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The effects of cement space thickness and material type on marginal discrepancy of restoration

Efeitos da espessura do cimento e do tipo de material na discrepância marginal da restauração.

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ABSTRACT

Objective: Studies demonstrated that as one of the newly developed restorative materials, monolithic zirconia resolved several issues of zirconia restoration. Therefore, marginal accuracy and internal fit are necessary for clinical success and quality of restorations, and cement space may influence the marginal fit. Thus, the present research aimed to investigate the effects of the cement thickness and kind of restoration on the marginal discrepancy. **Material and methods:** In this study, 20 maxillary left first molars, prepared by DRSK Co., were used to fabricate a full crown. Two types of material included monolithic zirconia (Zolid) and Sintron were used to make a full crown. Samples from each group were scanned by dental laboratory 3D scanner and designed and processed using CAD-CAM. The samples were divided into four groups of five with 30- and 50- μm cement spaces. In order to assess the vertical marginal discrepancy, the crowns were fitted on their respective teeth without using any mediator and examined by a micro-CT scanner. Data were analyzed by SPSS software. **Results:** It has been found that marginal discrepancy in Sintron is higher than the discrepancy of monolithic zirconia. In fact, monolithic zirconia with 50-micron cement space exhibited the least marginal discrepancy and the cement space in Sintron did not significantly influence the marginal discrepancy. **Conclusion:** It has been concluded that the material kinds and cement space influence the restoration marginal discrepancy constructed by digital workflow.

KEYWORDS

Dental cements; Dental marginal adaptation; X-Ray microtomography.

RESUMO

Objetivo: Estudos demostraram que a zircônia monolítica um dos materiais restauradores desenvolvidos recentemente, resolveu vários problemas de restauração de zircônia. Portanto, a precisão marginal e o ajuste interno são necessários para o sucesso clinico e para a qualidade da restauração, e o espaço do cimento pode influenciar o ajuste marginal. Assim, o presente estudo teve como objetivo investigar os efeitos da espessura do cimento e o tipo de restauração na discrepância marginal. **Material e métodos:** foram usadas para fabricação de coroa total. Dois tipos de materiais incluindo Zirconia monolítica (Zolid) e Sintron foram usadas para produzir a coroa total. As amostras de cada grupo foram digitalizadas em laboratório dentário por um scanner 3D, projetadas e acessadas usando CAD-CAM. As amostras foram divididas em quatro grupos de cinco com espaço de 30 e 50 mícrons de cimento. Para avaliar a discrepância marginal, as coroas foram colocadas em seus respectivos dentes sem o uso de qualquer intermediário e examinados em micro-CT. Os dados foram avaliados pelo software SPSS. **Resultados:** Descobriu-se que a discrepância marginal do Sintron é maior que a discrepância da zircônia monolítica. Na verdade, a zircônia monolítica com espaço de 50 μm de cimento exibiu uma menor discrepância marginal, e o espaço de cimento do Sintron não influenciou significantemente na discrepância marginal. **Conclusão:** Concluiu-se que os tipos de material e o espaço do cimento influencia na discrepância marginal da restauração construída pelo fluxo digital.

PALAVRAS-CHAVE

Adaptação marginal dentária; Cimentos dentários; Microtomografia por Raio-X.

BACKGROUND

All ceramic metal-free restorations attracted further attention of patients increasingly due to increased awareness of beauty and biocompatibility [1]. Proper properties of a material and high strength are some of the advantages that can be used for both anterior and posterior fixed prostheses, including high-performance zirconia ceramics [2]. The use of monolithic zirconia is expanding as a new restorative material due to its easier and cheaper fabrication [3,4]. These restorations not only have an acceptable beauty, but also have high fracture resistance and could even withstand the fracture forces above the maximal mean occlusal forces incurred on the posterior regions [5,6]. With the expansion of computer assisted design/computer assisted machining (CAD/CAM) technology, the use of zirconia ceramics has increased rapidly; this technology reduces the cost of manufacturing, materials, and laboratory time while increasing production [7]. The CAD-CAM restoration fitting accuracy is influenced by various factors including scan accuracy, CAD-CAM software, CAD-CAM system wearing protocols, and type of material used in milling. In addition, it has been shown that, after finishing the milling, the manual settings performed by the dental technician on the restoration improve restoration fitting accuracy [8,9]. Early studies on the fracture rate of monolithic zirconia restorations for posterior regions in a period of at least 5 years were counted between 0.2%-0.7% [10]. In vitro studies have cited a minimum thickness of 0.7 mm for implant-supported monolithic zirconia restorations and 0.5 mm for tooth-supported restorations to the long-term resistance of restoration against chewing forces [11]. Hence, this restoration can be a treatment candidate for people with limited interocclusal space, an inadequate clinical crown length and requiring maintaining a dental structure [5]. The success of dental restorations depends on four major components of biocompatibility, beauty, fracture resistance and marginal adaptation [12,13]. Some studies have shown that zirconia milling in presintering mode has a marginal fit better than zirconia milling after sintering; some have reported contradictory results [14]. Another study evaluated the marginal fit of the zirconia crown frame made from pre-sintered and sintered zirconia blocks and showed no difference between the two [15]. The difference in fabrication is attributed mainly to the baseline internal space [14,16,17], which can be system-sensitive and affects the zirconia crown fit [16,18]. However, increasing cement space can improve the marginal fit of crown, but the internal space of more than 120 μ will reduce the fracture resistance of ceramic crowns without improving marginal fit [19]. Eran Dolev et al. showed that both absolute marginal discrepancy and marginal discrepancy for the CAD-CAM method are lower than the hot-press [20]. During a research by Dahl et al., the internal fit by the lost-wax metal casting technique was similar to the CAD-CAM method [21]. The results of various studies indicate that the methods of measuring marginal discrepancy and its values are very different and various factors affect it and there is no consensus on it among the researchers [21-23-26]. Many studies evaluated the marginal fit accuracy of zirconia, all-ceramic, and metal ceramic crowns, nevertheless, the accuracy of CAD-CAM restorations is questioned. As well, few studies assessed the effect of different cement spaces on marginal fit. Accordingly, this study was conducted to investigate the marginal fit of monolithic zirconia and Sintron crowns and the effect of cement space on them before cementation.

MATERIAL AND METHODS

This in vitro- undirected fundamental-applied study was conducted on 20 maxillary left first molars (typodont, prepared by DRSK, Kasernvagen, Hassleholm, SWEDEN) with 0.5 mm axial reduction, 360-degree chamfer margin and 6-degree taper (Figure 1). Inclusion criteria were the full crowns of Monolithic Zirconia (Zolid: Amman Girrbach, Koblach, Austria) and Cr-Co alloy (Sintron, Amman Girrbach.Koblach, Austria) with the same dimensions and contours.

The crowns with dimensional changes or the need of an intense adjust to fit on the tooth were excluded. The teeth were randomly divided into 2 groups of 10, where one type of monolithic zirconia, Group ZA (Zolid: Amman Girrbach, Koblach, Austria) and one type of alloy, Group S (Sintron, Amman Girrbach.Koblach, Austria) were used as full contours to fabricate the crowns. The teeth were first scanned by dental laboratory 3D scanner (Imetric Courgenay, Switzerland) (Figure 2), and then a full crown, with the same contour and size, was designed using CAD software (Imetric Courgenay, Switzerland) for each of the 2 groups. The same template in the software library was used to uniformize the crowns for each of the two groups (Figure 3). Next, these two groups were divided in other 2 subgroups, according to the simulation of the cement layer: Group ZA 30 and Group S 30: 25-μm cement space in the margin region, and 30-μm cement space starting at 1 mm above the finish line; Group ZA 50 and Group S 50: 25-μm cement space in the margin region, and 50-μm cement space starting at 1 mm above the finish line. Finally, the design data was saved as a stl file. The crowns designed by CAD software were transported to the CAM and processed by Ceramil Motion. Subsequently, using Ceramil Motion 4-axis milling machine (Amman Girrbach.Koblach, Austria) from pre-sintered monolithic zirconia blocks, pre-sintered Sintron were exfoliated. The specimens were sintered according to the manufacturer's protocol, so that Sintron was sintered in a furnace with a pressure of 1.5 bar of argon gas and zolid in its specific furnace. After the sintering of restorations, the inner surface of the crowns except margin was manually adjusted by a dental technician familiar with the CAD-CAM system, using diamond rotary instruments and high-speed handpiece along with water. The purpose of this was a perfect restoration fit on the corresponding teeth and removal of the horizontal marginal discrepancy, if any [27]. After the crowns were prepared, they were fitted on the corresponding teeth without using any mediators by the micro CT device (Lotus, Tehran, Iran) to examine the vertical marginal discrepancy. The midpoints of the bacolingual and mesiodistal surfaces of each sample were considered to unify the measurement points for marginal discrepancy. Each specimen was fixed inside the scan tube and in a position perpendicular to the X-ray. The scan was performed for each sample at a voltage of 70 KVp and 114 mA with a resolution of 1024 × 1024 for 30 min. After reconstructing the images with its own software, Skyscan software was used to analyze and scan. As the reference, the first vertical cut was made in the mesiodistal direction and in the middle of the specimen, and then two vertical cuts were made on each side of the initial cut with a distance of 50 slices at a space between each cut. Finally, five vertical cuts with 50 slices between each cut were created in the mesiodistal direction in each sample. Similarly, five vertical cuts in buccolingual direction were created in each sample, with the difference that there were 25 slices between the cuts [26]. In each cut, two points were considered for vertical marginal discrepancy, so 20 sizes for vertical marginal discrepancy were obtained for each sample, whose mean was considered as marginal discrepancy of each sample (Figure 4). The same technician performed all measurements using the Skyscan software at the Research Center of Tehran University of Medical Sciences. Figure 1 shows the steps involved. All statistical analyzes were performed using SPSS version 22 software (SPSS, INC, Chicayo II). In this study, one-way ANOVA and Tukey's post hoc test was used to examine marginal discrepancy.

Figure 1 - Prepared maxillary left first molars.

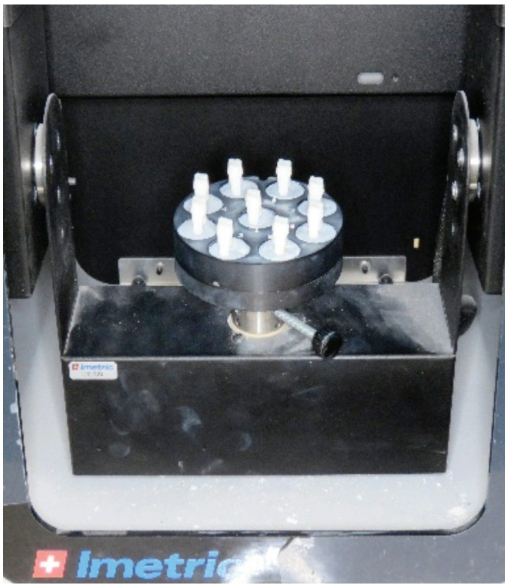

Figure 2 - Samples are scanning by scanner.

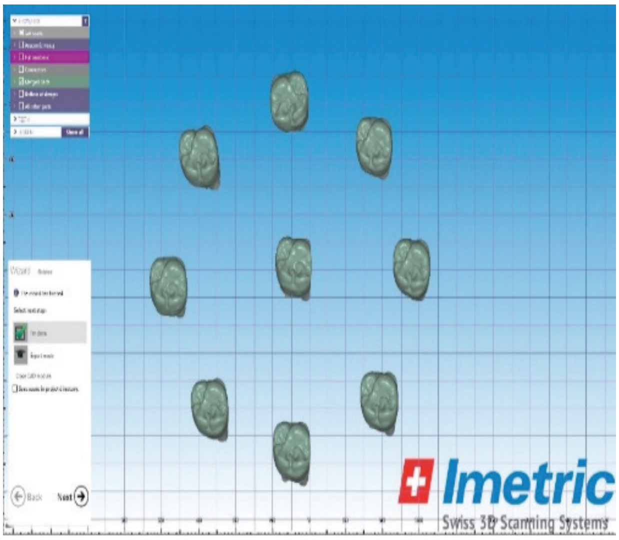

Figure 3 - Crown design by CAD software.

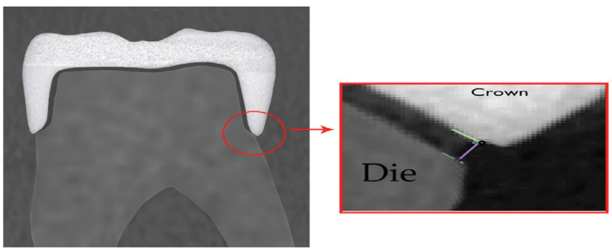

Figure 4 - Micro-CT scan image (Horizontal cut): 10 vertical slices with 50 slices between them in mesiodistal direction and 25 slices between them in buccolingual direction.

RESULTS

In this study, 20 samples consisted of 5 monolithic zirconia crowns with 50-micron cement space, 5 monolithic zirconia crowns with 30-micron cement space, 5 Sintron crowns with 50-micron cement space and 5 Sintron crowns with 30-micron cement space (Table 1).

Table I - Mean and standard deviation of marginal discrepancy in micron.

Cement Space		Mean	Std. Deviation	N
30 microns	Monolithic Zirconia	78.64	7.18	5
	Cr-Co alloy	135.24	18.60	5
50 microns	Monolithic Zirconia	50.40	4.51	5
	Cr-Co alloy	130.06	12.83	5
Total	Monolithic Zirconia	64.52	15.92	10
	Cr-Co alloy	132.65	15.31	10
		98.58	38.11	20

With regard to the lack of two-way ANOVA conditions due to the significant interaction between cement space and material types ($p = 0.048$) (Figure 5), one-way ANOVA and Tukey's post hoc test were used to compare the groups, which showed a significant difference between the 4 groups ($p < 0.001$). The vertical marginal discrpancy was significantly different between zirconia 30-micron and 50-micron cement space groups ($p = 0.009$), zirconia 30-micron cement space and Cr-Co alloy 30-micron cement space groups ($p < 0.001$), zirconia 30-micron cement space and Cr-Co alloy 50-micron cement space groups ($p < 0.001$), zirconia 50-micron cement space and Cr-Co alloy 30-micron cement space groups ($p < 0.001$), and zirconia 50-micron cement space and Cr-Co alloy 50-micron cement space groups ($p < 0.001$). However, there was no significant difference between Sintron groups with 30-micron cement space and 50-micron cement space ($p = 0.904$)

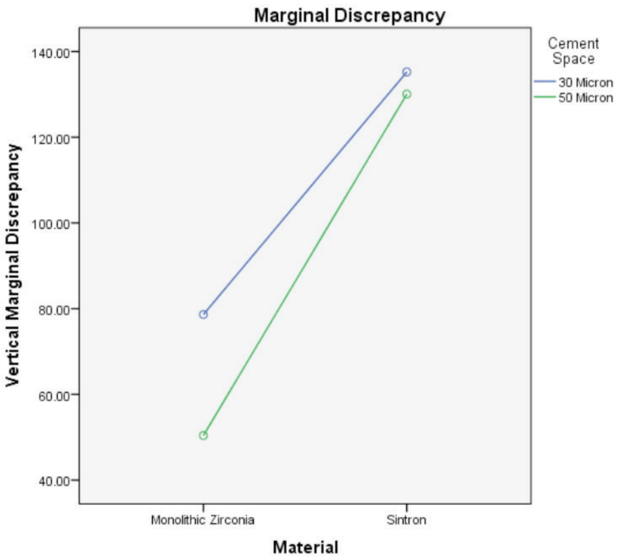

Figure 5 - Mean and standard deviation of marginal discrepancy in micron.

DISCUSSION

When a full crown is considered as a cure, it is important to achieve a clinically acceptable restoration with a good marginal fit. The use of CAD-CAM restorations is increasing rapidly today, and many dentists use them all over the world, however, the accuracy of CAD-CAM restorations is questioned. Therefore, this study examined the accuracy of two types of full crown made by the CAD-CAM method. Also there is no consensus on how to measure marginal discrepancy of dental restorations, the use of Micro-CT seems to be the best considering its benefits. Therefore, this method was used in this study. The results of our study showed that the cement space has a significant effect on marginal discrepancy, and compatible with Tuncer study [28] also is supported with Shohei Suzuki study that shows by increasing cement space, marginal discrepancy is decreased [29]. In contrast with aforementioned articles, Rinet Dauti study shows cement space has no significant effect on marginal discrepancy [30]. The effect of cement space was significant only in the monolithic zirconia restorations and was not significant in the Cr-Co alloy restorations, but the marginal discrepancy in the 50-micron group was slightly less than in the 30-micron group. According to the results of the study, the monolithic zirconia groups had a marginal discrepancy less than that of Cr-Co alloy groups and this difference was significant. In other words, the least marginal discrepancy was related to the monolithic zirconia group with 50-micron cement space and the most marginal discrepancy was seen in the Cr-Co alloy group with 30-micron cement space. This results are compatible with Elie E. Daou study that compares marginal discrepancy in zirconia and sintron framework and shows both are clinical acceptance but zirconia has less marginal discrepancy [31]. In the present study, the cement space was determined digitally for the restorations during computerized design. However, the question is whether the CAD-CAM can transmit this cement space from the milling unit with the same accuracy to the restoration. The parameters of the milling unit (the amount of using bur, milling material and drill diameter) and the teeth preparation (preparation method, occlusal preparation, the degree of tapering and the curvature of the cervical crown margin and the anatomical conditions) can affect this condition [32]. According to Lewinstein et al. [33], the cement space for restoration should be at least 50 microns, of which 30 μ is considered for cement thickness and reduction of friction due to surface roughness, and the remaining 20 μ is considered as a precautionary action for potential distortion of restoration caused by production process. This proposal was supported by the results of the present study, which showed less marginal discrepancy in groups with 50-micron cement space. Improved marginal fit with increased cement layer was observed in this study. Evidence has shown that cement space for CAD-CAM zirconia crown restorations should not be less than 60 microns for better fit on the abutment and the minimum need for manual adjustment [8]. An et al. [34] investigated the marginal fit of zirconia copings with 60-micron cement space and reported that the total mean vertical marginal discrepancy was 104 μ. Prasad and colleague [35] also evaluated the vertical marginal discrepancy of zirconia copings with 50-μm cement space, whose value was 59μ for postsentered zirconia and 68 μ for presentered group. Euan et al. [36] also reported that the mean vertical marginal discrepancy for zirconia copings with 50-μm cement space was 64 μm for the chamfer finish line and 53 μ for the round shoulder finish line. All of these findings were in line with our study results for zirconia crowns, and all of them were clinically acceptable (120 μ >). However, the Sintron crowns had a higher vertical marginal discrepancy, and were clinically unacceptable, but consistent with the results of the study of Vojdani et al. [37] who examined the vertical marginal discrepancy in the Sintron copings. Various articles reported varying amounts of marginal discrepancy that could be due to different measurement methods, differences in the type of dye, coping material, differences in scanning, design, and milling machines used [38]. Sachs et al. [1] argued that different parameters, including scanning, designing, milling and sintering, could affect the accuracy of restoration. Therefore, it is difficult to compare these studies with others. In the present study, the measurements of vertical marginal discrepancy were based on the definition of Holmes [39]. The horizontal marginal discrepancy is eliminated by finishing margin using the rotary tool. However, the vertical marginal discrepancy only decreases using cements, which may be washed or can create a rough surface. Therefore, we can say that the vertical marginal discrepancy is the most important parameter in the study of margin [40]. In this study, the samples were not cemented to prevent differences due to the type of cement used, and viscosity and force applied during cementation; as well as the cement reduced the vertical marginal discrepancy. Several studies have examined the marginal discrepancy of CAD-CAM crowns and have accordingly used a number of different points to measure. Some of them have measured 4-8 [34,40], 16-24 [8] and 80-360 [41,42] points in each sample. Accordingly, there is no consensus on the number of measurement points in each sample to check the accuracy of marginal fit. This parameter seems to be sensitive, and the more measurement points are, the more accurate the result, because at margins of 300 microns, the marginal gap can vary up to 100 microns in the same sample [43]. Matta et al. [42] measured the marginal fit of crown copings at 360 points with 1 degree of distance between them, and showed that the marginal discrepancy was around 100 μm for all samples, but each sample had a large degree of marginal discrepancy over 150μ. Hence, as in many studies [44,45], this study used 20 points to measure marginal discrepancy, which seems to be adequate. Different methods have been proposed to measure the marginal fit of CAD-CAM restorations, including CBCT, light microscope, electron microscope, replica technique and 3D measurement [38]. This study used the Micro-CT device to compare the marginal discrepancy of restorations, which is a new technique. The most important advantage of this method is its non-invasive nature and the creation of an image of the internal dimension of the sample to the form of the section and simultaneously. In addition, the method provides the possibility of 3D reconstruction at any selected position and multiple sections; hence, the Micro-CT provides the ability to measure marginal gap [44-45]. One of the disadvantages of this technique is the low capacity of distinguishing between micro-CT and light microscope and electron microscope. In addition, it should be noted that X-ray images might have artifacts due to refraction. There are many materials with different absorption coefficients. Hence, it is very difficult to distinguish between them using X-ray [44]. It is impossible to distinguish between two substances with the same absorption coefficient when they are in contact. Hence, this should be considered when using this method. Therefore, we used materials with different absorption coefficients. In addition, it can be said that there is no consensus on the method used to check marginal discrepancy. Hence, these conditions can be a limitation to compare the results obtained in various studies. The limitations of this study were only the use of full crowns, the failure to check the veneering effect on marginal discrepancy, and the lack of efforts to simulate oral conditions. In addition, all specimens were evaluated without cementation because the radiopacity of the luting agent may change the results of the study.

CONCLUSION

According to our research findings, we found that the marginal discrepancy was increased with decreasing cement space, and the cement space had a significant effect on the marginal fit of monolithic zirconia crowns compared to Sintron crowns. It is recommended that future research should examine the marginal discrepancy in multiunit restorations, simulate oral conditions to be closer to real conditions, and evaluate the effect of cement space on the internal fit and the restoration strength.

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Conflict of interest

The authors declared that there is no conflict of interest.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of:

Isfahan University of Medical Sciences. The approval code for this study is: IR.MUI.RESEARCH.REC.1398.114.

REFERENCES

1. Sachs C, Groesser J, Stadelmann M, Schweiger J, Erdelt K, Beuer F. Full-arch prostheses from translucent zirconia: accuracy of fit. Dent Mater. 2014;30(8):817-23. doi:10.1016/j.dental.2014.05.001

2. Schley JS, Heussen N, Reich S, Fischer J, Haselhuhn K, Wolfart S. Survival probability of zirconia-based fixed dental prostheses up to 5 yr: a systematic review of the literature. Eur J Oral Sci. 2010;118(5):443-50. doi:10.1111/j.1600-0722.2010.00767.x

3. Stober T, Bermejo JL, Rammelsberg P, Schmitter M. Enamel wear caused by monolithic zirconia crowns after 6 months of clinical use. J Oral Rehabil. 2014;41(4):314-22. doi:10.1111/joor.12139

4. Al-Amleh B, Lyons K, Swain M. Clinical trials in zirconia: a systematic review. J Oral Rehabil. 2010;37(8):641-52. doi:10.1111/j.1365-2842.2010.02094.x

5. Nakamura K, Harada A, Kanno T, Inagaki R, Niwano Y, Milleding P, et al. The influence of low-temperature degradation and cyclic loading on the fracture resistance of monolithic zirconia molar crowns. J Mech Behav Biomed Mater. 2015;47:49-56. doi:10.1016/j.jmbbm.2015.03.007

6. van der Bilt A. Assessment of mastication with implications for oral rehabilitation: a review. J Oral Rehabil. 2011;38(10):754-80. doi:10.1111/j.1365-2842.2010.02197.x

7. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. Br Dent J. 2008;204(9):505-11. doi:10.1038/sj.bdj.2008.350

8. Rinke S, Fornefett D, Gersdorff N, Lange K, Roediger M. Multifactorial analysis of the impact of different manufacturing processes on the marginal fit of zirconia copings. Dent Mater J. 2012;31(4):601-9. doi:10.4012/dmj.2012-017

9. Witkowski S, Komine F, Gerds T. Marginal accuracy of titanium copings fabricated by casting and CAD/CAM techniques. J Prosthet Dent. 2006;96(1):47-52. doi: 10.1016/j.prosdent.2006.05.013.

10. Ramos GF, Monteiro EB, Bottino MA, Zhang Y, Marques de Melo R. Failure probability of three designs of zirconia crowns. Int J Periodontics Restorative Dent. 2015;35(6):843-9. doi:10.11607/prd.2448

11. Lan TH, Liu PH, Chou MM, Lee HE. Fracture resistance of monolithic zirconia crowns with different occlusal thicknesses in implant prostheses. J Prosthet Dent. 2016;115(1):76-83. doi:10.1016/j.prosdent.2015.06.021

12. Beuer F, Aggstaller H, Richter J, Edelhoff D, Gernet W. Influence of preparation angle on marginal and internal fit of CAD/CAM-fabricated zirconia crown copings. Quintessence Int. 2009;40(3):243-50.

13. Gardner FM. Margins of complete crowns--literature review. J Prosthet Dent. 1982;48(4):396-400. doi:10.1016/0022-3913(82)90072-5

14. Att W, Komine F, Gerds T, Strub JR. Marginal adaptation of three different zirconium dioxide three-unit fixed dental prostheses. J Prosthet Dent. 2009;101(4):239-47. doi:10.1016/S0022-3913(09)60047-0

15. Pak HS, Han JS, Lee JB, Kim SH, Yang JH. Influence of porcelain veneering on the marginal fit of Digident and Lava CAD/CAM zirconia ceramic crowns. J Adv Prosthodont. 2010;2(2):33-8. doi:10.4047/jap.2010.2.2.33

16. Bindl A, Mormann WH. Fit of all-ceramic posterior fixed partial denture frameworks in vitro. Int J Periodontics Restorative Dent. 2007;27(6):567-75.

17. Beuer F, Aggstaller H, Edelhoff D, Gernet W, Sorensen J. Marginal and internal fits of fixed dental prostheses zirconia retainers. Dent Mater. 2009;25(1):94-102. doi:10.1016/j.dental.2008.04.018

18. Beuer F, Naumann M, Gernet W, Sorensen JA. Precision of fit: zirconia three-unit fixed dental prostheses. Clin Oral Investig. 2009;13(3):343-9. doi:10.1007/s00784-008-0224-6

19. Grajower R, Zuberi Y, Lewinstein I. Improving the fit of crowns with die spacers. J Prosthet Dent. 1989;61(5):555-63. doi:10.1016/0022-3913(89)90275-8

20. Dolev E, Bitterman Y, Meirowitz A. Comparison of marginal fit between CAD-CAM and hot-press lithium disilicate crowns. J Prosthet Dent. 2019;121(1):124-8. doi:10.1016/j.prosdent.2018.03.035

21. Dahl BE, Rønold HJ, Dahl JE. Internal fit of single crowns produced by CAD-CAM and lost-wax metal casting technique assessed by the triple-scan protocol. J Prosthet Dent. 2017;117(3):400-4. doi:10.1016/j.prosdent.2016.06.017

22. Cunali RS, Saab RC, Correr GM, Cunha LFD, Ornaghi BP, Ritter AV, et al. Marginal and internal adaptation of zirconia crowns: a comparative study of assessment methods. Braz Dent J. 2017;28(4):467-73. doi:10.1590/0103-6440201601531

23. Ji MK, Park JH, Park SW, Yun KD, Oh GJ, Lim HP. Evaluation of marginal fit of 2 CAD-CAM anatomic contour zirconia crown systems and lithium disilicate glass-ceramic crown. J Adv Prosthodont. 2015;7(4):271-7. doi:10.4047/jap.2015.7.4.271

24. Pimenta MA, Frasca LC, Lopes R, Rivaldo E. Evaluation of marginal and internal fit of ceramic and metallic crown copings using x-ray microtomography (micro-CT) technology. J Prosthet Dent. 2015;114(2):223-8. doi:10.1016/j.prosdent.2015.02.002

25. 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(4):437-44. doi:10.4103/1305-7456.143612

26. Mously HA, Finkelman M, Zandparsa R, Hirayama H. Marginal and internal adaptation of ceramic crown restorations fabricated with CAD/CAM technology and the heat-press technique. J Prosthet Dent. 2014;112(2):249-56. doi:10.1016/j.prosdent.2014.03.017

27. Kale E, Seker E, Yilmaz B, Özcelik TB. Effect of cement space on the marginal fit of CAD-CAM-fabricated monolithic zirconia crowns. J Prosthet Dent. 2016;116(6):890-5. doi:10.1016/j.prosdent.2016.05.006

28. Özçelik TB, Yilmaz B, Şeker E, Shah K. Marginal adaptation of provisional cad/cam restorations fabricated using various simulated digital cement space settings. Int J Oral Maxillofac Implants. 2018;33(5):1064-9. doi:10.11607/jomi.6271

29. Suzuki S, Katsuta Y, Ueda K, Watanabe F. Marginal and internal fit of three-unit zirconia fixed dental prostheses: Effects of prosthesis design, cement space, and zirconia type. J Prosthodont Res. 2020;64(4):460-7. doi:10.1016/j.jpor.2019.12.005

30. Dauti R, Lilaj B, Heimel P, Moritz A, Schedle A, Cvikl B. Influence of two different cement space settings and three different cement types on the fit of polymer-infiltrated ceramic network material crowns manufactured using a complete digital workflow. Clin Oral Investig. 2020;24(6):1929-38. doi:10.1007/s00784-019-03053-1

31. Daou EE, Baba NZ. Evaluation of marginal and internal fit of presintered Co-Cr and zirconia three-unit fixed dental prosthesis compared to cast Co-Cr [published online ahead of print, 2020 Apr 25]. J Prosthodont. 2020;10.1111/jopr.13183. doi:10.1111/jopr.13183

32. Song TJ, Kwon TK, Yang JH, Han JS, Lee JB, Kim SH, et al. Marginal fit of anterior 3-unit fixed partial zirconia restorations using different CAD/CAM systems. J Adv Prosthodont. 2013;5(3):219-25. doi:10.4047/jap.2013.5.3.219

33. Grajower R, Lewinstein I. A mathematical treatise on the fit of crown castings. J Prosthet Dent. 1983;49(5):663-74. doi:10.1016/0022-3913(83)90393-1

34. Yao Y, Wang W, Wang F, Yao W. General self-efficacy and the effect of hospital workplace violence on doctors' stress and job satisfaction in China. Int J Occup Med Environ Health. 2014;27(3):389-99. doi:10.2478/s13382-014-0255-y

35. Prasad R, Al-Kheraif AA. Three-dimensional accuracy of CAD/CAM titanium and ceramic superstructures for implant abutments using spiral scan microtomography. Int J Prosthodont. 2013;26(5):451-7. doi:10.11607/ijp.3302

36. Euan R, Figueras-Alvarez O, Cabratosa-Termes J, Oliver-Parra R. Marginal adaptation of zirconium dioxide copings: influence of the CAD/CAM system and the finish line design. J Prosthet Dent. 2014;112(2):155-62. doi:10.1016/j.prosdent.2013.10.012

37. Vojdani M, Torabi K, Atashkar B, Heidari H, Torabi Ardakani M. A comparison of the marginal and internal fit of cobalt- chromium copings fabricated by two different CAD/CAM Systems (CAD/ Milling, CAD/ Ceramill Sintron). J Dent (Shiraz). 2016;17(4):301-8.

38. Seker E, Ozcelik TB, Rathi N, Yilmaz B. Evaluation of marginal fit of CAD/CAM restorations fabricated through cone beam computerized tomography and laboratory scanner data. J Prosthet Dent. 2016;115(1):47-51. doi:10.1016/j.prosdent.2015.08.006

39. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. Journal of Prosthetic Dentistry. 1989 Oct 1;62(4):405-8.

40. 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(3):555-60. doi:10.1016/j.prosdent.2013.12.002

41. Martinez-Rus F, Ferreiroa A, Ozcan M, Pradies G. Marginal discrepancy of monolithic and veneered all-ceramic crowns on titanium and zirconia implant abutments before and after adhesive cementation: a scanning electron microscopy analysis. Int J Oral Maxillofac Implants. 2013;28(2):480-7. doi:10.11607/jomi.2759

42. Matta RE, Schmitt J, Wichmann M, Holst S. Circumferential fit assessment of CAD/CAM single crowns--a pilot investigation on a new virtual analytical protocol. Quintessence Int. 2012;43(9):801-9.

43. Chan C, Haraszthy G, Geis-Gerstorfer J, Weber H, Huettemann H. Scanning electron microscopic studies of the marginal fit of three esthetic crowns. Quintessence Int. 1989;20(3):189-93.

44. Pelekanos S, Koumanou M, Koutayas SO, Zinelis S, Eliades G. Micro-CT evaluation of the marginal fit of different In-Ceram alumina copings. Eur J Esthet Dent. 2009;4(3):278-92.

45. Tabata LF, de Lima Silva TA, de Paula Silveira AC, Ribeiro AP. Marginal and internal fit of CAD-CAM composite resin and ceramic crowns before and after internal adjustment. The Journal of Prosthetic Dentistry. 2020 Mar 1;123(3):500-5. doi:10.1016/j.prosdent.2019.01.010

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