2022 . The search was performed using a variety of keywords including CAD/CAM, complete/partial dentures, RP, rapid manufacturing, digitally designed, milled, computerized, and machined. Using a variety of keywords and aiming to find the topic, 104 publications were initially searched. For the main topic, the abstract of these 104 articles were scanned, and 64 publications were selected for reading in detail. Full text of these articles was gained and searched in detail. Totally, 34 articles that discussed the techniques (scanning and milling protocols), advantages, and disadvantages of CAD/ CAM and RP for removable denture fabrication, financial implications, patient satisfaction and the articles were incorporated in this review.

The inclusion criteria consisted of the following: (I) full-text original studies in the English language; (ii) research articles demonstrating the effect(s) digital dentures and digital workflow; and (iii) experimental studies involving the clinical success of digital dentures vs conventional denture (iv) Availability of different scanning protocol and milling systems. The references contained in original articles and review articles were also searched for possible inclusion. No further inclusion criteria were applied.

Timeline and Evolution of Dentures

The contemporary method of manufacturing crowns, bridges, or removable dentures involves a lot of labor-intensive work and processing, which leads to the loss of a lot of information and a lengthy turnaround time. The automotive and aerospace sectors were the first to use integrated CAD/CAM and rapid prototyping technologies. With the use of these processes, complex, customized items can be made right away without the need for laborious intermediate steps like the creation of dental moulds. These days, a lot of dentists are designing and creating dental restorations using these technologies. Dentists have adopted several commercially accessible CAD/CAM systems, including CEREC, DentiCAD, Duret, and others. Computerized design and manufacturing, initiated by reverse engineering, utilizes a CCD camera for imaging and a 3-axis milling machine for prosthesis fabrication, while a Coordinate Measurement Machine (CMM) digitizes objects to generate a CAD model [6]. Designers can mimic real-world situations and study things in multiple representations using CAD. CAM handles automated machines with CAD. CAM systems resemble CNC computer numerical control and DNC Direct numerical control. Mechanical geometrical data encoding distinguishes these systems from NC numerical control variants. Replicate dentures were CNC machined from wax [7]. Williams et al. created a metal frame using 3D models of removable partial prosthetic frameworks using digital moulds and electronic surveying [8]. Their method simplified the RP denture equator and tooth retentive zone definition. Eggbeer et al. (2005) invested-cast the prosthesis and built an RP sacrificial model [9]. This process was complicated. A 2006 clinical case study by Bibb et al. documented using CAD/CAM and RP to create a metal frame. With RP, they made prototype epoxy resin replaced wax in metal frame prep. Soft and rigid tissues adjusted to the metal structure [10]. Kanazawa et al. (2012) digitally assembled prosthetic and denture teeth using CBCT scans. The teeth were manually glued into denture foundation holes after CNC cutting an acrylic resin prosthetic base block [11].

Digital vs Conventional Dentures (TABLE 1.)Clinical and laboratory steps for conventional dentures are complex. A precise preliminary and final impression of the alveolar ridges is taken with border moulding and jaw relationship recording. Stone casts are attached to a semi-adjustable articulator with a facebow. The lab technician creates wax dentures with various sizes and shapes of prosthetic teeth for dentist and patient evaluation. Permanent dentures are manufactured after acceptance or changes [12, 13] (Paulino et al., 2015; Hsu, 2021). Recent advancements have streamlined prosthetic denture production by condensing multiple stages into a single visit and removing the aesthetic try-in step, aiming to enhance efficiency and patient comfort. [14]. However, the procedure of making traditional dentures has not changed [15]. While intraoral digital imprints can digitize edentulous jaws, the accuracy in capturing soft tissue is questioned [16]. Digital recordings enable denture reproduction when needed [Hirayama et al., 2019]. Digital denture technology creates acrylic resin dentures by additive printing or subtractive milling [3]. According to Baba et al. (2021) and Mubaraki et al. (2022), these dentures have a higher base fit and retention than conventional heat-polymerized dentures, require less labor, and may be completed in two appointments [17, 18]. Digital dentures exhibit good short-term clinical performance, positive patient outcomes, and appropriate time-cost effectiveness [19, 20]. Limited randomized clinical trials exist to indicate the greater efficacy of digital dentures over conventional prosthesis in terms of patient satisfaction and clinical outcomes.

3D-printed complete removable dental prostheses

3D printing can improve denture manufacturing processes, materials, and operations. [21].

Well-designed clinical studies are essential to validate the benefits of using 3D-printed complete dentures over traditional techniques, addressing constraints like unreliable virtual evaluations, retention issues, occlusion imbalance, stability concerns, bone resorption, and long-term color instability. [22]. These prostheses fulfil essential social and physiological needs for patients and have remained relatively consistent over time. [23]. Most standard CRDPs are made from polymer polymethyl methacrylate. Patients accept the material because of its biocompatibility, attractiveness, and ease of processing [24]. PMMA exhibits high polymerization shrinkage, oral bacteria colonization, have zero radio-opacity, exhibit allergic responses, mechanical degradation is also seen and low saliva wear resistance. These restrictions have led to new additive and subtractive materials and production methods [25] [Gautam et al., 2012]. Layer-by-layer object production is additive manufacturing (AM), often known as 3D printing or rapid prototyping (RP).Although young, 3D printing offers potential in engineering, medicine, and dentistry.

DIGITAL WORKFLOW

The workflow of any digital dentures starts with patient selection. Many patients may present with old dentures that they are unhappy with. In such cases, the old dentures can be used as a reference for teeth position, inter-occlusion relation, retention and esthetics and this technique is called the "Reference Denture technique". However, this technique should be avoided if the patient is unhappy with his/her current dentures or if the old dentures are unserviceable.

The scanning is either in a dental clinic using intra-oral scanners, wherein the scanning is done directly in the patient's mouth, or it is done in the laboratory with extra-oral scanners which scan from either impressions of edentulous ridges or the master models.

Impressions are taken on the existing denture or a commercially available tray. Border moulding is done using regular body Poly Vinyl Siloxane (PVS) and a wash impression is made using light body PVS. Horizontal and vertical dimensions are determined on the existing dentures or specific trays or using an anatomical measuring device (AMD)

[26]. Additionally, face scanners have been introduced by which data can be superimposed on the facial skeleton and soft tissues[27]. After scanning, data is sent to the CAM machine tool. CAM machines can be additive (Rapid prototyping procedure) or the more common, subtractive process (computerized numerical control milling). The workflow can be described in the given table 2

Scanning

The availability of different scanners and their utilization in different technologies varies. Coherent light tomography (E4D-D4D Technologies LLC), triangulation (Cerec Bluecam-Sirona), interferometry (DPI-3D-Dimensional photonics International Inc.), wavefront sampling (TrueDefinition scanner-LAVA 3M), confocal microscopy (Trios-3Shape) etc. Data can be taken either through still images (e.g. Cerec) or by video (e.g. Trios). Some of the techniques are listed in Table 3and different devices used for fabricating Digital Dentures are listed in Table 4.

Try-in

Denture prototypes can be fabricated digitally which has the added advantage of being heat resistant and more accurate than heat curing. Although it may seem like an unnecessary added step, it helps to test the prototype denture for any faults and helps prevent financial loss in case if denture were to fail. Three methods are commonly followed for try-in i.e. Bouma Try-In (BTI), Wagner Try-In (WTI) and Hybrid Try-In. The Bouma Try-In is done with a fully milled or printed monolithic prosthesis that is completely tooth colored or has a regular denture-like color. This can also be used as a spare denture. The WTI is a combination of conventional try-in and digital process. Specially formulated wax is used that softens with hot water, allowing movement of teeth. The maxillary anterior teeth are printed and placed in wax and the posterior teeth are stationary bite stops likewise, mandibular anterior are printed and placed in the special wax to establish desired overbite and overjet. Hybrid Try-in involves utilizing a monolithic piece that is a replica of the final designed denture. Changes are made by grinding and polishing. These changes can be transferred to the final denture [28].

InLab MC XL (Dentsply Sirona):

1. Scanning:

Dentsply utilizes inEOSX5 for digital dentures. Apart from these two types of scanners i.e. Primescan and Omnicam. Primescan is used for crowns, bridges, implants splints and surgical guides. Omnicam is smaller, giving an added advantage of access to smaller and difficult-to-reach areas. An In-vitro study concluded that Primescan gave better results for trueness index (4.79 µm) than Omnicam (19.13 µm).

2. CAD Design:

Design is done by the inLab CAD software. The software utilizes a unique tool called the “Biojaw algorithm” which uses biostatistical analysis to formulate a patient-specific prosthesis. It also has a virtual articulator function to determine static and dynamic occlusion.

3. CAM Milling:

The Sirona Iblab MC X5 is a five-axis milling machine. It has a milling trueness of (62.1 ± 17.1 µm).

Roland DWX Series:

1. Open Architecture: Roland DGA's open architecture DGSHAPE DWX-42W Chairside Milling Solution provides the option to save scanned information in a common format which can be sent to other mills or printers.
2. Milling Technology:

Roland DWX offers a 5-axis milling system.

3. Material Flexibility:

Materials commonly used with Roland DWX are Zirconia, Wax, Poly Methyl Methacrylate, Composite resin, Poly Ether Ether Ketone, Gypsum, Fiber reinforced resin and CoCr soft metal. Owning to the 5-milling axis, it is favoured for removable prostheses with PEEK material.

Planmeca PlanMill 40 S:

1. Intraoral Scanning:

The scanner used is Planmeca PlanScan. It has the added advantage of providing combined intraoral scanning and digital three-dimensional impressions.

2. Software:

Software compatible with Planmeca devices is PlanCad.

3. Milling Unit:

The machine has a compact design with a 4-axis milling system. It is known to be an intelligent unit with the feature of Automatic 10 tool changer which changes worn burs with appropriate burs and helps ensure required efficiency.

3Shape

1. Intraoral scanning: 3Shape has TRIOS scanners available in three models i.e. TRIOS 3, TRIOS 4 and TRIOS 5. Trueness for TRIOS 5 was 17.3 to 59 micros while TRIOS 4 was 20.8 microns
2. Software: 3Shape Dental System CAD Software, has a virtual articulator that enables all classical jaw movements (protrusion, retrusion, laterotrusion, mediotrusion and immediate side shift)
3. Milling unit: 3Shape doesn't have its milling unit but is compatible with most CAM devices available in the market.

Dental Wings

scanning: 3Series Model scanner 90 × 90 × 90 mm chamber and the 7Series Model and impression scanner has a diameter of 140 × 140 × 140 mm

Software: Dental Wings operates on DWOS software. DWOS Synergy links the DWOS and the coDiagnostiX systems which helps the dentist and the lab technician to make an appropriate treatment plan in real time.

Milling: Thw DWOS system is compatible with DWX CAM units.

Ivoclar Vivadent

Scanning and software: The PrograScan PS7 can scan maxillary and mandibular models simultaneously. Ivoclar also provides Ivoclar Smile software for consultations, where in the dentist can help the patient visualize the changes with a “virtual mirror” that is compatible with iPhone and iPad

Milling: PrograMill PM7 is a 5-axis milling machine used with Ivotion which is monolithic high-quality PMMA material.

Amann Girrbach

Intraoral scanning: Amann Girrbach promotes their Ceramil Map scanners including Ceramill Map 200+, Ceramill Map 600+, Ceramil MapFX and Ceramill DRS Connection kit for scanning.

Software: The software used is Ceramill D-Flow which is a component of Ceramill Full Denture System (FDS)

Milling: Compatible with Ceramill Matik with a 5-axis milling machine (Saponaro et al., 2016).

Financial Implications (Cost-effectiveness)

The cost of removable complete dentures made with conventional, partial, and total digital workflows was compared. Lucio Lo Russo et al. found that partial and complete digital workflows were more efficient and cost-effective than conventional methods of fabricating removable complete dentures, with digital plus conventional workflow having the lowest opportunity and variable costs and break-even point. Replacement of standard denture teeth with milled and 3D-printed teeth increased savings. Denture base milling materials and equipment cost more than 3D-printing. Milling monobloc dentures raised material costs but decreased opportunity and labor expenses [29].

In another university study, milled and traditional complete dentures were compared for cost. The personalized disc procedure enhanced patient satisfaction, according to Ryosuke Otake et al. Custom discs were far less than detachable complete dentures in labor and expense. The incremental cost-effectiveness ratio showed that the bespoke disc approach was cheaper than detachable complete dentures expense [30].

Despite higher material costs, Swiss researchers found digital denture protocol cheaper and time-efficient than conventional methods in a university clinic, benefiting elderly and complex edentulous patients with reduced clinical procedures, visits, treatment time, and expenses. [31].

Patient Satisfaction

Patient satisfaction with CAD/CAM dentures was consistently high according to multiple researchers [32]. Rapid prototyping of CAD/CAM dentures improves satisfaction due to shorter construction time and enhanced retention, aligning with similar conclusions from other studies. However, Ohara found differing results in patient satisfaction between digital (3D-printed) and traditional dentures [33]. Ohara's study revealed traditional dentures were preferred over digital ones due to better satisfaction in phonetics, comfort, stability, and overall quality of life, despite fewer clinical appointments for digital dentures. Other research emphasizes aesthetics' impact on patient satisfactions, they said printed teeth look worse than ordinary ones [34]. More research to ensure efficacy and success is required.

Limitations

This review does not depict the graphical representation of the digital workflow involved in fabricating digital dentures. Additionally, due to the lack of clinical studies in this field, no conclusive results can be made regarding the long-term success of digital dentures.

Discussion

The findings of this review emphasize the significant advancements in the field of digital denture technology. It highlights the ability of it for attaining better patient satisfaction, improved efficiency in the process of denture fabrication and also increased clinical outcomes. In spite of high initial financial charges and challenges related to taking precise digital impression of edentulous arches, digitally made dentures have been showing advantages over the traditional method of denture fabrication. Reduction in time taken for clinical procedure, higher retention, and its ability to document digital data for the future use are a few in the list. Still, the review underscores the need for conducting accurate clinical trials to resolve persistent problems like wastage of material, inaccuracies in occlusion and aesthetic concerns. Improper occlusion and cosmetic concerns often warrant additional visits for corrections. Digital denture previews on screens are challenging to evaluate compared to intraoral wax dentures. Even though many steps are streamlined by digital workflow, the variability in scanning protocols and milling systems, across different manufacturers indicate a need for standardization. Furthermore, research to optimize these processes for broader clinical applications are also required.

Future References

The digital revolution in dentistry impacts both clinical and lab stages of removable prosthodontics. Literature evaluates feasibility and accuracy, with promising workflows. Challenges exist in optical scanning for edentulous arches, but denture finalization shows more robust evidence. 3D printers are intriguing, especially for patients with existing prostheses, yet recording aesthetic and occlusal alterations remains unclear.

References

I. Goodacre CJ, Garbacea A, Naylor WP, Daher T, Marchack CB, Lowry J. CAD/CAM fabricated complete dentures: concepts and clinical methods of obtaining required morphological data. J prosth dent 2012.1;107(1):34-46.

II. Kattadiyil MT, Goodacre CJ, Baba NZ. CAD/CAM complete dentures: a review of two commercial fabrication systems. J Califor Dent Ass 2013. 1;41(6):407-16.

III. Smith PB, Perry J, Elza W. Economic and clinical impact of digitally produced dentures. J Prosthodont 2021.30(S2):108-12.

IV. Anadioti E, Kane B, Soulas E. Current and emerging applications of 3D printing in restorative dentistry. Curr Oral Heal Rep 2018.5:133-9.

V. Bilgin MS, Erdem A, Aglarci OS, Dilber E. Fabricating complete dentures with CAD/CAM and RP technologies. J Prosthodont 2015. 24(7):576-9.

VI. Chang CC, Lee MY, Ku YC. Digital custom denture design with new abrasive computer tomography and rapid prototyping technologies. Biomed Eng: App, Basis Comm 2003. 25;15(03):115-23.

VII. Kawahata N, Ono H, Nishi Y, Hamano T, Nagaoka E. Trial of duplication procedure for complete dentures by CAD/CAM. J oral rehab 1997.24(7):540-8.

8. Williams RJ, Bibb R, Rafik T. A technique for fabricating patterns for removable partial denture frameworks using digitized casts and electronic surveying. J pros dent 2004. 1;91(1):85-8.

IX. Srinivasan M, Kalberer N, Naharro M, Marchand L, Lee H, Müller F. CAD-CAM milled dentures: The Geneva protocols for digital dentures. J prosthet dent 2020.1;123(1):27-37.

X. Williams RJ, Bibb R, Eggbeer D, Collis J. Use of CAD/CAM technology to fabricate a removable partial denture framework. J pros dent 2006.1;96(2):96-9.

XI. Saponaro PC, Yilmaz B, Johnston W, Heshmati RH, McGlumphy EA. Evaluation of patient experience and satisfaction with CAD-CAM-fabricated complete dentures: A retrospective survey study. J pros dent 2016.1;116(4):524-8.

XII. Paulino MR, Alves LR, Gurgel BC, Calderon PS. Simplified versus traditional techniques for complete denture fabrication: a systematic review. J pros dent 2015. 1;113(1):12-6.

XIII. Hsu YJ, Lin JR, Hsu JF. Patient satisfaction, clinical outcomes and oral health-related quality of life after treatment with traditional and modified protocols for complete dentures. J Dent Sci 2021. 1;16(1):236-40.

XIV. Bilgin MS, Baytaroğlu EN, Erdem A, Dilber E. A review of computer-aided design/computer-aided manufacture techniques for removable denture fabrication. Euro j dent 2016.10(02):286-91.

XV. Eggbeer D, Bibb R, Williams R. The computer-aided design and rapid prototyping fabrication of removable partial denture frameworks. Proceedings of the Institution of Mechanical Engineers, Part H: J Eng Med 2005.1;219(3):195-202.

XVI. Cunha TR, Della Vecchia MP, Regis RR, Ribeiro AB, Muglia VA, Mestriner Jr W, De Souza RF. A randomised trial on simplified and conventional methods for complete denture fabrication: masticatory performance and ability. J dent 2013. 1;41(2):133-42.

XVII. Ceruti P, Mobilio N, Bellia E, Borracchini A, Catapano S, Gassino G. Simplified edentulous treatment: A multicenter randomized controlled trial to evaluate the timing and clinical outcomes of the technique. J Pros Dent 2017. 1;118(4):462-7.

XVIII. AlRumaih HS. Clinical applications of intraoral scanning in removable prosthodontics: a literature review. J Prosthodont 2021.30(9):747-62.

XIX. 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(S2):113-24.

XX. Mubaraki MQ, Moaleem MM, Alzahrani AH, Shariff M, Alqahtani SM, Porwal A, Al-Sanabani FA, Bhandi S, Tribst JP, Heboyan A, Patil S. Assessment of conventionally and digitally fabricated complete dentures: a comprehensive review. Mat 2022. 28;15(11):3868.

XXI. Srinivasan M, Kamnoedboon P, McKenna G, Angst L, Schimmel M, Özcan M, Müller F. CAD-CAM removable complete dentures: A systematic review and meta-analysis of trueness of fit, biocompatibility, mechanical properties, surface characteristics, color stability, time-cost analysis, clinical and patient-reported outcomes. J dent 2021. 1;113:103777.

XXII. Russo LL, 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. Journal Pros Dent 2022.

XXIII. https://www.aegisdentalnetwork.com/cced/2016/06/pala-digital-dentures-creates-better-fitting-dentures-faster

XXIV. Lee DJ, Saponaro PC. Management of edentulous patients. Dental Clin 2019. 1;63(2):249-61.

XXV. Thalji G, McGraw K, Cooper LF. Maxillary Complete Denture Outcomes: A Systematic Review of Patient-Based Outcomes. Int J Oral & Maxillofac Impl 2016.2;31.

XXVI. Vojdani M, Bagheri R, Khaledi AA. Effects of aluminum oxide addition on the flexural strength, surface hardness, and roughness of heat-polymerized acrylic resin. J dent sci 2012. 1;7(3):238-44.

XXVII. Gautam R, Singh RD, Sharma VP, Siddhartha R, Chand P, Kumar R. Biocompatibility of polymethylmethacrylate resins used in dentistry. J Biomed Mat Res Part B: Appl Biomat 2012.100(5):1444-50.

XXVIII. Pillai S, Upadhyay A, Khayambashi P, Farooq I, Sabri H, Tarar M, Lee KT, Harb I, Zhou S, Wang Y, Tran SD. Dental 3D-printing: transferring art from the laboratories to the clinics. Polymers 2021.4;13(1):157.

XXIX. Baba NZ, Goodacre BJ, Goodacre CJ, Lauciello F. Clinical Applications of Digital Dental Technology in Removable Prosthodontics. Clinic App Digi Dent Technol 2023. 1:154-94.

XXX. Fenlon MR, Juszczyk AS, Rodriguez JM, Curtis RV. Dimensional stability of complete denture permanent acrylic resin denture bases; A comparison of dimensions before and after a second curing cycle. Euro J Prosthodont Restor Dent 2010.1;18(1):33-8.

XXXI. Otake R, Kanazawa M, Iwaki M, Soeda Y, Hada T, Katheng A, Komagamine Y, Minakuchi S. Patient-reported outcome and cost-effectiveness analysis of milled and conventionally fabricated complete dentures in a university clinic: A retrospective study. J Pros Dent 2022.

XXXII. Dental B, WHITE I. Best Practices For Capital Investments in Dentistry. Accessed January. 2020 Dec;10.

XXXIII. Patzelt SB, Vonau S, Stampf S, Att W. Assessing the feasibility and accuracy of digitizing edentulous jaws. J American Dent Ass 2013.1;144(8):914-20.

XXXIV. Matsuda T, Goto T, Yagi K, Kashiwabara T, Ichikawa T. Part-digitizing system of impression and interocclusal record for complete denture fabrication. J Prosthodont 2016.;25(6):503-9.Figures and Legends

Advantages	Disadvantages
Reduced number of visits	Material wastage
Digital archiving	Instant relining is required
More favourable clinical and patient centred outcomes of CAD/CAM dentures	occlusion issues
Enhanced accuracy of fit of milled denture bases	Poor aesthetics
Less denture tooth movement	High cost
Increased toughness, ultimate strength and higher modulus of elasticity	Retention loss

Table 1. Advantages and disadvantages of Digital dentures

Conventional denture workflow		Digital dentures workflow	
Clinical steps	**Laboratory steps**	**Clinical steps**	**Laboratory steps**
Preliminary impression	Pouring of primary cast, fabrication of special trays	Digital impression	Arrange models and Jaw relation with virtual articulator
Final impression	Pouring of final cast, fabrication of denture base and occlusal rims	Denture delivery	Teeth set up and shade selection
Record jaw relations	Teeth arrangement	Review and maintenance	Milling the denture
wax try in	Flasking, dewaxing and acrylization		
Delivery of denture			

Review and maintenance

Table 2. Comparison of workflow of conventional denture fabrication and digital dentures

Table 3: Digital scanning technologies

Amplified light technology		**Light technology**		
Real time stitching ex:-Zfx scan	Still image capture ex:- iTero, PlanScan	Still image capture ex:- Omnicam	Video capture ex:- Lava COS	Real time image capture ex:- Trios

	Roland DWX	**Dentsply Sirona**	**PlanMeca Planmill**	**Dental wings**	**Amann Girrbach Ceramfill**	**3 Shape**	**Ivocla Vivad Weilar digital dentu**
Scanning	Open architecture system Compatible with 3Shape's Dental System and exocad	inEOSX5	Open Architecture	iSeries, 3 series and 7 series scanner	Ceramill DRS connection kit (closed mouth system)	TRIOS scanner	1.Prog 2.PS5 PS3 sc 3.UTS Gnath
Software	Full denture design of Exocad and 3 Shape, Dental wings DWOS	inLab CAD Software	Planmeca PlanCAD for design and Planmeca PlanCAM for nesting	DWOS Synergy	Ceramill	3Shape Digital denture design software	Progra PS7

Milling	DWX 52DCi, DWX 52DC and DWX 52D for CA-DK2 and DWX 53DC for DK2-53	inLab MCX5 milling unit (5 axis milling)	PlanMill 60S unit (5 axis unit)	Compatible with DWX milling units	Ceramill Matik (5 axis milling)	-	Progra PM7 (milling

Table 4: Different devices used for fabricating Digital Dentures