ORIGINAL ARTICLE
Essent Dent 2021; 1(1): 38-42
DOI: 10.5152/EssentDent.2021.21009

ISTANBUL UNIVERSITY CERRAHPAŞA

Effect of Abutment Shape on the Accuracy of Two Dental Computer-Aided-Design and Computer-Aided-Manufacturing Systems

Somchai Urapepon , Kanda Leelanarathiwat

Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Thailand

Cite this article as: Urapepon S, Leelanarathiwat K. Effect of abutment shape on the accuracy of two dental computer-aided-design and computer-aided-manufacturing systems. *Essent Dent*. *1*(1): 38-42.

Abstract

Objective: The international standard organization (ISO) evaluated the accuracy of the computer-aided-design and computer-aided-manufacturing (CAD-CAM) systems using their unique symmetry taper abutment. This study evaluated the effect of abutment shape on the accuracy of two CAD-CAM systems by using symmetry cylindrical taper die (ISO) compared with normal tooth preparation by marginal gap measurement.

Methods: The ISO taper die (ISO 12836; 2012) and plastic tooth form abutment (maxillary second premolar) were duplicated and casted with nichrome (Ni-Cr) alloy, then used as master die. Both dies were scanned and the zirconia crown coping was fabricated by two CAD-CAM systems, Cerec InLab (Dentsply Sirona Inc) and Ceramill (Amann Girrbach). The absolute marginal discrepancy (AMD) of the crowns were measured. The data were statistically analyzed by two-way Analysis of Variance (ANOVA) and Tukey's test ($\alpha = 0.05$).

Results: Cerec InLab showed a marginal discrepancy of the crown of 0.20 ± 0.03 mm in both abutment forms, and this was statistically larger than the Ceramill system (0.09 ± 0.04 mm and 0.07 ± 0.03 mm for ISO abutment and tooth form abutment, respectively).

Conclusion: The different abutment shapes did not affect the accuracy of the crown coping produced from the CAD-CAM system, whereas the different CAD-CAM systems affected the accuracy of the crown.

Keywords: Abutment, CAD-CAM, dental crown, marginal adaptation, standardization

Introduction

Computer-aided-design and computer-aided-manufacturing (CAD-CAM) technology has been used increasingly in dentistry for over 25 years.[1] The development of new materials such as zirconia ceramics, polycrystalline alumina ceramic, and partial-sintering cobalt-chromium (Co-Cr) alloy has driven more developments in the CAD-CAM systems along with the development of new materials to support the successful dental restorations of the patient.[2] Current CAD-CAM restorations are better fitting, stronger, and more aesthetic than previous CAD-CAM restorations.[3]

A lot of dental CAD-CAM systems are available in the world market. Each system has its own technology, both for CAD and CAM. Some systems have combined their own technology with some original equipment manufacturer (OEM) technology.[4] However, most of the systems are a closed system and it is impossible to transfer data between systems. This would cost higher expenses for restorations fabricated by CAD-CAM and spike the development of not only the CAD-CAM system but also the development of the materials.[5]

In clinical settings, the shape and size of the abutment from the tooth preparation for crown restoration was individually varied from tooth to tooth. Several researchers evaluated the accuracy of different techniques for crown construction based upon individual abutment shape and size; however, it is difficult to compare work by work.[6] The accuracy of the

Corresponding Author: Somchai Urapepon
s.urapepon@gmail.com

Received: June 8, 2021
Accepted: August 17, 2021
Available Online Date: September 16, 2021

CAD-CAM system was evaluated by the ISO, based on their typical abutment. The abutment was set up more simply and repeatably. Therefore, the results of the accuracy of the CAD-CAM system from different crown construction techniques can be compared and justified from laboratory to laboratory.[7] To avoid the uncontrolled shape of the abutment, the symmetrical cylindrical taper abutment was used for standard testing. This ISO abutment is quite big as compared with the usual tooth preparation abutment.[7] However, the accuracy of the restoration fabricated by CAD-CAM systems is influenced by multi-factors, not only by the factors of the fabrication process but also those of the shape and dimension of the restoration.[6]

Therefore, the purpose of this study is to evaluate of the effect of abutment shape on the accuracy of two different CAD-CAM systems using symmetry cylindrical taper die (ISO) compared with normal tooth preparation by marginal gap measurement.

Methods

The schematic picture of a symmetry cylindrical taper die is shown in Figure 1. This die was fabricated from stainless steel and is used for evaluating the accuracy of the CAD-CAM system as indicated in ISO 12836; 2012 Dentistry-Digitizing devices for CAD-CAM systems for indirect dental restorations-Test methods for assessing accuracy.[7]

The tooth form abutment was prepared from plastic Ivorine™ tooth (Columbia Dentoform Corp, NY, USA), using a maxillary right second premolar tooth model. The tooth preparation was performed to approximately achieve a 0.8 mm-deep chamfer finishing line, a 1.5 mm occlusal reduction, and 6-degree total occlusal convergences. The preparation of the plastic tooth was then duplicated and casted with Co-Cr alloy (Vitallium®, Dentsply Inc, PA, USA) and used as the master die.

Both die abutments were scanned and the crown coping was fabricated by two CAD-CAM systems, Cerec InLab (Dentsply Sirona Inc, PA, USA) and Ceramill (Amann Girrbach, Koblach, Austria). The Cerec InLab system is composed of an InEos Blue desktop scanner, an InLab software, and an InLab MC XL milling machine, whereas the Ceramill system is composed of a Ceramill map300 scanner, a Ceramill Mind software, and a Ceramill Motion milling machine. The scanner and the milling unit of both CAD-CAM systems were calibrated at the beginning of the study and recalibrated before each test.

Main Points

- The size and shape of the abutment did not affect the crown accuracy milled by the two dental CAD-CAM systems.
- The crown accuracy was affected by the different CAD-CAM systems.
- The typical ISO die abutment can be used for testing the accuracy of the CAD-CAM system employed.

Both master dies were fixed to a special model holder in the aligning tool provided by each CAD-CAM system and scanned to obtain abutment data. After scanning, the restoration on the abutment was designed by each CAD-CAM software. The full coverage cylindrical crown was designed for the symmetrical cylindrical taper die, as indicated in the ISO standard[7], and a full coverage 0.5 mm-thick substructure for all-ceramic crowns was designed for the tooth form abutment. The 20% oversize for zirconia shrinkage compensation, including the final firing and cement space for 10 μm, was applied. The restoration design was sent to each CAD-CAM milling machine to mill the zirconia block; InCoris ZI (Dentsply Sirona Inc, PA, USA) was used for Cerec InLab, and Ceramill ZI (Amann Girrbach, Koblach, Austria) was used for Ceramill. All scanning, designing, and milling procedures were repeated each time for ten coping for each group.

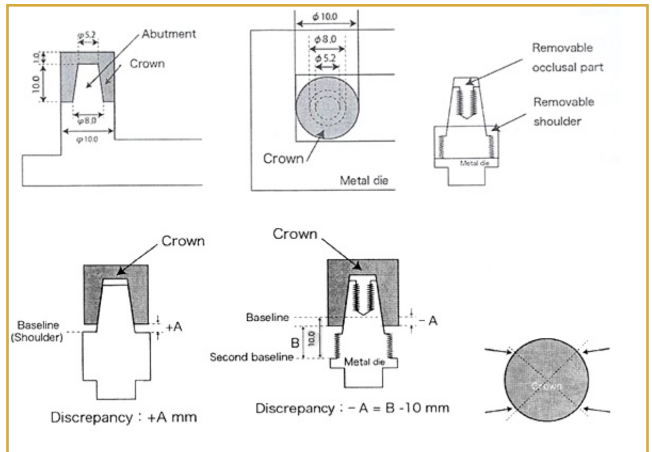

Figure 1. Schematic picture of the symmetry cylindrical taper die, its dimension and the discrepancy measurement (ISO 12836; 2012 Dentistry-Digitizing devices for CAD-CAM systems for indirect dental restorations -Test methods for assessing accuracy).

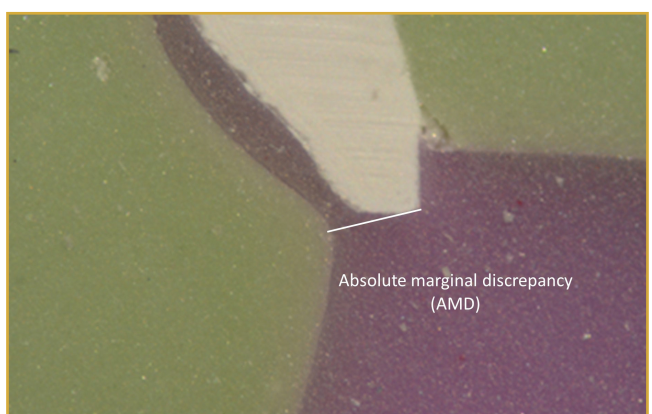

Figure 2. Cross-section of the absolute marginal discrepancy measurement (AMD); the gap from the margin of restoration to cavo-surface angle of preparation.

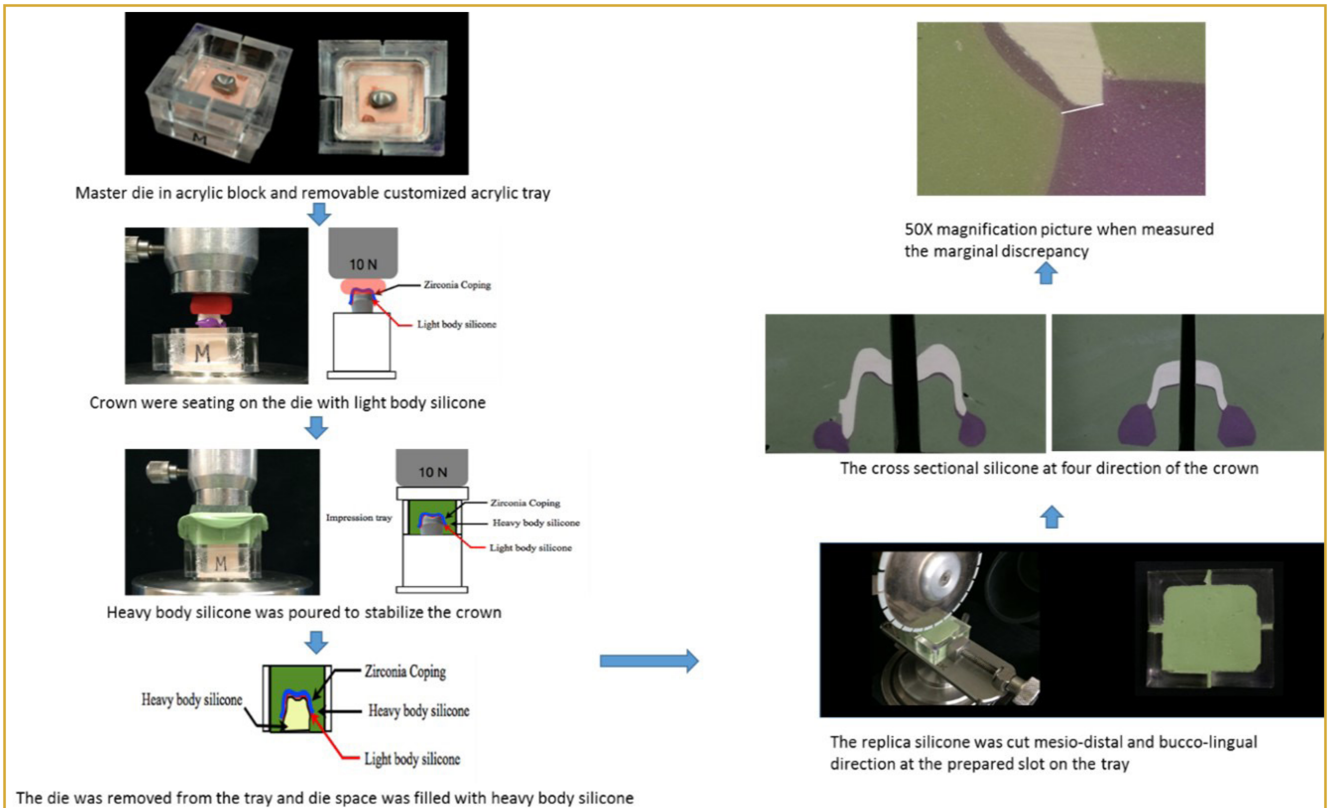

Figure 3. Schematic picture of the silicone replica technique procedure.

The absolute marginal discrepancy (AMD), which is the distance from the margin of the crown or the substructure to the cavo-surface angle of the finish-line preparation (as shown in Figure 2), was examined to represent the accuracy of the CAD-CAM system in this study. The discrepancy was examined using cross-sectional combined with silicone replica technique at four positions: mesial, distal, buccal, and lingual. The average to one datum for a crown was also examined.

The silicone replica technique was performed by filling a light body silicone into the crown coping and placing it on the master abutment. A 10 N load was applied on the center of the occlusal surface for 10 seconds, and then the load was removed and there was a waiting period until the silicone was completely set. The light body silicone films represented the space between the crown copings and the abutment. Each coping was stabilized by the application of a heavy body silicone in a customized perforated plastic tray. After the removal of the coping, the heavy body silicone was filled inside of the crown again to represent the abutment. A cutting instrument was used to cut the copings in a mesiodistal direction and buccolingual direction, along the prepared slot on the tray. The discrepancy of the crown was examined under an optical measuring microscope (Nikon Eclipse E400, Tokyo, Japan) at 50X magnification. The schematic picture of the silicone replica technique procedure is shown in Figure 3.

Statistical analysis

A statistical analysis software (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY, USA) was used in this study. Shapiro–Wilk and Levene's test was performed to test the normality and the equality of variances of the data. If the distribution of the data is normal and has equality of variances, a parametric analysis using two-way ANOVA followed by Tukey's multiple comparisons test at a significance level of α=0.05 will be used.

Results

The results of the mean and standard deviation of the marginal discrepancies of the crown fabricated from different abutment shapes by two CAD-CAM systems are shown in Table 1. The normality and equality of variances of the data were statistical confirmed by Shapiro–Wilk and Levene's test at $\alpha = 0.05$. The results of the ANOVA test, as shown in Table 2, demonstrated that the marginal discrepancy of the crown was influenced only by the CAD-CAM system ($P < .01$), regardless of abutment shape ($P = .22$) and their interaction ($P = .25$).

The Cerec InLab system showed a marginal discrepancy of the crown of 0.20 ± 0.03 mm for both different abutment forms, which was statistically ($\alpha = 0.05$) larger than Ceramill system (0.09 ± 0.04 mm and 0.07 ± 0.03 mm for ISO abutment and tooth form abutment, respectively).

Table 1.
Results of the Mean and Standard Deviation of Marginal Discrepancies of the Crown Fabricated from Different Abutment Shapes Using Two CAD-CAM Systems

	Marginal discrepancies in mm (mean ± SD)	
	Cerec in Lab®	Ceramill®
ISO abutment	0.20 ± 0.03[a]	0.09 ± 0.04[b]
Tooth form abutment	0.20 ± 0.03[a]	0.07 ± 0.03[b]

Abbreviations: ISO, international standard organization; SD, standard deviation.
Note: The value with same superscript letter means no statistically significant difference ($\alpha = 0.05$).

Table 2.
The Results of the Analysis of Variance Test

Source	Type III Sum of Squares	df	Mean Square	F	Significance
System	0.16	1	0.16	135.16	0.00
Form	0.002	1	0.002	1.56	0.22
System * form	0.002	1	0.002	1.34	0.25
Error	0.04	36	0.001	-	-
Total	0.97	40	-	-	-

Abbreviations: df, degree of freedom; F, value of F-distribution.

Discussion

The mean marginal discrepancy, as determined in this study, depends on the CAD-CAM system regardless of the different abutment shapes. This result agreed with the results of several studies[8-10], which showed that different abutment shapes or different margin types were not affected by the marginal gap of the crown milled from the CAD-CAM system; however, different CAD-CAM systems did show different marginal gaps.

The definitions of marginal fit vary considerably among investigators. In this study, the marginal discrepancy was determined according to the terminology previously reported by Holmes.[11] There are eight misfit terminologies: internal gap, marginal gap, overextended margin, underextended margin, vertical marginal discrepancy, horizontal marginal discrepancy, AMD, and seating discrepancy. The AMD, which is a parameter that measures the gap from the margin of restoration to the cavo-surface angle of preparation, was chosen for measuring the marginal gap because it is the angular combination of the marginal gap (both vertical and horizontal, either of overextension or underextension) that would reflect the true total misfit at the margin.[11] The AMD was applied to measure the marginal misfit of both abutment forms. Fortunately, the size of the crown prepared from the ISO abutment was quite big and only a vertical discrepancy without horizontal discrepancy was found; whereas, in the crown prepared from the tooth form abutment, both vertical and horizontal discrepancies were found. From this finding, a direct measurement via optical microscope can be applied to simplify the ISO test method.

In this study, Ceramill Motion, the milling unit of the Ceramill system, has a 4-axis milling unit, whereas the Cerec MC XL machine of Cerec InLab has a 3-axis milling unit. More axis devices can mill more complex geometry; this might be the reason for the different marginal discrepancies between both CAD-CAM systems. The efficiency of the milling unit was also affected to the discrepancy of the crown by the set-up of the cement space. In this study, the minimum required space of the cement space was set at 10 μm. A study[12] found that increasing the area of the die surface covered with a spacer can decrease the marginal gap. Also, the 20% oversize for zirconia shrinkage compensation would have a great effect on the marginal gap. The success of the shrinkage compensation of the zirconia material did not only depend on the software's ability but also depended on the composition and homogeneity of the pre-sintered zirconia block.[13,14] This would cause a big effect on the efficiency of the system.

For different all-ceramic systems, the marginal gap reported in several studies was within the range of 1–161 μm[15-17] for conventionally fabricated ceramic crowns. In contrast, marginal gaps of 17–118 μm have been reported for CAD-CAM-fabricated ceramic crowns.[15,17-21] Most investigators continue to use the criteria established by McLean and von Fraunhofer[22], which is less than 120 μm, for evaluating a clinically acceptable maximum marginal gap width. However, the marginal gap in this study from the Cerec InLab system exceeds the acceptable marginal gap for crowns in clinical usage. However, with cement space, the 3-axis machine of the Sirona system used in several studies[23-25] show a marginal discrepancy that is within the range of clinically acceptable. Several studies[26-28] showed that the axial wall space was found to be the smallest space among several measuring points in the crown and is sensitive enough to affect the other spaces in the crown when there is any interference to this wall.

The different abutment shapes did not affect the accuracy of the crown produced from the CAD-CAM system; whereas, the different CAD-CAM systems affected the accuracy of the crown. The typical ISO die abutment can be used for testing the accuracy of the CAD-CAM system.

Ethics Committee Approval: This work was a materials-based laboratory research without humans and animals related products involvement. The ethics committee approval was not required and/or submitted.

Informed Consent: This work was a materials-based laboratory research without humans and animals related products involvement, The patients consent form was not available.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – S.U.; Design – S.U., K.L.; Supervision – S.U.; Resources – S.U., K.L.; Materials – S.U., K.L.; Data Collection and/or Processing – S.U., K.L.; Analysis and/or Interpretation – S.U., K.L.; Literature Search – S.U., K.L.; Writing Manuscript – S.U., K.L.; Critical Review – S.U.; Other – S.U., K.L.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

References

1. Davidowitz G, Kotick PG. The use of CAD-CAM in dentistry. *Dent Clin North Am*. 2011;55(3):559-570. [Crossref]
2. 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 Mat J*. 2009;28(1):44-56. [Crossref]
3. Silva LHD, Lima E, Miranda RBP, Favero SS, Lohbauer U, Cesar PF. Dental ceramics: a review of new materials and processing methods. *Braz Oral Res*. 2017;31(Suppl 1):133-146. [Crossref]
4. Tapie L, Lebon N, Mawussi B, Fron-Chabouis H, Duret F, Attal JP. Understanding dental CAD-CAM for restorations--accuracy from a mechanical engineering viewpoint. *Int J Comput Dent*. 2015;18(4):343-367.
5. Miyazaki T, Hotta Y. CAD-CAM systems available for the fabrication of crown and bridge restorations. *Aust Dent J*. 2011;56(Suppl 1):97-106. [Crossref]
6. Papadiochou S, Pissiotis AL. Marginal adaptation and CAD-CAM technology: A systematic review of restorative material and fabrication techniques. *J Prosthet Dent*. 2018;119(4):545-551. [Crossref]
7. International Organization for Standardization. ISO 12836 Dentistry-Digitizing devices for CAD-CAM systems for indirect dental restorations -Test methods for assessing accuracy. Geneva: ISO; 2012.
8. Grenade C, Mainjot A, Vanheusden A. Fit of single tooth zirconia copings: comparison between various manufacturing processes. *J Prosthet Dent*. 2011;105(4):249-255. [Crossref]
9. Kokubo Y, Tsumita M, Kano T, Sakurai S, Fukushima S. Clinical marginal and internal gaps of zirconia all-ceramic crowns. *J Prosthodont Res*. 2011;55(1):40-43. [Crossref]
10. Baig MR, Tan KB, Nicholls JI. Evaluation of the marginal fit of a zirconia ceramic computer-aided machined (CAM) crown system. *J Prosthet Dent*. 2010;104(4):216-227. [Crossref]
11. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. *J Prosthet Dent*. 1989;62(4):405-408. [Crossref]
12. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD-CAM generated restorations. *Br Dent J*. 2008;204(9):505-511. [Crossref]
13. Kunii J, Hotta Y, Tamaki Y, Ozawa A, Kobayashi Y, Fujishima A, et al. Effect of sintering on the marginal and internal fit of CAD/CAM-fabricated zirconia frameworks. *Dent Mater J*. 2007;26(6):866-876. [Crossref]
14. Beuer F, Neumeier P, Naumann M. Marginal fit of 14-unit zirconia fixed dental prosthesis retainers. *J Oral Rehabil*. 2009;36(2):142-149. [Crossref]
15. Beschnidt SM, Strub JR. Evaluation of the marginal accuracy of different all-ceramic crown systems after simulation in the artificial mouth. *J Oral Rehabil*. 1999;26(7):582-593. [Crossref]
16. Schaerer P, Sato T, Wohlwend A. A comparison of the marginal fit of three cast ceramic crown systems. *J Prosthet Dent*. 1988;59(5):534-542. [Crossref]
17. Sulaiman F, Chai J, Jameson LM, Wozniak WT. A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. *Int J Prosthodont*. 1997;10(5):478-484.
18. Nakamura T, Dei N, Kojima T, Wakabayashi K. Marginal and internal fit of Cerec 3 CAD-CAM all-ceramic crowns. *Int J Prosthodont.* 2003;16(3):244-248.
19. Boening KW, Wolf BH, Schmidt AE, Kastner K, Walter MH. Clinical fit of Procera AllCeram crowns. *J Prosthet Dent*. 2000;84(4):419-424. [Crossref]
20. Yeo IS, Yang JH, Lee JB. In vitro marginal fit of three all-ceramic crown systems. *J Prosthet Dent*. 2003;90(5):459-464. [Crossref]
21. Bindl A, Mormann WH. Marginal and internal fit of all-ceramic CAD-CAM crown-copings on chamfer preparations. *J Oral Rehabil*. 2005;32(6):441-447. [Crossref]
22. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. *British Dent J*. 1971;131(3):107-111. [Crossref]
23. Lima FF, Neto CF, Rubo JH, Santos GC Jr, Moraes Coelho Santos MJ. Marginal adaptation of CAD-CAM onlays: Influence of preparation design and impression technique. *J Prosthet Dent*. 2018;120(3):396-402. [Crossref]
24. Habib SR. Digital microscopic evaluation of vertical marginal discrepancies of CAD-CAM fabricated zirconia cores. *Biomed Tech*. 2019;64(2):207-214. [Crossref]
25. Mello C, Santiago Junior JF, Galhano G, Quinelli Mazaro JV, Scotti R, Pellizzer E. Analysis of Vertical Marginal Adaptation of Zirconia Fixed Dental Prosthesis Frameworks Fabricated by the CAD-CAM System: A Randomized, Double-Blind Study. *Int J Prosthodont*. 2016;29(2):157-160. [Crossref]
26. Gaikwad BS, Nazirkar G, Dable R, Singh S. Comparative evaluation of marginal fit and axial wall adaptability of copings fabricated by metal laser sintering and lost-wax technique: An in vitro study. *J Indian Prosthodont Soc*. 2018;18(1):47-52.
27. Hasanzade M, Sahebi M, Zarrati S, Payaminia L, Alikhasi M. Comparative Evaluation of the Internal and Marginal Adaptations of CAD-CAM Endocrowns and Crowns Fabricated from Three Different Materials. *Int J Prosthodont*. 2021;34(3):341-347. [Crossref]
28. Han HS, Yang HS, Lim HP, Park YJ. Marginal accuracy and internal fit of machine-milled and cast titanium crowns. *J Prosthet Dent*. 2011;106(3):191-197. [Crossref]