Original Article

Evaluation of Marginal and Internal Fit Discrepancy of Crowns Fabricated Using Conventional, Milling, and Three Dimensional Printing Techniques

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ABSTRACT

Aim: The aim of this study was to evaluate and compare fit of metal crown fabricated through conventional, Computer-aided design and manufacturing (CAD/CAM), and direct metal laser sintering (DMLS) (3D printing) techniques. **Materials and Methods:** A lower typhodont molar tooth was prepared. The impression was made using elastomeric impression material. The impression was poured with type IV die stone. Molar die was prepared. Ten cobalt chromium crowns were prepared using lost wax technique. Then, the die was scanned using lab scanner (UP 3D Acublu, Germany) and the image was saved as a standard tesellation language (.stl) file in a CAD software (ExoCAD Matera, Germany). Crown was virtually designed and ten crowns were milled using cobalt chromium blocks. The same.stl file was sent to DMLS printer (Object Eden 260VS; Stratasys) and 30 crowns were printed using cobalt chromium powder with a 5 µm layering thickness. Silicone replica technique was used to measure the marginal and internal fit. Horizontal marginal fit was measured at eight different points on the sample. Then, the sample was sectioned mesiodistally and internal gap was measured at five different points. All the measurements were done in ×50 magnification of a stereolitho microscope. **Results:** The conventional group showed the highest mean internal and marginal gap of 90.37 µm and 73.05 µm, respectively. 3D-printed crowns showed lowest mean marginal and internal gap of 27.27 µm and 23.83 µm, respectively. **Conclusion:** Fit discrepancy of crowns fabricated through the three techniques was within clinically acceptable range. However, 3D-printed crowns showed the best fit.

Key words: CAD/CAM, 3D printing, Internal gap, Marginal gap, Metal crown

INTRODUCTION

"Fixed partial dentures (FPDs) are the dental prosthesis that is luted, screwed, or mechanically attached or otherwise securely retained to natural teeth, tooth roots, and/or dental implant abutments."[1] Due to replacement of single missing tooth with implant retained prosthesis, the conventional FPDs are being used more sparingly. However, it is still significantly indicated for the patients who have a bounded edentulous space, economical and medical issues, as well as the patients who do not want to opt for surgical innervation; FPD is an appropriate choice. The lost wax technique is the most widely used technique for their fabrication. Certain advantages of wax that makes the conventional technique widely accepted, which are convenient manipulation and the ability to form a specific shape.

The marginal and internal fit of a crown are of paramount importance for a successful FPDs. Incomplete fit has been associated with the dissolution of luting cement, development of secondary caries, adverse pulpal reactions, and periodontal inflammation. The conventional techniques of fabrication involves manual work that depends on technician's skills and

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several steps of fabrication. Furthermore, the technician has to deal with certain issues due to undesirable properties of wax such as thermal sensitivity, elastic memory, and a high coefficient of thermal expansion.[2] To save the time and lengthy process of the work, technology such as computer-aided design–computer-aided manufacturing (CAD-CAM) system has emerged and is available for prosthesis fabrication, due to which the processing error might be reduced.[3] CAD/CAM approaches have been employed to address some of the limitations of traditional processes and efficient use of different materials.[4,5] CAD/CAM accelerates the designing and processing of the prosthesis and making feasible restorations and appliances that would have been impossible otherwise. Other priorities include reducing the cost of units and making affordable restorations and equipment that would otherwise have been economically unfeasible.[6] However, the downside to this method is the substantial amount of raw material waste, as after milling, the unused parts of the monoblocks are discarded, and recycling of the surplus material is not feasible.

However, to supplement the weakness of the CAD/CAM milling system (subtractive manufacturing), the 3-D printing system (additive manufacturing) has emerged. In the recent dental restoration processing field, this system has the strength to fabricate the precise prosthesis with minimal materials. Additive manufacturing allows clinicians and technicians to transform virtual ideas into physical models and prototypical parts of the restorations, efficiently, and reliably. The ability to fulfill the demand for patient-customized dental restorations, and equipment, makes 3D printing a very viable choice for the profession. The first step in the process is the development of a CAD-generated 3D digital model of the prosthesis to be produced. Then, the CAM unit fabricates the finished product. The data for the CAD are collected either by indirect plaster model scanning or by intraoral scanning.[7] In fixed prosthodontics, the comparison between CAD-CAM technology and traditional fabrication processes with respect to marginal and internal adaptation has been extensively studied.[5] However, there are insufficient data on the fit of definitive study on the 3D printing technology. Therefore, in this study, the marginal and internal fit of the crowns fabricated with the CAD/CAM and 3D printing technology is evaluated with regard to the clinical importance[4] and compared with the crowns fabricated through conventional techniques. The null hypothesis of this study is, that there is no difference in the fit of the definitive crown that is fabricated for each system.

MATERIALS AND METHODS

Preparation of the Mandibular First Molar Tooth

A Typhodont First mandibular molar tooth (API typhodont teeth set) was prepared using an occlusal preparation of 0.7–1.2 mm and a buccolingual and mesiodistal preparation of 1–1.2 mm. A deep chamfer with a 1.0 mm width was the finished margin layout. Thirty research models were developed by producing the master model impressions (Aquasil Ultra XLV and Aquasil Ultra Heavy; Dentsply Intl) and pouring them with Type IV die stone (Kalrock Kalabhai Karson Pvt Ltd). Thirty definitive crowns were fabricated on the stone die models using three different types of fabrication methods: Lost wax (conventional group), CAD/CAM (milling group), and direct selective laser melting (3D printing group) technique which were divided into three groups based on their methods of fabrication.

Conventional casting technique (Group A)

In the molding group, four die pinholes were prepared in the region of the lower right and left first premolars and right and left first molars. Die pins were inserted and stabilized using cyanoacrylate. A plastic collar was used along with a die pin with respect to the mandibular right first molar. After this, the plaster base was poured for the cast. Die-cutting was done using the die-cutting machine (CIR-SAW-Labo 17, Confident). Die spacer (die: master Renfert) was applied on the die to obtain a cementation space of 60 μm. A spacer was applied 1 mm above the finish line. A die lubricant was applied to the die. Then, the wax pattern was formed using blue inlay wax. The pattern was then removed and all the surfaces were verified. A 2.5 mm of wax sprue was attached to the thickest portion of the wax pattern (mesiobuccal cusp) at 45° to the pattern. The other end of the sprue was attached to the crucible former. The surfactant was applied to the wax pattern and a ring with a liner was placed around the pattern. The phosphate-bonded investment material (Deguvest Impact, DeguDent, Dentsply) was then poured in the ring and filled up to the rim. After the investment, the material was set, and the crucible former was removed. Wax burnout was done in a wax burnout furnace (warmy 7 MANFREDI), where the temperature was raised gradually up to 927° for 60 min with the heating rate of 60°C/min for complete wax burnout. After this, the ring was positioned in the induction heating vacuum-pressure casting machine (MANFREDI SAED Multihertz Ally Digital Induction Casting Machine System) and cast with cobalt-chromium alloy (J BOND Ga, RUBY). After casting was completed, it was removed and was cooled underwater. Later, the investment was removed and impurities were removed and airborne particle abrasion with aluminum oxide powder (50 μm) was used to clean the casting.

CAD/CAM procedure (Group B)

In this group, a desktop scanner (UP 3D Acublu, Germany) [Figure 1] was used to digitize each model and saved in the standard tessellation language (.stl) format [Figure 2]. stl input was then translated into dental CAD software (ExoCAD Matera, Germany), which was used to design virtual crowns [Figure 3] with a cementation space of 60 μm virtual crowns, starting 1.0 mm above the finish line. A 5-axis milling system has been used to manufacture definitive crowns (CEREC In Lab) and cobalt-chromium metal blocks.

3D printing (Group C)

In the 3D printing group, definitive crowns were fabricated using the Selective Laser Melting technology. Each study model was saved in standard tessellation language format (.stl) [Figure 2] after being digitized with a desktop scanner (UP 3D Acublu, Germany) [Figure 1].stl data was then transferred into dental CAD software (ExoCAD Matera, Germany), where virtual crowns were designed [Figure 3] with 60 μm of cementation space, starting 1.0 mm above the finish line. The proximal contact was developed in the occlusal third of the crownt. The designed (.stl) files that were generated through CAD software were sent to a 3D printer (DMLS) (Object Eden 260VS; Stratasys), and definitive crowns were printed using printing cobalt-chromium metal powder (Wirobond C+; BEGO Medical) with 5 μm thickness of the layering.

Silicone Replica Technique

The stone die was adjusted on a universal testing machine (International equipment Private Limited) and polyvinyl siloxane impression material (light body; Photosil) was filled in up to 1/4th in the crown and the crown was seated on the stone die and around 50N of vertical force was applied by the Universal Testing Machine. After the polymerization of the material, the crown was retrieved and the different color heavy body impression material (Aquasil) was applied and the crown was reseated on the stone die. Force of 50N was applied to the crown. Regular set heavy body impression material was used to stabilize the light body material. After the material was polymerized, the crown was retrieved from the die. Silicone material was carefully separated from the crown and used further to measure the fit of the crown.[8]

Measurement of Marginal Fit

The silicone sample was placed under stereolitho microscope (Stereozoom, Zeiss, Germany) in ×50 magnification and the width of the light body silicone material was measured at the cervical area at the following eight points [Figure 4]:-

1. Buccal (B), 2. Disto buccal (DB), 3. Distal (D), 4. Disto lingual (DL), 5. Lingual (L), 6. Mesio lingual (ML), 7. Mesial (M), and 8. Mesio buccal (MB).

Measurement of the Internal Fit

The silicone samples were sectioned mesiodistally using the Bard–Parker blade. Internal Gap was measured at the following five points [Figure 5]:-

1. Occlusal (O), 2. Distoaxio-occlusal (DAO), 3. Distoaxial (DA), 4. Mesioaxio-occlusal (MAO), and 5. Mesioaxial (MA).

Statistical analysis for the fit discrepancy was done using SPSS version 23 (IBM Corp) software. To analyze the

Figure 1: Scanning of the cast

Figure 2: Scanned image saved as standard tessellation language (.stl) format

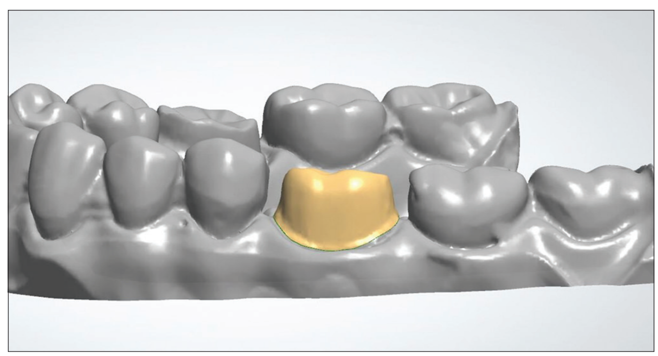

Figure 3: Virtual designing of crown in the software

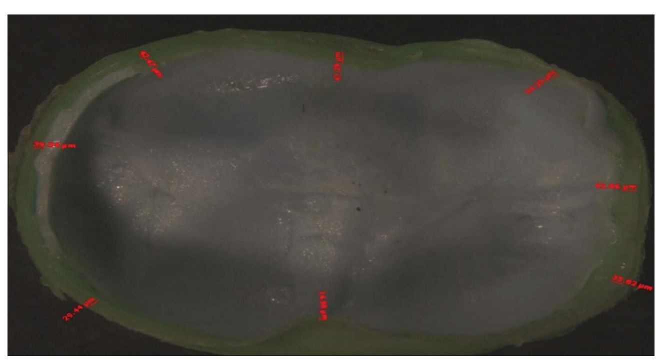

Figure 4: Horizontal marginal gap at ×50 magnification at eight different points

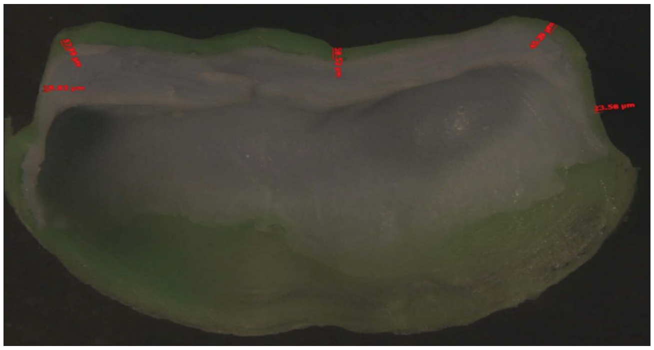

Figure 5: Internal gap under ×50 magnification at five different points

difference between means of fit discrepancy between the three groups, one-way ANOVA was used. Furthermore, the mean marginal and internal fit between and within each group were calculated using independent t-test.

DISCUSSION

The success of the fit of the restoration depends predominantly on its method of fabrication.

In this study, horizontal marginal gap and internal gap for 30 cobalt-chromium crowns were evaluated and compared between various techniques of fabrication. Crowns were fabricated by conventional lost wax techniques, CAD and CAM, and direct metal laser sintering (DMLS) (3D Printing) technique.

The gap width of restorations is investigated by several methods. Micro-CT is a non-destructive and reproducible method that assesses the marginal and internal restoration gaps. However, when there is deficient radiographic contrast, it is impossible to demonstrate an accurate analysis.[9] Direct-view techniques were the most commonly used, followed by cross-sectioning and replica techniques.[9]

The technique of direct viewing takes less time, because it can proceed without multiple or complex procedures. Besides, the method is low-cost and reproducible. Its disadvantage, on the other hand, is that it can be measured only at the margin, not at the internal surface.[9,10] A cross-section of the embedded specimen and silicone replica methods is the methods for marginal and internal distance calculations. The embedded technique is accurate since the measuring points are repeatable and reliable. However, the specimen is distorted in the later stages, with this technique. Thus, further investigations on the same specimen cannot be done.[11,12] The replica technique used in this research, on the other hand, is non-detrimental, easy to perform, less time-intensive, and inexpensive. Furthermore, the silicone layer, which simulates the width of the gap, can be cut and measured at many locations.

The number of measurement points must be considered when estimating the discrepancy width between a tooth and a restoration. A single crown in discrepancy analysis, Gassino *et al*., considered a minimum of 18 points,[13,14] while Groten *et al*. measured more than 50 points.[15,16] Yoon *et al*. measured three times (a total of 24 measurements) each of eight measurement points;[17,18] Vigolo and Fonzi measured once each of eight points, where gap width was to be analyzed (total eight measurements);[15,18] and Gonzalo *et al*. measured 30 times each of four points (total 120 measurements).[14,19] For this study, marginal gap was measured at eight points per crown [Figure 4] (total 240 measurements) and the internal gap was measured at five points [Figure 5] per crown (total 150 measurements). It is easy and quick to use few measurement points, but the variance increases according to that location, where the gap width has to be measured. Using several points for the measurement, on the other hand, can provide more accurate results, but it takes time.[20] However, no accurate data on the number of points on the restoration, where the fit can be measured, have yet been reported.[20]

For measuring the marginal gap, we chose the horizontal marginal discrepancy as it is most critical due to cement solubility. Furthermore, the internal gap was measured in this study.to prevent violating either the retention of the crown or its resistance, the internal fit must be uniform and must also provide a viable luting space.[13,21]

In ADA specification #8, the American Dental Association estimated the clinically acceptable range of 25–40 μm.[15] A marginal discrepancy of <50 μm was suggested by Sorensen *et al*.[22] The marginal gap of 80 μm or less was hardly detectable with radiological methods, and even with an 80 μm probe, the width of the 200 μm distance was imperceptible, as suggested by McLean and von Fraunhofer.[23,24] For more than 5 years, they analyzed 1000 intraoral restorations, and concluded that a marginal difference of 100 μm was not a clinical issue, so they proposed 160 μm as a marginal gap that was clinically acceptable.[23]

The width of the internal gap influences the restoration's retention. Jørgensen and Esbensen confirmed the mild impact on retention due to difference in cement thickness of 20–140 μm and found a substantial decrease in retention only in cases of a difference of 140 μm or greater.[25] In this study, the marginal gap of all the crowns fabricated by conventional, CAD/CAM, and DMLS (3D printing) techniques was within the clinically acceptable range of 25–160 μm as suggested by McLean and Von Fraunhofer.[24] Likewise, as suggested, the internal gap of all the crowns fabricated through the three separate techniques was within the clinically appropriate range of 20–140 μm.[24]

However, in this study, the conventional group showed the highest mean internal gap of 90.37 μm and mean marginal gap 73.05 μm among the three groups, except at the buccal and distobuccal point. The highest marginal gap of conventionally fabricated crowns could be due to shrinkage and stress induced in the casting. Moreover, in case of an internal gap, it is more probably due to discrepancy between mold expansion and casting shrinkage. Whereas, the lowest mean marginal gap of 27.27 μm was observed in crowns fabricated by DMLS (3D printing) at all the points, except the mesial point. Furthermore, 3D-printed crowns showed the least internal gaps of 23.83 μm at all points except the distoaxio occlusal and occlusal points. Without the risk of manual errors during the manufacturing process, the lowest marginal gaps may be attributed to compensation for polymerization shrinkage and improved accuracy. In printed crowns, a small internal gap was observed possibly, because the margin determination was performed under manual adjustment when scanning the master and building a 3D coping shell model image, while the external surface scanning of the master die was estimated by non-uniform offsetting in the scanning device program. When compared among the digital techniques, there is a difference between 3D-printed crowns and CAD/CAM which are significant at some points. This difference could be attributed to the fact that a five-axis milling machine was used for 3D printing, which has a complex geometry since a straight feeding axis was introduced for x, y, z-axis, and two rotation feed axis; furthermore, it was able to obtain more accurate results in the region under the cut. Whereas, CAD/CAM is fabricated in three axis technology, which is less accurate than 3D printing technology of five axis.[25,26] The results rejected the null hypothesis as 3D-printed crowns showed significantly low marginal and internal gap values. This research, however, has following drawbacks:

1. In the present study, eight reference points for marginal gap and five reference points for internal gap were measured per specimen which could, further, be increased for better credibility of the study
2. This was an *in vitro* study, where constant force was applied. Whereas in patients, force is generally applied with the clinician's finger. There could have some variation if they were *in vivo*
3. Only DMLS form 3D printing was used
4. There is a concern about the impact of the abutment tooth type on the fit of a restoration. Preparation was done only on molar crown in this study. Therefore, more research is needed for marginal and internal fit comparison concerning different abutment teeth
5. Universal Testing Machine used in this study moves at a slower speed to apply load on the crown which might cause the setting of the silicone before the load is equally distributed.

While several variables are thought to influence the results, further studies on DMLS and CAD/CAM are needed due to the difference in their marginal gap, both being digital techniques.

RESULTS

The marginal and internal fit discrepancy of the definitive restoration for the Conventional (Group A), CAD/CAM (Group B), and 3D printing (Group C) were measured at the designated location. One-way ANOVA and independent t-tests were performed to find out statistical differences between the three groups at all the points. The fit discrepancy of all the three groups was statistically significant ($P < 0.05$) [Tables 1 and 2]. The highest mean marginal gap of 73.05 ± 7.87 μm was shown by group A at distolingual region. The lowest mean marginal gap was of 27.27 ± 9.07 μm which was shown by Group C at buccal

Table 1: Mean horizontal marginal discrepancy of metal crowns of Group A, Group B, and Group C at eight points

Measurement Point	Group A	Group B	Group C	*P*-value
	Mean±SD	Mean±SD	Mean±SD	
Buccal	49.21±8.9	58.68±16.5	27.27±9.07	0.000
Disto buccal	55.44±11.6	58.42±15.7	29.94±7.2	0.000
Distal	57.48±10.8	45.50±8.3	39.47±9.1	0.001
Disto lingual	73.05±7.87	60.51±11.0	38.40±8.3	0.000
Lingual	60.51±11.0	60.51±11.0	36.13±11	0.016
Mesio lingual	45.55±5.8	38.35±14.1	34.60±6.6	0.001
Mesial	60.78±13.7	45.05±9.0	39.03±8.0	0.000
Mesio buccal	61.76±10.1	55.57±11.3	34.51±6.6	0.000

Table 2: Mean internal discrepancy of metal crowns of Group A, Group B, and Group C at five points

Measurement Point	Group A	Group B	Group C	*P*-value
	Mean±SD	Mean±SD	Mean±SD	
Disto axial	39.95±14.3	25.09±9.8	29.54±10.3	0.015
Disto axio occlusal	91.37±24.7	70.50±16.2	52.74±7.8	0.000
Occlusal	80.11±20.1	74.91±15.0	40.50±6	0.000
Mesio axial	32.01±8.6	19.63±5.5	23.83±6.0	0.002
Mesio axio occlusal	62.74±14.1	41.39±11.5	33.48±6.0	0.000

region [Table 1]. The highest internal discrepancy of 80.11 ± 20.1 μm was shown by Group A at occlusal point. The lowest internal discrepancy of 19.63 ± 5.5 μm was shown by Group B at mesioaxial region [Table 2]. Among the three groups, Group A showed the highest marginal gap at all the points except at buccal and distobuccal points. It also showed highest internal gap at all points. Furthermore, Group C showed the lowest marginal gap at all the points amongst the three groups. Group C also showed the lowest internal gaps at all points except at distoaxial and mesioaxial points.

CONCLUSION

The following conclusions can be drawn within the limits of this study:

1. Marginal gap width and internal gap width of the crowns fabricated through the three different techniques were within a clinically acceptable range
2. Compared to metal crowns manufactured by CAD/CAM and traditional technology, the 3D printed crowns demonstrated better fit accuracy
3. The mean marginal and internal gaps varied significantly for the same prepared tooth for different fabrication methods.

Hence, it can be concluded that along with an esthetic restoration, the DMLS form of the 3D system provides high accuracy in the fit, at margins, and internal surface of the crowns and can replace conventional metal restorations in the future as they can produce higher and more uniform – quality restorations in a shorter time interval with all the manual procedures such as waxing, investing, and casting being omitted. It could even replace CAD/CAM; as being an additive manufacturing technique, 3D Printing does not waste the raw material and is more economical than the other two techniques. With the evolution of an array of new versions of already available systems, the future of dentistry will be digital, and these new materials will be more esthetic and user-friendly. The outcome of this could have been affected by the site of the measurement, operator's skills, machinery, and the software used for digital techniques. Hence, to determine the fit of fixed prosthodontic restorations in the future, it is desirable to establish a systematic approach.

Clinical Significance

Clinical significance of this study is that a proper fabrication technique must be used for crown fabrication that produces less fit discrepancies. Crowns fabricated with precise fit that is within the clinical acceptable range that shows long-term success of the restoration.

REFERENCES

1. Rosenstiel SF, Land MF, Fujimoto J, Cockerill JJ. Contemporary Fixed Prosthodontics. St. Louis: Mosby, Inc.; 2001. p. 380-416.
2. Demir N, Ozturk AN, Malkoc MA. Evaluation of the marginal fit of full ceramic crowns by the microcomputed tomography (micro-CT) technique. Eur J Dent 2014;8:437-44.
3. Lee WS, Lee DH, Lee KB. Evaluation of internal fit of interim crown fabricated with CAD/CAM milling and 3D printing system. J Adv Prosthod 2017;9:265-70.
4. Mai HN, Lee KB, Lee DH. Fit of interim crowns fabricated using photopolymer-jetting 3D printing. J Prosthet Dent 2017;118:208-15.
5. Grajower R, Zueri Y. Improving the fit of the crowns with die spacers. J Prosthet Dent 1989;16:555-63.
6. Al Essa HA. CAD/CAM in prosthodontics: A gate to the future. Int J Appl Dent Sci 2019;5:394-7.
7. Al Mortadi N, Eggbeer D, Lewis J, Williams RJ. CAD/CAM/AM applications in the manufacture of dental appliances. Am J Orthod Dentofac Orthop 2012;142:727-33.
8. Rahme HY, Tehini GE, Adib SM, Ardo AS, Rifai KT. *In vitro* evaluation of "replica technique" in the measurement of the fit of Procera crowns. J Contemp Dent Pract 2008;9:25-32.
9. Peng CC, Chung KH, Yau HT. Assessment of the internal fit and marginal integrity of interim crowns made by different manufacturing methods. J Prosthet Dent 2020;123:514-22.
10. Sorensen JA. A standardized method for determination of crown margin fidelity. J Prosthet Dent 1990;64:18-24.
11. Nawafleh NA, Mack F, Evans J, Mackay J, Hatamleh MM. Accuracy and reliability of methods to measure marginal adaptation of crowns and FDPs: A literature review. J Prosthod 2013;22:419-28.
12. Schmalz G, Federlin M, Reich E. Effect of dimension of luting space and luting composite on marginal adaptation of a class II ceramic inlay. J Prosthet Dent 1995;73:392-9.
13. Nakamura T, Dei N, Kojima T, Wakabayashi K. Marginal and internal fit of Cerec 3 CAD/CAM all-ceramic crowns. Int J Prosthodont 2003;16:244-8.
14. Gassino G, Monfrin SB, Scanu M, Spina G, Preti G. Marginal adaptation of fixed prosthodontics: A new *in vitro* 360-degree external examination procedure. Int J Prosthodont 2004;17:218-23.
15. Groten M, Axmann D, Pröbster L, Weber H. Determination of the minimum number of marginal gap measurements required for practical *in-vitro* testing. J Prosthet Dent 2000;83:40-9.
16. Yun MJ, Jeon YC, Jeong CM, Huh JB. Comparison of the fit of cast gold crowns fabricated from the digital and the conventional impression techniques. J Adv Prosthodont 2017;9:1-3.
17. Yoon JW, Yang JH, Han JS, Lee JB. A study on the marginal fit of collarless metal ceramic fixed partial dentures. J Korean Acad Prosthodont 2005;43:707-16.
18. Vigolo P, Fonzi F. An *in vitro* evaluation of fit of zirconiumoxide-based ceramic four-unit fixed partial dentures, generated with three different CAD/CAM systems, before and after porcelain firing cycles and after glaze cycles. J Prosthodont 2008;17:621-6.
19. Gonzalo E, Suárez MJ, Serrano B, Lozano JF. Comparative analysis of two measurement methods for marginal fit in metal-ceramic and zirconia posterior FPDs. Int J Prosthodont 2009;22:374-7.
20. Gonzalo E, Suárez MJ, Serrano B, Lozano JF. A comparison of the marginal vertical discrepancies of zirconium andmetal ceramic posterior fixed dental prostheses before and after cementation. J Prosthet Dent 2009;102:378-84.
21. Shearer B, Gough MB, Setchell DJ. Influence of marginal configuration and porcelain addition on the fit of In-Ceram crowns. Biomaterials 1996;17:1891-5.
22. Sorensen SE, Larsen IB, Jörgensen KD. Gingival and alveolar bone

reaction to marginal fit of subgingival crown margins. Scand J Dent Res 1986;94:109-14.
23. Christensen GJ. Marginal fit of gold inlay castings. J Prosthet Dent 1966;16:297-305.
24. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an *in vivo* technique. Br Dent J 1971;131:107-11.
25. Jørgensen KD, Esbensen AL. The relationship between the film thickness of zinc phosphate cement and the retention of veneer crowns. Acta Odontol Scand 1968;26:169-75.
26. Passon C, Lambert RH, Lambert RL, Newman S. The effect of multiple layers of die-spacer on crown retention. Oper Dent 1992;17:42-9.

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