DENTAL MEDICINE

Marginal fit of milled versus different 3D-printed materials for provisional fixed dental prostheses: an *in vitro* comparative study

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Abstract

Introduction. Provisional dental prostheses are used as interim restorations to help patients perform oral functions between the time of tooth preparation and the placement of the final restoration. A provisional dental prosthesis should protect the abutment from pulpal and gingival aggressions, adapt correctly to keep healthy gingival tissues, be durable, and have a low price. The purpose of this in vitro study was to compare the marginal adaptation of different types of provisional fixed dental prostheses (PFDP), fabricated using 3D printing technology versus the milling (computer-aided manufacturing [CAM]) technique.

Method. Two resin teeth (second premolar and second molar) on a typodont were prepared for three-unit provisional fixed dental prostheses. Thirty models were 3D-printed after a digital model was created using an intraoral scanner. Then, 30 provisional fixed dental prostheses (PFDPs) were made from a variety of materials using a digital design of a 3-unit PFDP and STL files delivered to a milling machine and a 3D printer, respectively. Ten PFDP were milled (CAM), and two sets of ten each, were fabricated with 3D printing technology (stereolithography), using two different materials. All restorations were analyzed under a microscope, and marginal gap was then measured using the software Image J.

Results. The milled group presented the best marginal gap values (ranging from 86 to 108 µm) and a median value of 93 µm, followed by GC group with (110-251 µm) with a median value of 205 µm and the PR group with median value of 316.5 µm.

Conclusion. According to the findings of this in vitro study, the milling (CAM) technique and SLA technology provides acceptable marginal fit values to fabricate provisional fixed partial dentures.

Keywords: digital dentistry, 3D printing, CAD/CAM, materials

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Background and aims

Digital technology has revolutionised the field of prosthodontics; removable partial dentures and temporary restorations are now more sophisticated than ever. Moreover, fixed partial dentures can now be made using dental scanners, computer-aided design /computer-aided manufacturing (CAD/CAM) techniques [1]. Due to the intraoral scaners, conventional methods could be abandoned, the edges of the preparation can be identified easily, and the design of the future restoration can be realized and analyzed in order to avoid possible errors that may occur along the way [2]. Although the CAD/CAM technology produces restorations without the help of the dental technician in a shorter period of time and with a higher productivity [3] than the conventional methods, it utilises a lot of milling tools and results in a large volume of unprocessed material waste. 3D printing technology produces less waste and is more cost-effective [4-6]. Applications of 3D printing in dentistry include temporary restorations, fixed prostheses, removable and complete dentures, orthodontic models, night guards, bite splints, surgical guides, and maxillofacial prostheses [6-9]. The process of 3D printing is as follows: (1) objects to be printed are designed using the CAD software based on the data received from 3D scanners (3D CAD data); (2) printing supports are then added and the model is sliced into thin cross-sections or different ready-to-print layers [5,6,8]; (3) after the object is printed, the supports are removed and a post-processing treatment is applied; (4) this is followed by washing and polishing of the printed model [6,8].

There are several types of 3D printing technologies available for dental and medical use, such as stereolithography (SLA), digital light projection (DLP), polyjet or multijet, fused deposition modelling (FDM), and powder bed fusion (PBF) [5,10,11]. The differences between these technologies lie in the material used and in the way the layers are deposited to create the final object. The materials used are classified into the following three categories: liquid, powders, and solid.

SLA is a highly accurate additive manufacturing process, also referred to as 3D printing. Its accuracy is superior to that of other technologies because it can print objects with complex geometries and fine details. SLA is a photopolymerisation process that creates solid items in different layers from liquid resin material using an ultraviolet light (UV) or laser for added strength [5,6,9,10]. The items are built in layers, and each layer is cured by UV light with another thin layer of the polymer [5,10]. This process continues until the final object is created [6,9], after which it is removed from the bath [9,11]. Application of post-processing treatment such as removing the structural printing supports, turning off the cured UV light or laser, and carrying out some surface treatments for roughness are necessary [5]. The most common materials used in SLA are acrylic resin, silicone, and epoxy [10,11]. These materials are available in different colours and exhibit different mechanical and physical properties [10].

Provisional dental prostheses are used as intermediate restoration to help the patient carry out oral functions from the time of tooth preparation until the final restoration is placed in the oral cavity [12,13]. As it is well known that a provisional prosthesis should protect the abutment against pulpal and gingival aggressions, it must adapt correctly because we need healthy gingival tissues, resist fracture, and have a low price, being intermediate restoration [14]. Contrastly, it can cause pulpal lesions, periodontal diseases, and bone loss [15].

Provisional restorations might need to be functional for increased periods of time while treating complex full mouth rehabilitation cases [16], and according to the treatment plan, they may be modified to improve aesthetics, cases of discoloration or defects, correct contour, proximal contact and occlusion issues, and marginal area fit [17].

One of the objectives during restoration fabrication and cementation is to achieve a minimal marginal gap between the restoration and the preparation in order to obtain suitable periodontal and pulpal responses and optimal cement performance [18]. An increased marginal discrepancy at the restoration-tooth interface can cause microleakage which leads to pulpal reactions, and/or secondary caries [18]. Various ranges of acceptable marginal gaps have been reported in the literature, depending on the used cement type, restorative material, and measuring procedure [18]. However, there is no clear agreement. From a clinical point of view, a marginal opening of 50-120 μm is currently considered acceptable for indirectly manufactured restorations; however, a marginal gap of less than 25 μm would be ideal [18].

There is currently no adequate and recommended gap measurement technique. There are several options available, each with its own set of benefits and drawbacks. Here are several examples: the first is a direct microscopic examination of the marginal area; the second is the measurement of distances using cross-sections of a cemented restoration, the third is the analysis of light body silicone replicas of the cement gap (using a microscope), the fourth is the laser videography of the digitized silicone replica and die, the fifth is an indirect measurement of absolute marginal discrepancy (using a profilometer), the sixth is X-ray microtomography; and others [18]. The precision relates to the repeatability of measurement, while trueness refers to the discrepancies of the measured values from the planned values [18]. The accuracy and precision of milled restorations have been studied more frequently than those of printed ones, and there is no clear conclusion as to whether or not 3D-printed zirconia crowns can be considered as precise and accurate as milled ones [18].

Regarding provisional restorations, polymethyl methacrylate (PMMA) is frequently used in their fabrication [19]. Provisional resins should have suitable physical and mechanical characteristics togheter with marginal fit in order to function properly for longer periods of time [16]. 3D-printed provisional fixed dental prostheses and materials have been claimed to have superior mechanical qualities, while CAD-CAM milled provisional materials have improved physical attributes compared to traditionally manufactured provisionals [16]. The downsides of employing CAD-CAM technology for provisional restorations include expensive production devices and increasing fabrication costs [16].

The purpose of this *in vitro* study was to compare the marginal adaptation of provisional fixed dental prostheses manufactured using 3D printing (SLA technology) with two different materials and milling technology. The null hypothesis was that there was no difference between the marginal gaps of the types of the aforementioned prostheses.

Methods

A mandibular typodont model (Frasaco, Greenville, N.C., USA) was used to prepare the left second premolar and molar for a three-unit ceramic fixed dental prosthesis. Both abutments were prepared by the same operator using identical preparation techniques and finishing equipment (Komet 4573.314, Germany). The anatomical occlusal reduction was 1.5–2 mm, axial reduction was 1 mm, with an occlusal convergence angle of 6° and a rounded-shoulder supragingival finish line.

Next, the abutments and the adjacent edentulous ridge were scanned using an intraoral scanner (PlanScan; Planmeca, Helsinki, Finland) (Figure 1). The digital model was then uploaded to a 3D printer (Prusa SL1; Prusa by Josef Prusa, Czech Republic), and 30 models were printed (Figure 2a).

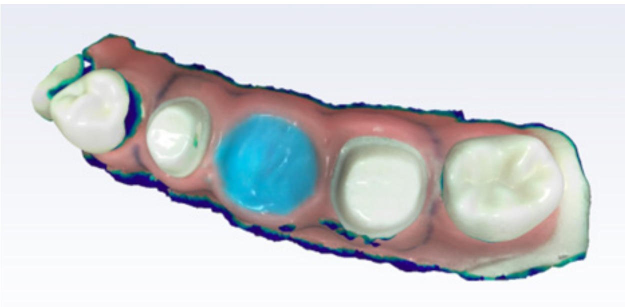


Figure 1. Digital model obtained after scanning with Planscan (Planmeca).

The digital models were analyzed using CAD software (Romexis; Planmeca, Finland), and the digital design for the final restoration was finalized with a spacer thickness of 0.1 mm and a marginal gap of 0,25 mm. Next, the three-unit fixed dental provisional prosthesis were milled from polymethyl methacrylate (PMMA, Telio CAD; Ivoclar, Vivadent, Schaan, Liechtenstein) using a chairside milling machine (PlanMill 40; Planmeca, Helsinki, Finland), hereafter termed as the "milled group" (Figure 2b). The milling time for each Telio CAD block was 30 minutes, therefore the total milling for all the Telio provisional restorations was five hours.

The same digital design was used to fabricate 3D-printed restorations (SLA). Ten restorations were fabricated using Prusa resin (PR group) (Prusa White Tough, Czech Republic) (Figure 3a), and another ten were printed using a resin for temporary crowns and bridges (GC group) (GC Temp PRINT, USA) (Figure 3b). The advantage of 3D printer is the short printing time of multiple restorations which can be printed simultaneously. Prusa resin was used, resulting 10 printed restorations in one hour. Next, GC resin was used to fabricate the last 10 restorations. Using a 30-degree construction angle, the restorations were printed from cervical to occlusal. The restoration is roughly 0.025 millimeters thick. After the printing procedure, the restorations were introduced in isopropyl alcohol, removing the uncured resin, followed by drying and UV-light curing.

(a)

(b)

Figure 2. a) 3D printed model using the Prusa SL1 3D printer; **b)** CAD-CAM restoration on the model (the milled group).

(a)

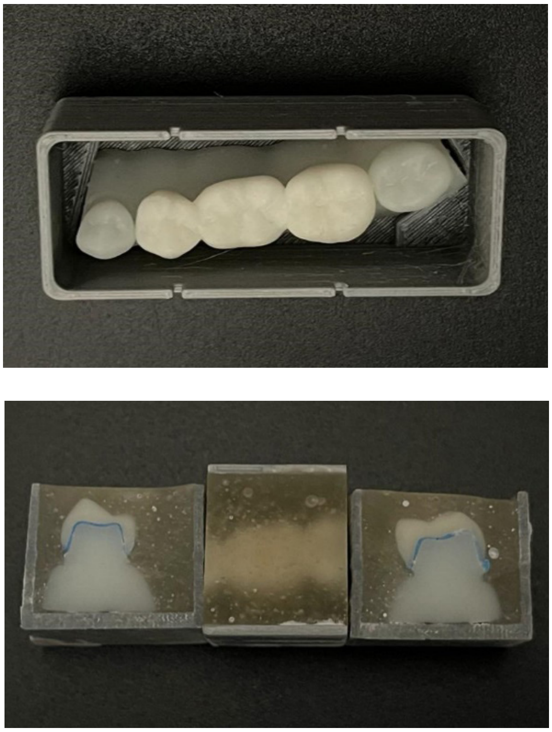
(b)

Figure 3. a) PR restorations (PR group); b) GC restorations (GC group).

The materials used for each group are presented in table I. Consequently, 30 restorations were obtained corresponding to the two types of manufacturing processes (milled group: 10; PR resin: 10; GC resin: 10).

Marginal gap is defined as the discrepancy between the restoration and the margin of the prepared tooth. A cement was used (Ketac Cem radiopaque, USA) with added dye for a better evaluation of the marginal fit. A thin layer of material was applied to the intaglio surface of each prosthesis and was held in place with finger pressure for approximately 20s.

The supports used to fix the protheses were made using 3D printing with fused deposition modeling technology using and acrylonitrile butadiene styrene filaments (Figure 4a).



(a)

(b)

Figure 4. a) The support for fixing the prostheses; **b)** The restoration fixed in the support with self curing acrylic.

The restorations were fixed in the supports and self-curing acrylic (Duracryl Plus set, Czech Republic) was poured covering both the restorations and the printed models. The acrylic curing time was 15 minutes and then each sample was sectioned with a disc in buccal-lingual direction following the midline of the abutments (premolar and molar) (Figure 4b). Marginal gap was observed under an stereomicroscope (Edmund E-Zoom) with 40X magnification and the restorations were then photographed with a digital camera (Sony Alpha 600) mounted on microscope at the same distance and position.

The marginal gap was measured using Image J software (Java-based image processing), an image processing programme developed at the National Institutes of Health and the Laboratory for Optical and Computational Instrumentation (University of Wisconsin) [20,21]. Each restoration was uploaded to the ImageJ program, and a starting point was determined by placing a marker at the intersection of the restoration margin and the abutment. Additional markers were placed at the same coordinates as the starting point, but with an additional 0.5 millimeters of spacing between them. A calibration was added in Image J, wherein 1 mm corresponded to 70 pixels, and measured the marginal fit of each restoration (Figure 5).

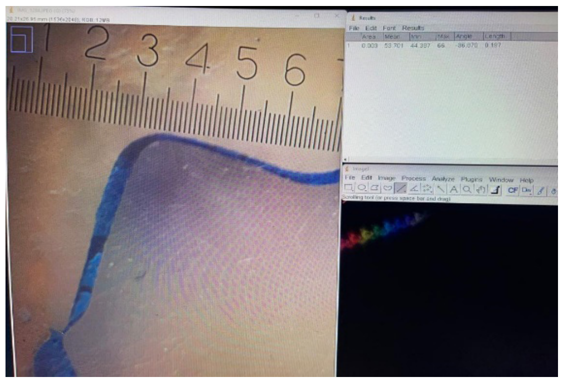


Figure 5. Measurements with Image J software.

Table I. Composition of subtractive and additive CAD/CAM materials used in the study.

Technology	Material	Composition
Milled Machine (CAM) PlanMill 40; Planmeca, Helsinki, Finland	Telio CAD PMMA, Telio CAD; Ivoclar, Vivadent, Schaan, Liechtenstein	Poly methyl methacrylate
3D printer (SLA) Prusa White Tough, Czech Republic	Prusa resin Prusa White Tough, Czech Republic	Epoxy resin, Monomer, colour pigments, photoinitiator, dyes
3D printer (SLA) Prusa White Tough, Czech Republic	GC resin GC Temp PRINT, USA	Urethane dimethacrylate, dimethacrylate component, quartz, photoinitiator, synergist, UV-light absorber

Results

All images were analysed, and marginal gap distances were measured for both abutments (6 points/ abutment). The results presented in Table 2 are the means of the restoration's measurements. Six measurements were performed per abutment, which means that six measurements were taken for the premolar and another six for the molar; then, the average of all measurements was calculated.

The results of this study are presented in table II.

Table II. Marginal gap for all the samples.

	Milled	PR	GC
Sample 1	86 µm	317 µm	204 µm
Sample 2	90 µm	333 µm	206 µm
Sample 3	102 µm	340 µm	221 µm
Sample 4	95 µm	440 µm	228 µm
Sample 5	98 µm	292 µm	249 µm
Sample 6	89 µm	281 µm	251 µm
Sample 7	105 µm	294 µm	110 µm
Sample 8	87 µm	316 µm	170 µm
Sample 9	91 µm	301 µm	190 µm
Sample 10	108 µm	320 µm	130 µm
Median (IQR)	93 µm (11.75)	316.5 µm (34)	205 µm (51.25)

*milled group, PR group, GC group.

The statistical analyses were performed using the MedCalc software (version 20.011, Belgium). The Kolmogorov-Smirnov test resulted that the data for marginal gap distances were non parametric. Further analysis was performed on the data, the Kruskall Wallis test was used on the datasets, to analyze the differences between the marginal discrepancies of each group with a *p* value <0.05.

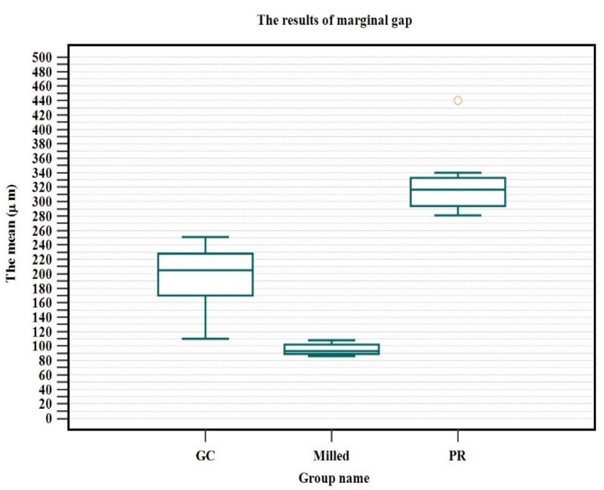


Figure 6. Groups results using the boxplot.The marginal gap between the groups, the minimum, the maximum, and the median values.

Regarding the marginal gap values, the Kruskal-Wallis test showed statistically significant differences between the groups ($p < 0.001$).

The results of the present study reflected that the milled group had the best marginal gap values (ranging from 86 to 108 µm) and a median value of 93 µm, followed by GC group with (110-251 µm) with a median value of 205 µm and the PC grup with median value of 316.5 µm (Figure 6).

The post-hoc analysis (Conover) was performed. This analysis also concluded that there were differences between the investigated groups.

Discussion

Advances in digital technology and dental materials give the opportunity to the practician to improve clinical workflow. With the popularization of CAD/ CAM process, several areas of dentistry improved their technique by using digital impressions, making treatment planning with reduced discomfort and increased treatment efficiency. The high strength materials with exceptional biocompatibility and aesthetic design improve the precision of fit and longevity.

The subtractive method offers the advantage of fabricating dental restorations with increased quality over a short period [22]. However, for provisional restorations, when trying to find a balance between costs and efficiency, the additive method is a good area to be explored mainly because they are more cost-effective [4-6].

Optimal marginal adaptation is a major factor to stabilize fixed dental prostheses biologically and mechanically in the oral cavity [23]. This study measured the marginal gap of different types of provisional dental prostheses using Image J software (Java-based image processing http://imagej.nih.gov). This software counts the area and pixel value statistics of user-defined selections; measures distances and angles; and edits, processes, saves, and prints images [20,21].

The purpose of this study was to compare the marginal fit of provisional restorations manufactured by milling and 3D printing. The null hypothesis of this study was rejected, as the results demonstrate that there are differences between the materials and technology employed. The accepted marginal gap is a maximum of 120 µm, according to a 5-year study by McLean and von Fraunhofer [24,25]. Other studies estimated that the accepted marginal discrepancy is between 50-120 µm [26]. In the present study, all samples from the milled group were below the 120 µm value (86-108 µm). The GC group, presented values between 110-251 µm, with the median value of 205 µm which exceeds the previously stated interval. The PR group, reported the highest marginal gap values with a median value of 316.5 µm , therefore excluding the posibility of clinical use. Similar results were observed in another study which used this method to evaluate and measure the marginal fit of CAD-CAM milled crowns [25].

Armin et al. considered that increased application of cement leads to an increase in the risk of a marginal gap [26]. In our study, only a thin layer of dyed cement was applied on the intaglio surfaces to provide a better contrast for the assesment of marginal adaptation .

Some authors have reported that the magnitude of the marginal discrepancy depends on the type of preparation used [27-29]. Over-contouring a tooth is considered more harmful than under-contouring because it increases plaque formation, thereby increasing the possibility of gingival inflammation and loss of attachment of the periodontal ligament [30-31].

The restoration material can also play a role in the quality of a crown's marginal fit. In our study, dimethacrylates and epoxy resin for 3D printing were used, as well as polymethyl methacrylate (PMMA) blocks for the milled group. Zandparsa considered that the group of methacrylates produce a better marginal fit and have better mechanical properties [26]. These findings are similar with the results of the present study, PMMA and dimethacrylate samples having superior results when compared to to epoxy resin.

Park et al. evaluated the internal and marginal fit of resin-built interim definitive fixed partial dentures that were 3D printed using the DLP technology with two different thickness layers and five build orientations. However, most 3D printed groups showed worse results than the milled ones [32]. According to Blatz, the accuracy and material properties of current 3D printing resins are limited, i.e., they are inaccurate enough to provide a proper marginal fit for indirect restorations on 3D printed models [33,34].

The present study focuses on finding a cost-effective printing treatment option as an alternative to the the substractive CAD/CAM method by comparing two types of materials. Based on the results of this study, both the manufacturing technique and the material used, influence the marginal adaptation. Research and development for new materials used in 3D printing will pave the way for new possibilities for practitioners to create in short time, low-cost, highly functional, and accurate restorations for their patients.

Being an in vitro study, there are a number limitations. The handling of the samples (the application of cement, quantity of cement, its kneading, pressure applied to sample cementation) were not standardized. Also, the measurements for marginal discrepancies were made manually in an image analysis software using a calibrated grid leaving room for potential inaccuracies. Another possible limitation can be related to the slicing procedure which was performed manually as well.

Conclusions

Based on the results of this study the following conclusions can be drawn:

- The milling and SLA technology provides acceptable marginal fit values when used to fabricate provisional fixed partial dentures.
- GC resin is more suitable for clinical use in dentistry because of their good marginal fit values.
- Due to high marginal gap values, PR resin is not suitable for provisional restorations.

References

1. Shim JS, Kim JE, Jeong SH, Choi YJ, Ryu JJ. Printing accuracy, mechanical properties, surface characteristics, and microbial adhesion of 3D-printed resins with various printing orientations. J Prosthet Dent. 2020;124:468–475.
2. Ng J, Ruse D, Wyatt C. A comparison of the marginal fit of crowns fabricated with digital and conventional methods. J Prosthet Dent. 2014;112:555-560.
3. Della Bona A, Cantelli V, Britto VT, Collares KF, Stansbury JW. 3D printing restorative materials using a stereolithographic technique: a systematic review. Dent Mater; 2021;37.336–350.
4. Corazza PH, de Castro HL, Feitosa SA, Kimpara ET, Della Bona A. Influence of CAD-CAM diamond bur deterioration on surface roughness and maximum failure load of Y-TZP based restorations. Am J Dent. 2015;28:95–99.
5. van Noort R. The future of dental devices is digital. Dent Mater. 2012;28:3–12.
6. Stansbury JW, Idacavage MJ. 3D printing with polymers: Challenges among expanding options and opportunities. Dent Mater. 2016;32:54–64.
7. Ventola CL. Medical Applications for 3D Printing: Current and Projected Uses. P T. 2014;39:704–711.
8. Dawood A, Marti Marti B, Sauret-Jackson V, Darwood A. 3D printing in dentistry. Br Dent J. 2015;219:521–529.
9. Azari A, Nikzad S. The evolution of rapid prototyping in dentistry: A review. Rapid Prototyping Journal. 2009;15:216–225.
10. Barazanchi A, Li KC, Al-Amleh B, Lyons K, Waddell JN. Additive Technology: Update on Current Materials and Applications in Dentistry. J Prosthodont. 2017;26:156–163.
11. Liu Q, Leu MC, Schmitt SM. Rapid prototyping in dentistry: technology and application. Int J Adv Manuf Technol. 2006;29:317–335.
12. Abdullah AO, Tsitrou EA, Pollington S. Comparative in vitro evaluation of CAD/CAM vs conventional provisional crowns. J Appl Oral Sci. 2016;24:258–263.
13. Rodrigues VA, Dal Piva AO, Yamaguchi CA, Borges AL, Mukai MK, Tribst JP. Effect of framework type on survival probability of implant-supported temporary crowns: An in vitro study. J Clin Exp Dent. 2020;12:e433–e439.
14. Rakhshan V. Marginal integrity of provisional resin restoration materials: A review of the literature. The Saudi

Journal for Dental Research. 2015;6:33–40.

15. Gudapati S, Jagadish HG, Sajjan RK, Ramya K, Naveen D. Evaluation and comparison of marginal fit of provisional restoration fabricated using light cure acrylic resin with other commercially available temporary crown resin materials. Trends Biomater Artif Organs. 2014;28:47–51.
16. Al Wadei MHD, Sayed ME, Jain S, Aggarwal A, Alqarni H, Gupta SG, et al. Marginal Adaptation and Internal Fit of 3D-Printed Provisional Crowns and Fixed Dental Prosthesis Resins Compared to CAD/CAM-Milled and Conventional Provisional Resins: A Systematic Review and Meta-Analysis. Coatings. 2022;12:1777;
17. Jeong KW, Kim SH. Influence of surface treatments and repair materials on the shear bond strength of CAD/CAM provisional restorations. J Adv Prosthodont. 2019;11:95-104.
18. Abualsaud R, Alalawi H. Fit, Precision, and Trueness of 3D-Printed Zirconia Crowns Compared to Milled Counterparts. Dent J (Basel). 2022;10:215.
19. Yang MS, Kim SK, Heo SJ, Koak JY, Park JM. Investigation of the marginal fit of a 3D-printed three-unit resin prosthesis with different build orientations and layer thicknesses. J Adv Prosthodont. 2022;14:250-261.
20. Schneider CA, Rasband WS, Eliceiri KW. NIH Image to ImageJ: 25 years of image analysis. Nat Methods. 2012;9:671–675.
21. Collins TJ. ImageJ for microscopy. Biotechniques. 2007;43(1 Suppl):25–30.
22. Sriram S, Shankari V, Chacko Y. Computer Aided Designing/ Computer Aided Manufacturing in Dentistry (CAD/ CAM) - A Review. International Journal of Current Research and Review. 2018;10:20–24.
23. Kim MJ, Choi YJ, Kim SK, Heo SJ, Koak JY. Marginal Accuracy and Internal Fir of 3-D Printing Laser-Sintered Co-Cr Alloy Copings. Materials (Basel). 2017;10:93.
24. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971;131:107-111.
25. Jivanescu A, Birkenheier N, Rotar RN, Topala F, Goguta L. Marginal fit of ceramic crowns fabricated with CAD-CAM technology using a direct and indirect digital workflow. Research and Clinical Medicine. 2019;3:1-6
26. Aldahian N, Khan R, Mustafa M, Vohra F, Alrahlah A. Influence of Conventional, CAD-CAM, and 3D Printing Fabrication Techniques on the Marginal Integrity and Surface Roughness and Wear of Interim Crowns. Applied Sciences. 2021;11:8964.
27. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthet Dent. 1989;62:405–408.
28. Gavelis JR, Morency JD, Riley ED, Sozio RB. The effect of various finish line preparations on the marginal seal and occlusal seat of full crown preparations. J Prosthet Dent. 1981;45:138–145.
29. Pera P, Gilodi S, Bassi F, Carossa S. In vitro marginal adaptation of alumina porcelain ceramic crowns. J Prosthet Dent. 1994;72:585–590.
30. White SN, Yu Z, Tom JF, Sangsurasak S. In vitro marginal adaptation of cast crowns luted with different cements. J Prosthet Dent. 1995;74:25–32.
31. Lang NP, Kiel RA, Anderhalden K. Clinical and microbiological effects of subgingival restorations with overhanging or clinically perfect margins. J Clin Periodontol. 1983;10:563–578.
32. Molinero-Mourelle P, Gómez-Polo M, Gómez-Polo C, Ortega R, del Rio Highsmith J, Celemín-Viñuela A. Preliminary Study on the Assessment of the Marginal Fit of Three-Dimensional Methacrylate Oligomer Phosphine Oxide Provisional Fixed Dental Prostheses Made by Digital Light Processing. Prosthesis. 2020;2:240–245.
33. Scherer MD, Blatz MB, Kellum B. How does 3D printing compare clinically with CAM milling?. Compendium of Continuing Education in Dentistry. 2020;41(10) Available from: https://www.aegisdentalnetwork.com/cced/2020/11/how-does-3d-printing-compare-clinically-with-cam-milling
34. Berli C, Thieringer FM, Sharma N, Müller JA, Dedem P, Fischer J et al. Comparing the mechanical properties of pressed, milled, and 3D-printed resins for occlusal devices. J Prosthet Dent. 2020;124:780–786.