BÖLÜM 4

EKLEMELİ ÜRETİM TEKNİKLERİ ve DİŞ HEKİMLİĞİNDEKİ YERİ

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GİRİŞ

Eklemeli üretim (additive manufacturing) veya daha genel olarak bilinen adı ile 3D baskı, nesnelerin üretilme biçimine yeni bir boyut katması sebebiyle üçüncü sanayi devrimi olarak nitelendirilebilir. Geleneksel üretim tekniklerinde, bir hammaddenin tamamlanmış ve kullanılabilir bir ürüne dönüştürülmesi birkaç adımda gerçekleştirilebilirken; eklemeli üretim son ürünün çok daha hızlı bir biçimde doğrudan hammaddeden elde edilebilmesini sağlamaktadır. Bu nedenle otomotiv, havacılık, basılı elektronik ve sağlık hizmetleri gibi çeşitli sektörlerde yaygın şekilde kullanılmaktadır. Hastaya özgü tedavi seçeneklerinin istenilen doğruluk ve hassasiyetle üretilebilme potansiyeli nedeniyle sağlık sektöründe de popülaritesi git gide artmakta olan eklemeli üretim teknikleri ile kalp kapakçıkları, göğüs kafesleri ve kemikler üretilebilmektedir. Eklemeli üretim teknikleri ile seramik, metal, polimer ve kompozit gibi çeşitli diş hekimliği materyallerinin kullanımı mümkündür. Bu derlemede eklemeli üretim tekniklerinin diş hekimliği uygulamalarındaki yeri ve bu konuyla ilgili literatür incelenmektedir.

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koyduğunu rapor etmişlerdir[131]. SLA ile üretilen implant üstü zirkonya kronların internal ve marjinal uyumlarını değerlendiren bir çalışmada ise frezeleme yöntemi ile elde edilen kronların uyumlarının istatistiksel olarak daha yüksek olduğu ifade edilmiştir. Bununla birlikte, aynı çalışmada SLA kronlarda meydana getirilen boyutsal ve yapısal değişikliklerin iki değişken üzerinde de pozitif yönde bir etki yaptığı bildirilmiştir[133]. Zandinejad ve ark. SLA yöntemi ile hazırlanan implant üstü zirkonya kronların kırılma dayanımlarını inceledikleri çalışmalarında, frezelenerek hazırlanan zirkonya ve lityum disilikat kronların daha yüksek değerler göstermelerine rağmen test grupları arasında istatistiksel herhangi bir fark bulunmadığını göstermişlerdir[132].

SONUÇ

Eklemeli üretim teknolojileri, farklı tipte yazılımlar kullanarak çeşitli dental uygulamaların özelleştirilmiş tasarımına yönelik yenilikçi bir tekniktir. Protetik restorasyonların, ortodontik apareylerin, implantların ve birçok diğer tedavinin hasta gereksinimine göre etkili bir şekilde tasarlanması ve uygulanmasına olanak sağlamaktadır. Diş hekimliği uygulamalarının yanı sıra laboratuvar aşamalarında da hızlı ve etkili çözümler sunması, eklemeli üretim teknolojilerinin popülerliğini arttırmaktadır. Dijital diş hekimliği uygulamalarını da materyal çeşitliliği, üretim hızı, hassasiyeti ve maliyetiyle kökünden değiştirebilecek olan eklemeli üretim teknolojilerinin hala detaylı olarak araştırılması ve geliştirilmesi gerekmektedir.

KAYNAKLAR

1:Birnbaum NS, Aaronson HB. Dental impressions using 3D digital scanners: virtual becomes reality. Compend Contin Educ Dent. 2008;29:494-496.

2:Brawek PK, Wolfart S, Endres L, et al. The clinical accuracy of single crowns exclusively fabricated by digital workflow—the comparison of two systems. Clin Oral Investig. 2013;17:2119-2125.

3:Revilla-León M, Özcan M. Additive manufacturing technologies used for

processing polymers: current status and potential application in prosthetic dentistry. J Prosthodont. 2019;28:146-158.
4:Dawood A, Marti BM, Sauret-Jackson V, et al. 3D printing in dentistry. Br Dent J. 2015;219:521-529.
5:Van Noort R. The future of dental devices is digital. Dent Mater. 2012;28:3-12.
6:Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. Br Dent J. 2008;204:505-511.
7:Zandparsa R. Digital imaging and fabrication. Dent Clin North Am. 2014;58(1):135-58.
8:May KB, Russell MM, Razzoog ME, et al. Precision of fit: the Procera AllCeram crown. J Prosthet Dent. 1998;80:394-404.
9:Methani MM, Revilla-León M, Zandinejad A. The potential of additive manufacturing technologies and their processing parameters for the fabrication of all-ceramic crowns: A review. J Esthet Restor Dent. 2020;32:182-192.
10:Reiss B. Cerec standard 3-d occlusal contouring in comparison with the new biogeneric occlusal morphing: a case report. Int J Comput Dent. 2007;10:69-75.
11:Mehl A, Gloger W, Kunzelmann KH, et al. A new optical 3-D device for the detection of wear. J Dent Res. 1997;76:1799-1807.
12:Horn TJ, Harrysson OL. Overview of current additive manufacturing technologies and selected applications. Sci Prog. 2012;95:255-282.
13: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.
14:Miyazaki T, Hotta Y. CAD/CAM systems available for the fabrication of crown and bridge restorations. Aust Dent J. 2011;56:97-106.
15:Azari A, Nikzad S. The evolution of rapid prototyping in dentistry: a review. Rapid Prototyp J. 2009;15:216-225.
16:Revilla-León M, Meyer MJ, Zandinejad A, et al. Additive manufacturing technologies for processing zirconia in dental applications. Int J Comput Dent. 2020;23:27-37.
17:Lebon N, Tapie L, Duret F, et al. Understanding dental CAD/CAM for restorations-dental milling machines from a mechanical engineering viewpoint. Part A: chairside milling machines. Int J Comput Dent. 2016;19:45-62.
18:Strub JR, Rekow ED, Witkowski S. Computer-aided design and fabrication of dental restorations: current systems and future possibilities. J Am Dent Assoc. 2006;13:1289-1296.
19:Kessler A, Hickel R, Reymus M. 3D printing in dentistry-state of the art. Oper Dent. 2020;45:30-40.
20:Davis BK. The role of technology in facial prosthetics. Curr Opin Otolaryngol Head Neck Surg. 2010;18:332-340.
21:Webb P. A review of rapid prototyping (RP) techniques in the medical and biomedical sector. J Med Eng Technol. 2000;24:149-153.

22:Chen LH, Tsutsumi S, Iizuka T. A CAD/CAM technique for fabricating facial prostheses: a preliminary report. Int J Prosthodont. 1997;10:497-472.
23:Runte C, Dirksen D, Deleré H, et al. Optical data acquisition for computer-assisted design of facial prostheses. Int J Prosthodont. 2002;15:129-132.
24:Feng Z, Dong Y, Zhao Y, et al. Computer-assisted technique for the design and manufacture of realistic facial prostheses. Br J Oral Maxillofac Surg. 2010;48:105-109.
25:Traini T, Mangano C, Sammons R, et al. Direct laser metal sintering as a new approach to fabrication of an isoelastic functionally graded material for manufacture of porous titanium dental implants. Dent Mater. 2008;24:1525-1533.
26:Akova T, Ucar Y, Tukay A, et al. Comparison of the bond strength of laser-sintered and cast base metal dental alloys to porcelain. Dent Mater. 2008;24:1400-1404.
27:Ucar Y, Akova T, Akyil MS, et al. Internal fit evaluation of crowns prepared using a new dental crown fabrication technique: laser-sintered Co-Cr crowns. J Prosthet Dent. 2009;102:253-259.
28:Jockusch J, Özcan M. Additive manufacturing of dental polymers: An overview on processes, materials and applications. Dent Mater J. 2020;39:345-354.
29:Deckers J, Vleugels J, Kruth JP. Additive manufacturing of ceramics: a review. J Ceram Sci Technol. 2014;5:245-260.
30:Wohlers TT, Caffrey T. (2015) Wohlers Report 2015: 3D printing and additive manufacturing state of the industry annual worldwide progress report. Fort Collins, Colo.: Wohlers Associates.
31:Cho JH, Park W, Park KM, et al. Creating protective appliances for preventing dental injury during endotracheal intubation using intraoral scanning and 3D printing: a technical note. J Dent Anesth Pain Med. 2017;17:55-59.
32:Ruppin J, Popovic A, Strauss M, et al. Evaluation of the accuracy of three different computer-aided surgery systems in dental implantology: optical tracking vs. stereolithographic splint systems. Clin Oral Implants Res. 2008;19:709-716.
33:Salmi M, Paloheimo KS, Tuomi J, et al. A digital process for additive manufacturing of occlusal splints: a clinical pilot study. J R Soc Interface. 2013;10:20130203.
34:Manapat JZ, Chen Q, Ye P, et al. 3D printing of polymer nanocomposites via stereolithography. Macromol Mater Eng. 2017;302:1600553.
35:Thrimurthulu K, Pandey PM, Reddy NV. Optimum part deposition orientation in fused deposition modeling. Int J Mach Tools Manuf. 2004;44:585-594.
36:Galante R, Figueiredo-Pina CG, Serro AP. Additive manufacturing of ceramics for dental applications: a review. Dent Mater. 2019;35:825-846.
37:Maleksaeedi S, Eng H, Wiria F, et al. Property enhancement of 3D-printed alumina ceramics using vacuum infiltration. J Mater Process Technol.

2014;214:1301-1306.
38:Vogt U, Gorbar M, Dimopoulos-Eggenschwiler P, et al. Improving the properties of ceramic foams by a vacuum infiltration process. J Eur Ceram Soc. 2010;30:3005-3011.
39:Stansbury JW, Idacavage MJ. 3D printing with polymers: challenges among expanding options and opportunities. Dent Mater. 2016;32:54-64.
40:Alharbi N, Wismeijer D, Osman RB. Additive manufacturing techniques in prosthodontics: where do we currently stand? a critical review. Int J Prosthodont. 2017;30:474-484.
41:Koutsoukis T, Zinelis S, Eliades G, et al. Selective laser melting technique of Co-Cr dental alloys: a review of structure and properties and comparative analysis with other available techniques. J Prosthodont. 2015;24:303-312.
42:Alcisto J, Enriquez A, Garcia H, et al. Tensile properties and microstructures of laser-formed Ti-6Al-4V. J Mater Eng Perform. 2011;20:203-212.
43:Abd-Elghany K, Bourell D. Property evaluation of 304L stainless steel fabricated by selective laser melting. Rapid Prototyp J. 2012;18:420-428.
44:Revilla-León M, Meyer MJ, Özcan M. Metal additive manufacturing technologies: literature review of current status and prosthodontic applications. Int J Comput Dent. 2019;22:55-67.
45:King B, Dimos D, Yang P, et al. Direct-write fabrication of integrated, multilayer ceramic components. J Electroceramics. 1999;3:173-178.
46:Mazzoli A, Ferretti C, Gigante A, et al. Selective laser sintering manufacturing of polycaprolactone bone scaffolds for applications in bone tissue engineering. Rapid Prototyp J. 2015;21:386-392.
47:Butler J. Using selective laser sintering for manufacturing. Assem Autom. 2011;31:212-219.
48:Javaid M, Haleem A. Current status and applications of additive manufacturing in dentistry: A literature-based review. J Oral Biol Craniofac Res. 2019;9:179-185.
49:Mazzoli A. Selective laser sintering in biomedical engineering. Med Biol Eng Comput. 2013;51:245-256.
50:Santos EC, Shiomi M, Osakada K, et al. Rapid manufacturing of metal components by laser forming. Int J Mach Tools Manuf. 2006;46:1459-1468.
51:Kruth JP, Mercelis P, Vaerenbergh JV, et al. Binding mechanisms in selective laser sintering and selective laser melting. Rapid Prototyp J. 2005;11:26-36.
52:Kaleli N, Saraç D. Protetik diş tedavisinde lazer sinterleme sistemleri. Ondokuz Mayıs Üniversitesi Diş Hekimliği Fakültesi Dergisi. 2014;15:27-33.
53:Azeez GM, Çekiç Nagaş I. Protetik diş hekimliğinde kullanılan metal üretim tekniklerinde güncel gelişmeler. EÜ Dişhek Fak Derg. 2017;38:128-139.
54:Levy GN, Schindel R, Kruth JP. Rapid manufacturing and rapid tooling with layer manufacturing (LM) technologies, state of the art and future perspectives. CIRP Ann Manuf Technol. 2003;52:589-609.
55:Simchi A, Petzoldt F, Pohl H. On the development of direct metal laser sintering for rapid tooling. J Mater Process Technol. 2003;141:319-238.

56:Uçar Y, Gürbüz GA, Erken O. Diş hekimliğinde lazer sinterizasyon ve diğer tabakalı üretim yöntemleri. Turkiye Klinikleri Prosthodontics-Special Topics. 2015;1:13-22.
57:Quante K, Ludwig K, Kern M. Marginal and internal fit of metal-ceramic crowns fabricated with a new laser melting technology. Dent Mater. 2008;24:1311-1315.
58:Mangano C, Piattelli A, Raspanti M, et al. Scanning electron microscopy (SEM) and X-ray dispersive spectrometry evaluation of direct laser metal sintering surface and human bone interface: a case series. Lasers Med Sci. 2011;26:133-138.
59:Mangano F, Bazzoli M, Tettamanti L, et al. Custom-made, selective laser sintering (SLS) blade implants as a non-conventional solution for the prosthetic rehabilitation of extremely atrophied posterior mandible. Lasers Med Sci. 2013;28:1241-1247.
60:Mangano F, Pozzi-Taubert S, Zecca PA, et al. Immediate restoration of fixed partial prostheses supported by one-piece narrow-diameter selective laser sintering implants: a 2-year prospective study in the posterior jaws of 16 patients. Implant Dent. 2013;22:388-393.
61:Mangano F, Luongo F, Shibli JA, et al. Maxillary overdentures supported by four splinted direct metal laser sintering implants: a 3-year prospective clinical study. Int J Dent. 2014;2014:252343.
62:Mangano F, Chambrone L, Van Noort R, et al. Direct metal laser sintering titanium dental implants: a review of the current literature. Int J Biomater. 2014;2014:461534.
63:Mangano FG, Caprioglio A, Levrini L, et al. Immediate loading of mandibular overdentures supported by one-piece, direct metal laser sintering mini-implants: a short-term prospective clinical study. J Periodontol. 2015;86(2):192-200:
64:Kim KB, Kim WC, Kim HY, et al. An evaluation of marginal fit of three-unit fixed dental prostheses fabricated by direct metal laser sintering system. Dent Mater. 2013;29:e91-e96.
65:Xiang N, Xin XZ, Chen J, et al. Metal–ceramic bond strength of Co–Cr alloy fabricated by selective laser melting. J Dent. 2012;40:453-457.
66:Al Jabbari Y, Koutsoukis T, Barmpagadaki X, et al. Metallurgical and interfacial characterization of PFM Co–Cr dental alloys fabricated via casting, milling or selective laser melting. Dent Mater. 2014;30:e79-e88.
67:Vandenbroucke B, Kruth JP. Selective laser melting of biocompatible metals for rapid manufacturing of medical parts. Rapid Prototyp J. 2007;13:196-203.
68:Osakada K, Shiomi M. Flexible manufacturing of metallic products by selective laser melting of powder. Int J Mach Tools Manuf. 2006;46:1188-1193.
69:Murr LE, Gaytan SM, Ramirez DA, et al. Metal fabrication by additive manufacturing using laser and electron beam melting technologies. J Mater Sci Technol. 2012;28:1-14.

70:Sireesha M, Lee J, Kiran ASK, et al. A review on additive manufacturing and its way into the oil and gas industry. RSC Adv. 2018;8:22460-22468.
71:Guo N, Leu MC. Additive manufacturing: technology, applications and research needs. Front Mech Eng. 2013;8:215-243.
72:Kruth JP, Levy G, Klocke F, et al. Consolidation phenomena in laser and powder-bed based layered manufacturing. CIRP Ann Manuf Technol. 2007;56:730-759.
73:Caulfield B, McHugh PE, Lohfeld S. Dependence of mechanical properties of polyamide components on build parameters in the SLS process. J Mater Process Technol. 2007;182(1-3):477-88:
74:Zarringhalam H, Majewski C, Hopkinson N. Degree of particle melt in Nylon-12 selective laser-sintered parts. Rapid Prototyp J. 2009;15:126-132.
75:Ahn SH, Montero M, Odell D, et al. Anisotropic material properties of fused deposition modeling ABS. Rapid Prototyp J. 2002;8:248-257.
76:Schmidt M, Pohle D, Rechtenwald T. Selective laser sintering of PEEK. CIRP Ann Manuf Technol. 2007;56:205-208.
77:Leong K, Wiria F, Chua C, et al. Characterization of a poly-ε-caprolactone polymeric drug delivery device built by selective laser sintering. Biomed Mater Eng. 2007;17:147-157.
78:Ramanath H, Chua C, Leong K, et al. Melt flow behaviour of poly-ε-caprolactone in fused deposition modelling. J Mater Sci Mater Med. 2008;19:2541-2550.
79:Agarwala M, Bourell D, Beaman J, et al. Post-processing of selective laser sintered metal parts. Rapid Prototyp J. 1995;1:36-44.
80:Agarwala M, Bourell D, Beaman J, et al. Direct selective laser sintering of metals. Rapid Prototyp J. 1995;1:26-36.
81:Das S, Wohlert M, Beaman JJ, et al. Producing metal parts with selective laser sintering/hot isostatic pressing. JOM. 1998;50:17-20.
82:Mudge RP, Wald NR. Laser engineered net shaping advances additive manufacturing and repair. Weld J. 2007;86:44-48.
83:Balla VK, Bose S, Bandyopadhyay A. Processing of bulk alumina ceramics using laser engineered net shaping. Int J Appl Ceram Technol. 2008;5:234-242.
84:Niu F, Wu D, Yan S, et al. Process optimization for suppressing cracks in laser engineered net shaping of Al_2O_3 ceramics. JOM. 2017;69:557-562.
85:Wilkes J, Hagedorn YC, Meiners W, et al. Additive manufacturing of ZrO_2-Al_2O_3 ceramic components by selective laser melting. Rapid Prototyp J. 2013;19:51-57.
86:Bourell D, Kruth JP, Leu M, et al. Materials for additive manufacturing. CIRP Ann Manuf Technol. 2017;66:659-681.
87:Ferraris E, Vleugels J, Guo Y, et al. Shaping of engineering ceramics by electro, chemical and physical processes. CIRP Ann Manuf Technol. 2016;65:761-784.
88:Joshi SC, Sheikh AA. 3D printing in aerospace and its long-term sustainabi-

lity. Virtual Phys Prototyp. 2015;10:175-185.
89:Wu H, Cheng Y, Liu W, et al. Effect of the particle size and the debinding process on the density of alumina ceramics fabricated by 3D printing based on stereolithography. Ceram Int. 2016;42:17290-17294.
90:Bhargav A, Sanjairaj V, Rosa V, et al. Applications of additive manufacturing in dentistry: A review. J Biomed Mater Res B Appl Biomater. 2018;106:2058-2064.
91:Michalski MH, Ross JS. The shape of things to come: 3D printing in medicine. JAMA. 2014;312:2213-2214.
92:Schubert C, Van Langeveld MC, Donoso LA. Innovations in 3D printing: a 3D overview from optics to organs. Br J Ophthalmol. 2014;98:159-161.
93:Li H, Song L, Sun J, et al. Dental ceramic prostheses by stereolithography-based additive manufacturing: potentials and challenges. Adv Appl Ceram. 2019;118:30-36.
94:Chawla K. 3D bioprinting: technology in dentistry. Int J Dent Res Oral Sci. 2017;2:63-64.
95:Coachman C, Calamita MA, Coachman FG, et al. Facially generated and cephalometric guided 3D digital design for complete mouth implant rehabilitation: a clinical report. J Prosthet Dent. 2017;117:577-586.
96:Zeng L, Zhang Y, Liu Z, et al. Effects of repeated firing on the marginal accuracy of Co-Cr copings fabricated by selective laser melting. J Prosthet Dent. 2015;113:135-139.
97:Salmi M, Paloheimo KS, Tuomi J, et al. Accuracy of medical models made by additive manufacturing (rapid manufacturing). J Craniomaxillofac Surg. 2013;41:603-609.
98:Anadioti E, Aquilino SA, Gratton DG, et al. 3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impressions. J Prosthodont. 2014;23:610-617.
99:Reyes A, Turkyilmaz I, Prihoda TJ. Accuracy of surgical guides made from conventional and a combination of digital scanning and rapid prototyping techniques. J Prosthet Dent. 2015;113:295-303.
100:Di Giacomo G, Silva J, Martines R, et al. Computer-designed selective laser sintering surgical guide and immediate loading dental implants with definitive prosthesis in edentulous patient: A preliminary method. Eur J Dent. 2014;8:100-106.
101:Dawood A, Patel S, Brown J. Cone beam CT in dental practice. Br Dent J. 2009;207:23-28.
102:Kaeppler G. Applications of cone beam computed tomography in dental and oral medicine. Int J Comput Dent. 2010;13:203-219.
103:Tunchel S, Blay A, Kolerman R, et al. 3D printing/additive manufacturing single titanium dental implants: a prospective multicenter study with 3 years of follow-up. Int J Dent. 2016;2016:8590971.
104:Flügge TV, Nelson K, Schmelzeisen R, et al. Three-dimensional plotting and printing of an implant drilling guide: simplifying guided implant surgery. J

Oral Maxillofac Surg. 2013;71:1340-1346.
105:Klammert U, Gbureck U, Vorndran E, et al. 3D powder printed calcium phosphate implants for reconstruction of cranial and maxillofacial defects. J Craniomaxillofac Surg. 2010;38:565-570.
106:Javaid M, Haleem A, Kumar L. Current status and applications of 3D scanning in dentistry. Clin Epidemiology Glob Health 2019;7:228-233.
107: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.
108:Huang Z, Zhang L, Zhu J, et al. Clinical marginal and internal fit of metal ceramic crowns fabricated with a selective laser melting technology. J Prosthet Dent. 2015;113:623-627.
109:Tamac E, Toksavul S, Toman M. Clinical marginal and internal adaptation of CAD/CAM milling, laser sintering, and cast metal ceramic crowns. J Prosthet Dent. 2014;112:909-913.
110:Tara MA, Eschbach S, Bohlsen F, et al. Clinical outcome of metal-ceramic crowns fabricated with laser-sintering technology. Int J Prosthodont. 2011;24;46-48.
111:Harish V, Mohamed Ali S, Jagadesan N, et al. Evaluation of internal and marginal fit of two metal ceramic system–In vitro study. J Clin Diagn Res. 2014;8:ZC53-ZC6.
112:Wu J, Wang X, Zhao X, et al. A study on the fabrication method of removable partial denture framework by computer-aided design and rapid prototyping. Rapid Prototyp J. 2012;18:318-323.
113:Bibb R, Eggbeer D, Williams R. Rapid manufacture of removable partial denture frameworks. Rapid Prototyp J. 2006;12:95-99.
114:Maeda Y, Minoura M, Tsutsumi S, et al. A CAD/CAM system for removable denture. Part I: Fabrication of complete dentures. Int J Prosthodont. 1994;7:17-21.
115:Inokoshi M, Kanazawa M, Minakuchi S. Evaluation of a complete denture trial method applying rapid prototyping. Dent Mater J. 2012;31:40-46.
116:Sancho-Puchades M, Fehmer V, Hämmerle C, et al. Advanced smile diagnostics using CAD/CAM mock-ups. Int J Esthet Dent. 2015;10:374-391.
117:Alharbi N, Osman R, Wismeijer D. Effects of build direction on the mechanical properties of 3D-printed complete coverage interim dental restorations. J Prosthet Dent. 2016;115:760-767.
118:Wu J, Wang X, Zhao X, et al. A study on the fabrication method of removable partial denture framework by computer-aided design and rapid prototyping. Rapid Prototyp J. 2012;18:318-323.
119:Kattadiyil MT, Mursic Z, AlRumaih H, et al. Intraoral scanning of hard and soft tissues for partial removable dental prosthesis fabrication. J Prosthet Dent. 2014;112:444-448.
120:Hazeveld A, Slater JJH, Ren Y. Accuracy and reproducibility of dental replica models reconstructed by different rapid prototyping techniques. Am J

Orthod Dentofacial Orthop. 2014;145:108-115.
121:Soares PV, de Almeida Milito G, Pereira FA, et al. Rapid prototyping and 3D-virtual models for operative dentistry education in Brazil. J Dent Educ. 2013;77:358-363.
122:Hoang LN, Thompson GA, Cho SH, et al. Die spacer thickness reproduction for central incisor crown fabrication with combined computer-aided design and 3D printing technology: an in vitro study. J Prosthet Dent. 2015;113:398-404.
123:Tay B, Evans J, Edirisinghe M. Solid freeform fabrication of ceramics. Int Mater Rev. 2003;48:341-370.
124:Ebert J, Özkol E, Zeichner A, et al. Direct inkjet printing of dental prostheses made of zirconia. J Dent Res. 2009;88:673-676.
125:Revilla-León M, Husain NA-H, Ceballos L, et al. Flexural strength and Weibull characteristics of stereolithography additive manufactured versus milled zirconia. J Prosthet Dent. 2020.
126:Hinczewski C, Corbel S, Chartier T. Ceramic suspensions suitable for stereolithography. J Eur Ceram Soc. 1998;18:583-590.
127:Doreau F, Chaput C, Chartier T. Stereolithography for manufacturing ceramic parts. Adv Eng Mater. 2000;2:493-496.
128:Bertsch A, Jiguet S, Renaud P. Microfabrication of ceramic components by microstereolithography. J Micromech Microeng. 2003;14:197-203.
129:DeLong R, Douglas WH. Development of an artificial oral environment for the testing of dental restoratives: bi-axial force and movement control. J Dent Res. 1983;62:32-36.
130:Lu Y, Mei Z, Zhang J, et al. Flexural strength and Weibull analysis of Y-TZP fabricated by stereolithographic additive manufacturing and subtractive manufacturing. J Eur Ceram Soc. 2020;40:826-834.
131:Wang W, Yu H, Liu Y, et al. Trueness analysis of zirconia crowns fabricated with 3-dimensional printing. J Prosthet Dent. 2019;121:285-291.
132:Zandinejad A, Methani MM, Schneiderman ED, et al. Fracture resistance of additively manufactured zirconia crowns when cemented to implant supported zirconia abutments: an in vitro study. J Prosthodont. 2019;28:893-897.
133:Revilla-León M, Methani MM, Morton D, et al. Internal and marginal discrepancies associated with stereolithography (SLA) additively manufactured zirconia crowns. J Prosthet Dent. 2020.