Published online: 2019-09-23

Review Article

A review of computer-aided design/computer-aided manufacture techniques for removable denture fabrication

Mehmet Selim Bilgin[1], Ebru Nur Baytaroğlu[1], Ali Erdem[1], Erhan Dilber[1]

Correspondence: Dr. Mehmet Selim Bilgin
Email: selim.bilgin@sifa.edu.tr

[1]Department of Prosthodontics, Sifa University, Izmir, Turkiye

ABSTRACT

The aim of this review was to investigate usage of computer-aided design/computer-aided manufacture (CAD/CAM) such as milling and rapid prototyping (RP) technologies for removable denture fabrication. An electronic search was conducted in the PubMed/MEDLINE, ScienceDirect, Google Scholar, and Web of Science databases. Databases were searched from 1987 to 2014. The search was performed using a variety of keywords including CAD/CAM, complete/partial dentures, RP, rapid manufacturing, digitally designed, milled, computerized, and machined. The identified developments (in chronological order), techniques, advantages, and disadvantages of CAD/CAM and RP for removable denture fabrication are summarized. Using a variety of keywords and aiming to find the topic, 78 publications were initially searched. For the main topic, the abstract of these 78 articles were scanned, and 52 publications were selected for reading in detail. Full-text of these articles was gained and searched in detail. Totally, 40 articles that discussed the techniques, advantages, and disadvantages of CAD/CAM and RP for removable denture fabrication and the articles were incorporated in this review. Totally, 16 of the papers summarized in the table. Following review of all relevant publications, it can be concluded that current innovations and technological developments of CAD/CAM and RP allow the digitally planning and manufacturing of removable dentures from start to finish. As a result according to the literature review CAD/CAM techniques and supportive maxillomandibular relationship transfer devices are growing fast. In the close future, fabricating removable dentures will become medical informatics instead of needing a technical staff and procedures. However the methods have several limitations for now.

Key words: Computer-aided design/computer-aided manufacture, rapid prototyping, removable partial denture

INTRODUCTION

With continuous developments over several years, present-day technological advancements allow the use of different systems with computer-aided design/computer-aided manufacture (CAD/CAM) technology for the fabrication of removable dentures, including milling and rapid prototyping (RP).[1]

CAD/CAM technology refers to digital design and manufacture. CAD software recognizes the geometry of an object while CAM software is used for the manufacture. The CAD/CAM manufacturing process can either include additive (RP) or subtractive manufacturing (computer numerical control [CNC] machining; milling). RP has been used for industrial purposes and was developed from CAD/CAM technology. It is used to create

Access this article online
Quick Response Code:
Website: www.eurjdent.com

How to cite this article: Bilgin MS, Baytaroglu EN, Erdem A, Dilber E. A review of computer-aided design/computer-aided manufacture techniques for removable denture fabrication. Eur J Dent 2016;10:286-91.

DOI: 10.4103/1305-7456.178304

automatically physical models from computerized three-dimensional (3D) data.[2,3] RP, also known as solid freeform fabrication or layered manufacturing, has been used for creating 3D complex models in the field of medicine since the 1990s and has recently become popular for the fabrication of removable dental prostheses.[4,5] CAD/CAM and RP have been used for several years for the fabrication of inlays, onlays, crowns, fixed partial dentures, implant abutments/prostheses, and maxillofacial prostheses.[6] Currently, not only fixed restorations but also removable dentures are manufactured using CAD/CAM and RP.[7-14] However, few studies have reported on the use and effectiveness of RP for removable denture fabrication.[4]

Subtractive manufacturing technique is based on milling the product from a block by a CNC machine. The CAM software automatically transfers the CAD model into tool path for the CNC machine. This involves computation that points the CNC milling, including sequencing, milling tools, and tool motion direction and magnitude. Due to the anatomical variances of dental restoration, the milling machines combine burs with different sizes. The accuracy of milling is shown to be within 10 μm.[15,16]

The first removable prosthesis based on 3D laser lithography was manufactured by Maeda *et al*.[12] in 1994. Subsequently, the removable prosthesis duplication technique was improved using CAD/CAM with a computerized numerical control (CNC) system and ball-end mills by Kawahata *et al*.[11] in 1997. Then, Sun *et al*.[13] fabricated individual physical flasks using a 3D printer.

Impressions of the edentulous maxilla and mandible or existing dentures are subjected to laser scanning during CAD.[11,12] Also, cone beam computed tomography is used for the modification of previous dentures.[7] CNC, laser lithography, and RP are used for the CAM process.[10-13]

AvaDent and Dentca are the two available commercial manufacturers of removable complete dentures with CAD/CAM, using a gadget for transferring the maxillomandibular relation (MMR) to a digital articulator and finalizing the dentures completely with CAD/CAM. In the process used by AvaDent, denture bases are milled using a subtractive technique from prepolymerized denture resin. The Dentca technique uses an additive process, wherein a trial denture can be prepared, if the dentist requires, using RP (stereolithography [SLA]) before the conventional fabrication of a definitive prosthesis.[17-19]

An electronic search was conducted in the PubMed/MEDLINE (National Library of Medicine, Washington, DC), ScienceDirect, Google Scholar, and Web of Science databases for identifying English articles using the following key word combinations:

- "CAD/CAM and complete dentures"
- "CAD/CAM and removable partial dentures (RPDs)"
- "CAD/CAM and removable dentures"
- "CAD/CAM and removable prosthesis"
- "RP and complete dentures"
- "RP and RPDs"
- "RP and removable dentures"
- "RP and removable prosthesis"
- "Digitally designed and removable dentures"
- "Digitally designed and complete dentures"
- "Digital complete dentures"
- "Digital removable dentures"
- "Rapid manufacturing and removable dentures"
- "Milled," "machined," "computerized," and "removable dentures."

Articles about removable dentures fabricated using CAD/CAM and RP that were published from 1987 to 2014 were selected. These included reviews and laboratory and clinical reports. Articles published in non-English languages that included identified search terms in the title or abstract were excluded. The search process was executed in three phases as searching of titles, analysis of abstracts, and identification of full-text articles. Also, Google search was conducted for available commercial manufacturers of CAD/CAM prostheses and their processing techniques. The identified developments (in chronological order), techniques, advantages, and disadvantages of CAD/CAM and RP for removable denture fabrication are summarized in Table 1.

TECHNIQUES AND MATERIALS USED FOR DENTAL COMPUTER-AIDED MANUFACTURE

CAM includes subtractive and additive manufacturing techniques [Figure 1].

Early CAM systems are based on substractive method that was relied on cutting the restoration from a prefabricated block using burs, drills, or diamond disks. Subtractive manufacturing includes CNC

Table 1: The table of published articles about CAD/CAM techniques for removable denture fabrication from 1994 until 2015

Article	Technique	Summary
Maeda *et al*.[12]	Rapid prototyping	Maeda *et al*. manufactured the first removable prosthesis using 3D laser lithography Silicone was used to obtain maxillary and mandibular impressions for 3D laser scanning and imaging using CCD cameras. Complete dentures were manufactured using rapid prototyping (3D laser lithography) from photopolymerized composite resin material
Kawahata *et al*.[11]	Milling	Kawahata *et al*. improved the digitally duplication technique for removable prostheses using CAD/CAM with a CNC system. Duplicate dentures were fabricated from a block of wax using CNC milling
Williams *et al*.[20]	Rapid prototyping	Williams *et al*. used digitized molds and electronic surveying for integrating 3D models of removable partial prosthesis frameworks and created a metal frame. They also recommended a technique to ease the definition of the retentive regions of the teeth and equator of the RP denture
Eggbeer *et al*.[21]	Rapid prototyping	Eggbeer *et al*. used RP for manufacturing a sacrificial model of the prosthesis and used the investment-cast technique for casting. However, their technique was slightly complicated and time-consuming
Bibb *et al*.[22]	Milling and rapid prototyping	Bibb *et al*. described the fabrication of a metal frame using CAD/CAM and RP in a clinical case report. They produced prototype epoxy resin using RP, and the prototype was used as a replacement for the wax used during conventional processing of the metal frame. Sufficient adaptation for hard tissues and soft tissues was provided by the metal frame
Busch and Kordass[8]	Milling	Busch and Kordass digitally scanned edentulous models using laser and other kind of digital scanners and digitally arranged the teeth with anatomic measurements/averages provided by specific computer software
Sun *et al*.[13]	Rapid prototyping	Virtual flasks were constructed with 3D laser scanning of maxillary and mandibular gypsum casts, and the teeth were digitally arranged. Physical flasks were constructed using RP. Conventional laboratory steps were used for tooth insertion
Guo-Dong *et al*.[23]	Rapid prototyping	Guo-Dong *et al*. presented easier and more effective techniques for designing and processing digital models of RPD frameworks. They used current commercial 3D software for scanning plaster casts, with the scanner based on the structured light technique. A digital model of the RPD framework was designed, and its sacrificial model was fabricated using RP. Then, the alloy framework was processed using the cast mold method
Kanazawa *et al*.[7]	Milling	Kanazawa *et al*. used CBCT scans of prostheses and denture teeth and digitally arranged the teeth. The prosthesis base was fabricated from a block of acrylic resin using CNC milling, following which the teeth were manually bonded in the holes created in the denture base
Jevremović *et al*.[24]	Rapid prototyping	Jevremović *et al*. studied about alloys used for fabricating prostheses using SLM. They concluded that Co-Cr alloys did not have cytotoxic effects, while some metals commonly resulted in side effects, mentioning that 30 alloys showed similar characteristics used in SLM for cast alloy processing
Goodacre *et al*.[9]	Milling	Goodacre *et al*. scanned silicone impressions by neutral zone technique for scanning, additionally recorded interocclusal relations, then teeth were arranged digitally. The prosthesis base was fabricated from a block of acrylic resin using CNC milling, following which the teeth were manually bonded in the holes created in the denture base
Inokoshi *et al*.[10]	Rapid prototyping	Inokoshi *et al*. scanned wax trial prostheses of 10 patients using CBCT and modified the scanned digital prostheses using computer software. Seven prototypes were fabricated using RP, with various modifications in teeth arrangements for researching the applicability of prototype prostheses for trial placement functions
Alifui-Segbaya *et al*.[25]	Rapid prototyping	They researched the effects of the corrosive function of artificial saliva on cast and Co-Cr alloys manufactured using RP. They found that some dental alloys, including Co, Cr, and molybdenum, can be used in the oral cavity because of their acceptable ion release levels
Yoon *et al*.[26]	Milling	The research group had tried a different approach for restoring worn artificial teeth by onlays on removable partial denture case by milling technique. The CAD CAM blocks that they used to restore the worn teeth were lithium disilicate blocks
Yamamoto *et al*.[27]	Milling	This study mentioned that in CAD/CAM complete denture, the recesses need offset for accurate teeth positions and the optimal offset values differ with the basal shape of artificial teeth. And revealed optimal offset values as 0.15-0.25 mm for upper left 1, 0.15 and 0.25 mm for upper left 3, 0.25 mm for upper left 4, and 0.10-0.25 mm for upper left 6
Infante *et al*.[28]	Milling	This clinical report describes the manufacture of removable complete dentures using CAD/CAM technology. Infante *et al*. manufactured complete removable dentures using the AvaDent system from PMMA resin in two appointments. Acrylic teeth were not manufactured using CAD/CAM. The article reports that clinical records can be obtained using AMD in the first appointment itself
Bilgin *et al*.[29]	Milling and rapid prototyping	This study presents a new technique of design as one set aligned artificial tooth arrangement fabricated by CAD/CAM techniques for complete dentures

3D: Three-dimensional, CCD: Charge coupled-device, CAD/CAM: Computer-aided design/computer-aided manufacture, RP: Rapid prototyping, CNC: Computerized numerical control, RPD: Removable partial denture, CBCT: Cone beam computed tomography, SLM: Selective laser melting, Co-Cr: Cobalt-chromium, PMMA: Polymethyl methacrylate, AMD: Anatomical measurement device

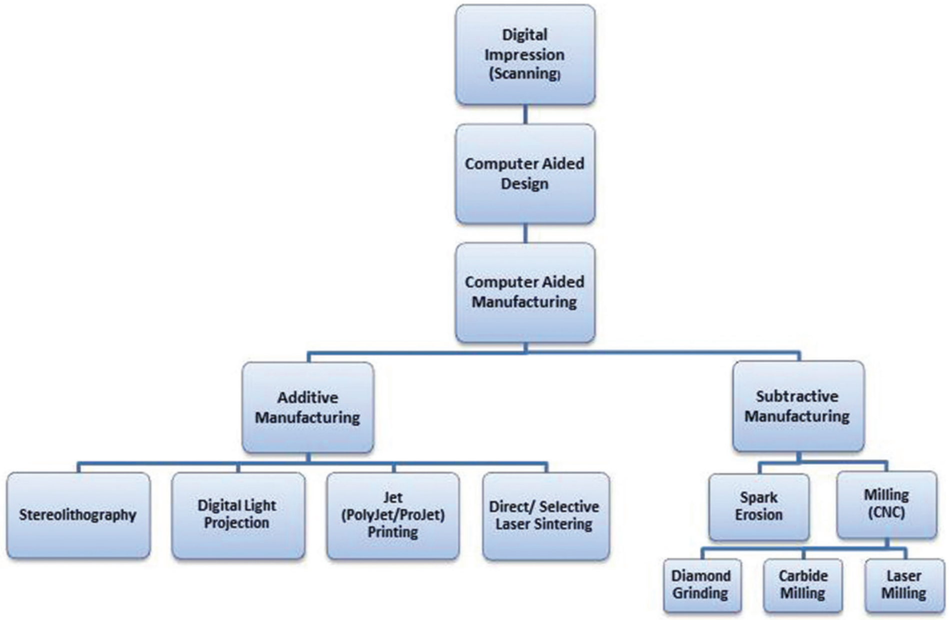

Figure 1: Overview of computer-aided design/computer-aided manufacture systems for dental use

machining used for the manufacture of crowns, posts, inlays, and onlays. The subtractive production methods include spark erosion and milling. The spark erosion can be defined as a metal substractive process using continuing sparks to erode material from a metal block according to the CAD under required conditions. Milling techniques are diamond grinding and carbide milling which are now found together in chairside and inLab CAD/CAM devices together and as the latest transferred technology from manufacture industry to dental use is laser milling, which was announced in first quarter of 2015. Milling techniques are mostly dependent on the device properties such as the dimensional approach and possibilities of working axis: 3 spatial direction X, Y, and Z which refers to 3 axis milling devices while 3 spatial direction X, Y, Z and tension bridge refers to 4 axis milling device, and finally 3 spatial direction X, Y, Z, tension bridge with milling spindle is classified as 5 axis milling device.[30]

Additive 3D printing techniques include SLA, digital light projection (DLP), jet (PolyJet/ProJet) printing, and direct laser metal sintering (DLMS)/selective laser sintering (SLS).

The SLA technique uses ultraviolet (UV) laser for layer-by-layer polymerization of materials. The technique is used for the manufacture of dental models from UV-sensitive liquid resins. DLP uses UV laser and visible light for polymerization and is used for the manufacture of dental models, wax patterns, removable partial frameworks, and provisional restorations from visible light-sensitive resins, wax, and composite materials. After the material is printed, it is cured using a light-emitting diode light source or lamp.[31] Also, polymethyl methacrylate (PMMA) is used in the DLP technique.[32] Jet (PolyJet/ProJet) printing uses a series of ink-jet print heads and tiny pieces of material jetted onto support material and create each layer of the part. Then, each jetted layer is hardened using a UV lamp, light source, or heating. This technique is used for the manufacture of dental models, surgical drill guides, aligners, wax patterns, and removable frameworks from dental resin and waxes. DLMS/SLS is a powder-based technique wherein high-power laser beam hits the powder, resulting in melt and fusion of the powder particles. This technique is used for the manufacture of dental models, copings, and surgical guides from cobalt-chrome, palladium chrome, and nylon.[31]

MANUFACTURING PROCESS OF REMOVABLE PROSTHESIS WITH COMPUTER-AIDED DESIGN/ COMPUTER-AIDED MANUFACTURE AND RAPID PROTOTYPING

Manufacturing steps for complete dentures

First, models can be prepared using conventional impression or intraoral digital impression. When digital impression is considered, practitioner will need for high speed, high density, small size, and multifunctional device which has driven the development of 3D imaging.[33] The precision of digital impression has been studied by several researchers and found out that use of digital models is a relatively new technique that has an accuracy of up to 10 μm, and the models have been found to be as reliable as traditional stone casts.[34] Nalcaci *et al*.[35] found out statistically significant differences between measurements obtained for width of 6 anterior teeth and 12 overall teeth using plaster and digital models; however, these differences were not within the clinically significant range (~0.27–0.30 mm). Therefore, casts are scanned using digital scanner for conventional technique. After taking impression, the next step is making MMR transfer during complete prosthesis fabrication using CAD/CAM. There are three options for MMR transfer during complete prosthesis fabrication using CAD/CAM: The MMR can be transferred using conventional impression and transfer techniques, the AvaDent system kit, or the Dentca system kit.[18,19]

Two clinical appointments are required for the manufacture of removable complete dentures using the Avadent and Dentca systems. In the first appointment, impressions are recorded using special trays provided in the AvaDent or Dentca system. Then, the jaw relation is recorded using an anatomical measuring device. The occlusal vertical dimension (OVD) is determined using conventional methods. Subsequently, the centric relation is recorded, and teeth are selected. The last step of the first appointment is the delivery of the final impression to the manufacturer (AvaDent or Dentca).

At the laboratory, the denture borders are first defined and marked using the system's computer software. Then, the teeth are virtually set, and the prosthesis base is milled from traditional denture resin material. A trial denture can be prepared as per the dentist's request.

In the second clinical appointment, the dentures are delivered and any occlusal adjustments made. These steps are similar to those for conventional prosthesis delivery. Only the AvaDent technique of denture base manufacture is not conventional.[17-19]

Manufacturing steps for framework of partial prosthesis

Designing of the RPD framework generally consists of four parts as base, plate, clasp, major, and minor connector of the framework. Every part of the RPD framework must be done proper design and thick value in the designing process.[23] Because of the variety of RPD parts and their irregular forms, 3D designing of RPD framework is taking much time and complicated. For this reason, researchers investigated proper CAD/CAM method and software for 3D designing of RPD framework for many years.[20,21,36,37]

Basically, steps for manufacturing of framework of partial prosthesis with CAD/CAM and RP are: First, dental casts are prepared using conventional impression method or digital impression. Casts are scanned using digital scanner for conventional technique. Path of insertion of the RPD is defined digitally, and then shape of the components of the framework is designed 3D by dentists or laboratory technicians. Finally, digitally designed metal RPD frameworks are produced with RP.[36]

Advantages of digital fabrication of dentures

- Decreased number of appointments
- Shrinkage of acrylic base caused by milling of prepolymerized acrylic resin with an increase in the strength and fit of dentures
- Decreased duration of prosthesis manipulation
- Decrease in the risk of microorganism colonization on the denture surfaces and consequent infection
- Advances in standardization for clinical research on removable prostheses
- Easy reproduction of the denture and manufacture of a trial denture using stored digital data
- Superior quality control by clinicians and technicians.[38]

Limitations and disadvantages of digital fabrication of dentures

- Manufacturing challenge caused by impression-taking and OVD-recording procedures, MMR transfer, and maintenance of lip support, which are all similar to the procedures used in the conventional process
- Inability to define the mandibular occlusal plane
- Expensive materials and increased laboratory cost compared with those for conventional methods
- Lack of trial denture manufacture by the Avadent system,[18] which precludes the evaluation of dentures by patients and dentists before final denture fabrication.

CONCLUSIONS

Since the fabrication of the first modern removable dentures using PMMA, no significant changes in fabricating techniques were introduced until CAD/CAM techniques came into the picture in the 1990s. Current innovations and developments in dental technology allow the fabrication of removal dentures using CAD/CAM technologies from start to finish, thus decreasing the chair side and working time for patients and dentists and providing superior or satisfactory functional and esthetic outcomes. The development of a digital face simulator using imaging techniques with lower effective doses of radiation in the close future will be another milestone for removable denture fabrication with digital OVD recording and MMR transfer before finalization with CAM.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Lima JM, Anami LC, Araujo RM, Pavanelli CA. Removable partial dentures: Use of rapid prototyping. J Prosthodont 2014;23:588-91.
2. Di Giacomo GA, Cury PR, de Araujo NS, Sendyk WR, Sendyk CL. Clinical application of stereolithographic surgical guides for implant placement: Preliminary results. J Periodontol 2005;76:503-7.
3. Sarment DP, Sukovic P, Clinthorne N. Accuracy of implant placement with a stereolithographic surgical guide. Int J Oral Maxillofac Implants 2003;18:571-7.
4. Sun J, Zhang FQ. The application of rapid prototyping in prosthodontics. J Prosthodont 2012;21:641-4.
5. Webb PA. A review of rapid prototyping (RP) techniques in the medical and biomedical sector. J Med Eng Technol 2000;24:149-53.
6. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y. A review of dental CAD/CAM: Current status and future perspectives from 20 years of experience. Dent Mater J 2009;28:44-56.
7. Kanazawa M, Inokoshi M, Minakuchi S, Ohbayashi N. Trial of a CAD/CAM system for fabricating complete dentures. Dent Mater J 2011;30:93-6.
8. Busch M, Kordass B. Concept and development of a computerized positioning of prosthetic teeth for complete dentures. Int J Comput Dent 2006;9:113-20.
9. 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 Prosthet Dent 2012;107:34-46.
10. Inokoshi M, Kanazawa M, Minakuchi S. Evaluation of a complete denture trial method applying rapid prototyping. Dent Mater J 2012;31:40-6.
11. Kawahata N, Ono H, Nishi Y, Hamano T, Nagaoka E. Trial of duplication procedure for complete dentures by CAD/CAM. J Oral Rehabil 1997;24:540-8.
12. Maeda Y, Minoura M, Tsutsumi S, Okada M, Nokubi T. A CAD/CAM system for removable denture. Part I: Fabrication of complete dentures. Int J Prosthodont 1994;7:17-21.
13. Sun Y, Lü P, Wang Y. Study on CAD and RP for removable complete denture. Comput Methods Programs Biomed 2009;93:266-72.
14. Zhang YD, Jiang JG, Liang T, Hu WP. Kinematics modeling and experimentation of the multi-manipulator tooth-arrangement robot for full denture manufacturing. J Med Syst 2011;35:1421-9.
15. Abduo J, Lyons K, Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: A review of the available streams. Int J Dent 2014;2014:783948.
16. Rekow ED, Erdman AG, Riley DR, Klamecki B. CAD/CAM for dental restorations – Some of the curious challenges. IEEE Trans Biomed Eng 1991;38:314-8.
17. Kattadiyil MT, Goodacre CJ, Baba NZ. CAD/CAM complete dentures: A review of two commercial fabrication systems. J Calif Dent Assoc 2013;41:407-16.
18. Sirirungrojying S, Srisintorn S, Akkayanont P. Psychometric profiles of temporomandibular disorder patients in southern Thailand. J Oral Rehabil 1998;25:541-4.
19. Sülün T, Akkayan B, Duc JM, Rammelsberg P, Tuncer N, Gernet W. Axial condyle morphology and horizontal condylar angle in patients with internal derangement compared to asymptomatic volunteers. Cranio 2001;19:237-45.
20. Williams RJ, Bibb R, Rafik T. A technique for fabricating patterns for removable partial denture frameworks using digitized casts and electronic surveying. J Prosthet Dent 2004;91:85-8.
21. Eggbeer D, Bibb R, Williams R. The computer-aided design and rapid prototyping fabrication of removable partial denture frameworks. Proc Inst Mech Eng H 2005;219:195-202.
22. Bibb RJ, Eggbeer D, Williams RJ, Woodward A. Trial fitting of a removable partial denture framework made using computer-aided design and rapid prototyping techniques. Proc Inst Mech Eng H 2006;220:793-7.
23. Guo-Dong Y, Wen-He L, Dai N. The Computer-Aided Design and Rapid Prototyping Fabrication of Removable Partial Denture Framework. Paper Presented at: Computer Science and Information Technology, 2009. ICCSIT 2009. 2nd IEEE International Conference on; 2009.
24. Jevremović D, Kojić V, Bogdanović G, Puškar T, Eggbeer D, Thomas D, *et al*. A selective laser melted Co-Cr alloy used for the rapid manufacture of removable partial denture frameworks: Initial screening of biocompatibility. J Serbian Chem Soc 2011;76:43-52.
25. Alifui-Segbaya F, Foley P, Williams R. The corrosive effects of artificial saliva on cast and rapid manufacture-produced cobalt chromium alloys. Rapid Prototyp J 2013;19:95-9.
26. Yoon TH, Madden JC, Chang WG. A technique to restore worn denture teeth on a partial removable dental prosthesis by using ceramic onlays with CAD/CAM technology. J Prosthet Dent 2013;110:331-2.
27. Yamamoto S, Kanazawa M, Iwaki M, Jokanovic A, Minakuchi S. Effects of offset values for artificial teeth positions in CAD/CAM complete denture. Comput Biol Med 2014;52:1-7.
28. Infante L, Yilmaz B, McGlumphy E, Finger I. Fabricating complete dentures with CAD/CAM technology. J Prosthet Dent 2014;111:351-5.
29. Bilgin MS, Erdem A, Aglarci OS, Dilber E. Fabricating complete dentures with CAD/CAM and RP technologies. J Prosthodont 2015 Jun 1. doi: 10.1111/jopr.12302. [Epub ahead of print].
30. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: An overview of recent developments for CAD/CAM generated restorations. Br Dent J 2008;204:505-11.
31. Hazeveld A, Huddleston Slater JJ, Ren Y. Accuracy and reproducibility of dental replica models reconstructed by different rapid prototyping techniques. Am J Orthod Dentofacial Orthop 2014;145:108-15.
32. Brkic B, France N, Clare AT, Sutcliffe CJ, Chalker PR, Taylor S. Development of quadrupole mass spectrometers using rapid prototyping technology. J Am Soc Mass Spectrom 2009;20:1359-65.
33. Karatas OH, Toy E. Three-dimensional imaging techniques: A literature review. Eur J Dent 2014;8:132-40.
34. Gumus HO, Dincel M, Buyuk SK, Kilinc HI, Bilgin MS, Zortuk M. The effect of pouring time on the dimensional stability of casts made from conventional and extended-pour irreversible hydrocolloids by 3D modelling. J Dent Sci 2015;10:275-81.
35. Nalcaci R, Topcuoglu T, Ozturk F. Comparison of Bolton analysis and tooth size measurements obtained using conventional and three-dimensional orthodontic models. Eur J Dent 2013;7 Suppl 1:S66-70.
36. Han J, Wang Y, Lü P. A preliminary report of designing removable partial denture frameworks using a specifically developed software package. Int J Prosthodont 2010;23:370-5.
37. Williams RJ, Bibb R, Eggbeer D, Collis J. Use of CAD/CAM technology to fabricate a removable partial denture framework. J Prosthet Dent 2006;96:96-9.
38. Bidra AS, Taylor TD, Agar JR. Computer-aided technology for fabricating complete dentures: Systematic review of historical background, current status, and future perspectives. J Prosthet Dent 2013;109:361-6.