ADITUM
Enrich your Research

Dental Science and Innovative Research Research Article

The Effect of Zirconia Framework Design on The Marginal and Internal Adaptations of Zirconia Crowns: An In-Vitro Study.

Sara Tavakolizadeh
TMD Center, INI Hospital, Hannover, Germany.

Article Info

Received: February 01, 2024
Accepted: February 10, 2024
Published: February 20, 2024

***Corresponding author:** Sara Tavakolizadeh, TMD Center, INI Hospital, Hannover, Germany.

Citation: Tavakolizadeh S. (2024) "The Effect of Zirconia Framework Design on The Marginal and Internal Adaptations of Zirconia Crowns: An In-Vitro Study". Dental Science and Innovative Research, 3(1); DOI: 10.61148/DSIR/003.

Copyright: © 2024 Sara Tavakolizadeh. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract:

Background: Internal and marginal adaptation is an important parameter in long-term durability of dental crowns. The aim of this study was to evaluate the fit of zirconia crowns with different framework designs.

Materials and Methods: A natural upper central incisor tooth was prepared with chamfer finishing line and 1mm reduction in all walls (except 1.5mm for the incisal edge). The prepared tooth was scanned and four different core designs (simple, cut back, anatomic, and monolithic) were designed with computer software. Veneering process was done manually for all cores, except for the monolithic group. The crowns and the natural tooth were scanned and then internal and marginal gaps were evaluated in different areas using CATIA software. Two-way ANOVA and Tukey tests were used for statistical analyses ($\alpha = 0.05$).

Results: Internal gap of monolithic group was significantly lower than cut back and anatomic core design groups (P=0.007). Marginal gap in monolithic group was also lower than other groups and it was significantly lower than cut back design group (P<0.05). However, all the gaps were within clinically acceptable range.

Conclusion: Internal and marginal adaptation of monolithic crowns were better than other groups in this study.

Keywords: CAD/CAM, ceramics; dental materials; digital dentistry; prosthodontics

Introduction:

Due to ongoing progression of computer-aided design and computer-aided manufacturing (CAD/CAM) techniques and high strength ceramic materials, the current use of full-ceramic restorations has increasingly developed.[1] Among current CAD/CAM ceramic restorations, due to being esthetically pleasant and resistance to fracture, zirconia crowns are being used widely nowadays.[2] Among the basic requirements for a successful long-term fixed dental crowns, marginal and internal adaptations are of great importance.[6-8]

The cement space between the crown and the underlying tooth should not exceed the clinically acceptable limits.[9] A cement space of 50 to 100µm is considered the acceptable range for internal gap.[10] Beside increasing the chance of cement wash out and recurrent caries, it has been reported that the internal gaps of more than 70µm could decrease the fracture resistance of zirconia crowns.[8] Also, a marginal discrepancy of 73 to 150µm has been reported to be clinically desirable.[11-13]

Marginal and internal adaptations of monolithic and layered zirconia crowns and fixed partial dentures have been the subject of various studies. Different parameters that could possibly affect the adaptation of the zirconia crowns in these studies include finish line design, impression technique (conventional vs. digital), scanning system, fabrication system (CAD/CAM system), zirconia block type (green vs. pre-sintered), sintering process, veneering technique, firing cycles numbers, and also the design of fixed partial denture.[14-35] The porcelain framework design might influence the crown adaptation, as well as its esthetic and strength. Therefore, this study aimed to evaluate the effect of four different framework designs on the marginal and internal fits of CAD/CAM zirconia crowns.

Materials and Methods

A sound maxillary right central incisor extracted due to periodontal problems was used in this in vitro study. The tooth was mounted in a resin pattern block (ACROPARS, Marlic Medical Industries Co, Iran) 3mm apically to the CEJ. Condensational silicone material (Speedex putty, COLTENE, Berlin, Germany) was used to make indices from the tooth crown. Also, the crown segment of tooth was scanned by a scanner (Open Technologies Dental, Italy, Brescia). Using a high-speed handpiece and a torpedo diamond bur, the tooth was prepared 1mm coronally to the CEJ, with 1.5mm incisal reduction and 1mm axial walls reduction with a 6-degree taper and a heavy chamfer finish line.

After scanning the prepared tooth (Figure 1), four different frameworks were designed using EXOCAD software (Exocad Dental CAD, Darmstadt, Germany) with 60micron cement space. Four groups each containing 10 samples was formed according to the framework designs.

Group 1: consisted of simple 0.5mm thickness zirconia cores without any anatomical contour (Figure 2, A).

Group 2: included zirconia cores with a cut back design contour and a 3mm lingual collar and proximal struts up to the half of the proximal wall height (Figure 2, B).

Group 3: consisted of zirconia cores with anatomic core contour. To create this group first an acrylic resin pattern of the full contour tooth was made using the previously made putty index. Then the resin pattern was cut back according to the mean enamel thickness in five different points (mesial, distal, buccal, lingual, incisal) (Figure 2, C). Mean enamel thickness was calculated using CBCT of five sound central maxillary teeth. Then, the cutback resin pattern was scanned for designing the zirconia anatomic core.
Group 4: consisted of full anatomical contour monolithic zirconia crowns (Figure 2, D).

The milling process was carried out using a green zirconia blank (KATANA, Kuraray Noritake Dental Inc, Japan). Then, veneering porcelain (Zr-FS, GC, Europe A.G., E.U.) was applied by an experienced technician on the first three core groups. A previously made putty index was used to ensure the same full contour for all the crowns.

Prepared tooth surfaces and internal/marginal surfaces of crowns were scanned by a scanner (ATOS, GOM GmbH, Braunschweig, Germany) with an accuracy of 1 million dots per scan. This scanner has two cameras that receive the reflected beam and with its own algorithms (Triple Scan Principle and Dynamic Referencing) produces a 3D image which can be used by various softwares. After scanning the specimens, the crowns and the tooth were aligned in CATIA software (Dassault Systèmes SE, Vélizy-Villacoublay, France) (Figure 3) to analyze the internal and marginal fit between the crown and the tooth (Figure 4). Internal gap was measured in six areas (mesiopalatal, mesiobuccal, distopalatal, distobuccal, midpalatal, and midbuccal) and marginal gap was measured in eight areas (mesiopalatal, mesiobuccal, midpalatal, midbuccal, distobuccal, distopalatal, mesial, and distal). Each point was measured for ten times and the average measurement of ten points in each area was considered as the gap of that area.

The collected data were analysed using R 3.6.0 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria) software using 2-way ANOVA and Tukey tests. The statistical significance level was determined to be at 0.05.

Results

The results showing the mean marginal and internal gaps of 4 different zirconia core designs crowns at the six measuring points are presented in Table 1. According to one-way ANOVA analysis, the mean internal gap was the highest in anatomic core design group (75.33 µm) and the lowest in monolithic crown group (49.07 µm) (*P*=0.007). Although, the mean marginal gap difference in the cut back design and monolithic groups was statistically significant (*P*=0.043), the differences between the other groups were not significant (*P*>0.05).

Table 1: Mean (and standard deviation) marginal and internal gaps of zirconia cores by 6 measuring areas.

Location	Monolithic	Simple core	Anatomic core	Cut-back
Marginal-palatal	40.07 (13.117)	53.63 (16.755)	61.63 (37.518)	62.10 (25.778)
Marginal-labial	40.73 (13.701)	47.83 (12.545)	62.93 (27.375)	71.37 (28.754)
Marginal-mesial	38.20 (12.136)	46.40 (6.168)	59.50 (33.669)	58.10 (20.415)
Marginal-distal	51.40 (15.299)	46.80 (11.243)	48.10 (27.747)	50.80 (14.219)
Internal-palatal	53.33 (16.643)	65.43 (17.785)	69.30 (30.311)	70.83 (18.516)
Internal-labial	49.07 (17.734)	58.47 (18.682)	75.33 (23.884)	70.63 (20.619)

According to the Tukey test the monolithic crown group had the least marginal gap in all the measured areas, except for the distal area. There were statistically significant differences between monolithic crown group and cut back design group in mesiopalatal, midpalatal, and distopalatal areas (*P* = 0.024, 0.009, and 0.032, respectively).

Based on the two-way ANOVA analysis, there were significant

Copy right © Sara Tavakolizadeh

differences among 6 measuring points. The interactive effect of the two factors was not significant, indicating that there are no statistical differences in design groups and measuring areas combinations (Table 2).

Table 2: Results of two-way ANOVA analysis.

Source	Type III sum of squares	D.F.	Mean squares	F-value	P-value
Design groups	24704.487	3	8234.829	17.078	<0.001
Measuring areas	16360.338	5	3272.068	6.786	<0.001
Crown groups and measuring areas	7839.600	15	522.640	1.084	0.368

R Squared = .201 (Adjusted R Squared = .167)

Discussion

In partial fixed dentures, the effect of the prosthesis design (straight vs. curved) has been studied on the marginal gap.[22] However, in single zirconia crowns proper framework architecture has been evaluated only in term of its effect on esthetic and fracture strength of the restoration.[36] Therefore, this study aimed to evaluate the effect of three different designs of layered zirconia copings and the anatomic design (monolithic) on the marginal and internal adaptation of finalized zirconia crowns. While the importance of marginal gap lies in the prevention of carious and periodontal disease,[7] a thin and uniform internal gap is necessary for resistance, retention and strength of the zirconia restorations.[37]

According to the findings, internal and marginal gaps of the non-veneering (monolithic) group were significantly lower than the three veneering groups. However, there was no significant difference between the veneering groups. Marginal gap in monolithic group (41.50±5.15µm) was significantly lower than cut back design group (63.66±20.5µm). However, all these gaps were within clinically acceptable ranges.[12] Also, internal gap of the monolithic group was significantly lower than the cut back and anatomic core design groups (70.73±14.30 and 72.31±18.33µm, respectively). Internal inaccuracy of zirconia restorations has been generally attributed to the cooling process, firing contraction, and also the geometry of the milling burs.[19,23,24] However, using additive manufacturing techniques could overcome the limitation caused by the size and shape of burs used in the subtractive CAD/CAM milling method.[38] The most amount of veneering porcelain was used in the simple core design group and the smallest amount was used in the anatomic core design group. Therefore, it seemed that the amount of veneering porcelain did not necessarily affect the gap. Furthermore, high standard deviation (SD) seen in this study might be due to various marginal fit of each crown at different locations.[39]

One of the factors that could affect the marginal accuracy is the material used for crown fabrication. Kunii et al.[14] studied the effect of sintering on the marginal and internal gaps of the KATANA zirconia crowns (the same zirconia material as used in this study). They reported a lower marginal gap (3.6±5.8µm). However, the amount of axial gap was similar to that of the monolithic group in this study, and the occlusal gap was higher than all the groups in our study.

It has been reported that the veneering process including layering, pressing or CAD-on techniques could increase the marginal gap. However, a higher marginal gap has been associated with the hand layering technique.[25] The reasons suggested for this finding include the higher mismatch of coefficients of thermal expansion (CTE) of coping and veneering porcelain. Also, the shrinkage of veneering porcelain due to the more firing cycle numbers in this technique could lead to lifting of the margin off the die.[26,27]Also, it has been reported that repeated firing cycles could change the CTE of both core and veneering porcelain.[40,41]Other studies have also showed an increase in the marginal gap after veneering process due to compressive stresses created in the coping after melting and contraction of veneering porcelain particles.[19,28,29] The anisotropic contraction of zirconia copings and the inconsistent firing shrinkage of the veneering porcelain could have also played a part in the results.[30] However, this simple contraction force might not quite explain the marginal gap developed after veneering process due to the high flexural strength and fracture toughness of zirconia framework.[42] Therefore, a more reasonable explanation could be development of microcracks during the milling process of pre-sintered zirconia block. They could then cause stress points after subjecting to the wet veneering porcelain and grow during firing resulting in 3-5% volume increase due to zirconia phase transformation. This compressive stress together with the CTE incompatibility between zirconia coping and the veneering porcelain could cause the marginal gap.[27, 31,43]

Differences in the studies regarding the increasing the marginal gap after veneering process might be attributed to different veneering thickness and uniformity of porcelain mass (greater marginal gaps in buccal and palatal margins in comparison to mesial and distal margins), different core thicknesses, different number of firing cycles, different coping shape (regarding the tooth shape), different materials used for core and veneering, operator manual skills, geometric complexity of the restoration (single crown versus fixed partial dentures), and also various methods used for measuring the gaps. [21, 28,32,44,45] To eliminate the errors associated with non-digital measuring methods, crowns were digitally scanned using GOM ATOS scanner and the marginal and internal gaps were measured by CATIA reverse engineering software in this study. Measuring internal gap is only possible through digital measurement, internal microscopes or replica technique. [46-48]

Another factor reported to affect the marginal fit of zirconia restoration is cement space which has been suggested to not to be less than50- 60 micron.[33,34] Excess cement space could also decrease the fracture strength of the prosthesis and add to the failures of the veneering porcelain.[49,50] On the other hand, according to Yilmaz et al[35] decreasing the cement space could improve the marginal gap of monolithic crowns.

Copy right © Sara Tavakolizadeh

One of the limitations of this study was not subjecting the samples to the aging process to simulate intraoral conditions. Also, more studies should be conducted to evaluate the marginal and internal gaps of frameworks before application of veneering porcelain.

Conclusion

Within limitations of this study, the amount of internal and marginal gaps of zirconia crowns with four different coping designs were within clinically acceptable range. Also, the monolithic group had the lowest marginal and internal discrepancies.

References

1. Möller H. Dental gold alloys and contact allergy. Contact Dermatitis. 2002;47(2):63-6.
2. Komine F, Blatz MB, Matsumura H. Current status of zirconia-based fixed restorations. J Oral Sci. 2010;52(4):531-9.
3. Zitzmann NU, Hagmann E, Weiger R. What is the prevalence of various types of prosthetic dental restorations in Europe? Clin Oral Implants Res. 2007;18:20-33.
4. Carlsson GE. Critical review of some dogmas in prosthodontics. J Prosthodont Res. 2009;53(1):3-10.
5. Shepard FE, Moon PC, Grant GC, Fretwell LD. Allergic contact stomatitis from a gold alloy--fixed partial denture. J Am Dent Assoc. 1983;106(2):198-9.
6. Rad FAA, Succaria FG, Morgano SM. Fracture resistance of porcelain veneered zirconia crowns with exposed lingual zirconia for anterior teeth after thermal cycling: An in vitro study. Saudi Dent J. 2015;27(2):63-9.
7. Felton D, Kanoy B, Bayne Sa, Wirthman G. Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent. 1991;65(3):357-64.
8. Tuntiprawon M, Wilson PR. The effect of cement thickness on the fracture strength of all-ceramic crowns. Aust Dent J. 1995;40(1):17-21.
9. Shillingburg HT, Sather DA, Wilson EL, Cain J, Mitchell D, Blanco L, et al. Fundamentals of fixed prosthodontics: Quintessence Publishing Company; 2012.
10. Ozcelik TB, Yilmaz B, Seker E, Shah K. Marginal adaptation of provisional CAD/CAM restorations fabricated using various simulated digital cement space settings. 2018.
11. Boening KW, Wolf BH, Schmidt AE, Kästner K, Walter MH. Clinical fit of Procera AllCeram crowns. J Prosthet Dent. 2000;84(4):419-24.
12. Abduo J, Lyons K, Swain M. Fit of zirconia fixed partial denture: a systematic review. J Oral Rehabil. 2010;37(11):866-76.
13. Kokubo Y, Ohkubo C, Tsumita M, Miyashita A, Vult von Steyern P, Fukushima S. Clinical marginal and internal gaps of Procera AllCeram crowns. J Oral Rehabil. 2005;32(7):526-30.
14. Euán R, Figueras-Álvarez O, Cabratosa-Termes J, Oliver-Parra R. Rekow the finish line design. J Prosthet Dent. 2014;112(2):155-162.
15. Ha SJ, Cho JH. Comparison of the fit accuracy of zirconia-based prostheses generated by two CAD/CAM systems. J Adv Prosthodont. 2016;8(6):439-448.
16. Cetik S, Bahrami B, Fossoyeux I, Atash R. Adaptation of zirconia crowns created by conventional versus optical impression: in vitro study. J Adv Prosthodont. 2017;9(3):208-216.
17. Rödiger M, Schneider L, Rinke S. Influence of Material Selection on the Marginal Accuracy of CAD/CAM-Fabricated Metal- and All-Ceramic Single Crown Copings. Biomed Res Int. 2018;2018:2143906.
18. Ahmed WM, Abdallah MN, McCullagh AP, Wyatt CCL, Troczynski T, Carvalho RM. Marginal Discrepancies of Monolithic Zirconia Crowns: The Influence of Preparation Designs and Sintering Techniques. J Prosthodont. 2019;28(3):288-298.
19. 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):33-38.
20. Khaledi AAR, Vojdani M, Farzin M, Pirouzi S, Orandi S. The Effect of Sintering Time on the Marginal Fit of Zirconia Copings. J Prosthodont. 2019;28(1):e285-e289.
21. Komine F, Gerds T, Witkowski S, Strub JR. Influence of framework configuration on the marginal adaptation of zirconium dioxide ceramic anterior four-unit frameworks. Acta Odontol Scand. 2005;63(6):361-366.
22. Büchi DL, Ebler S, Hämmerle CHF, Sailer I. Marginal and internal fit of curved anterior CAD/CAM milled zirconia fixed dental prostheses: an in-vitro study. Quintessence Int 2014;10:837-46.
23. Juntavee N, Sirisathit I. Internal accuracy of digitally fabricated cross-arch yttria-stabilized tetragonal zirconia polycrystalline prosthesis. Clin Cosmet Investig Dent. 2018;10:129-140.
24. Pfeiffer J. Dental CAD/CAM technologies: the optical impression (II). Int J Comput Dent. 1999;2(1):65–72.
25. Torabi K, Vojdani M, Giti R, Taghva M, Pardis S. The effect of various veneering techniques on the marginal fit of zirconia copings. J Adv Prosthodont. 2015;7(3):233-239.
26. Weaver JD, Johnson GH, Bales DJ. Marginal adaptation of castable ceramic crowns. J Prosthet Dent 1991;66:747-53.
27. DeHoff PH, Barrett AA, Lee RB, Anusavice KJ. Thermalcompatibility of dental ceramic systems using cylindrical and spherical geometries. Dent Mater 2008;24:744-52.
28. Balkaya MC, Cinar A, Pamuk S. Influence of firing cycles on the margin distortion of 3 all-ceramic crown systems. J Prosthet Dent 2005;93:346-55.
29. Lee KB, Park CW, Kim KH, Kwon TY. Marginal and internal fit of all-ceramic crowns fabricated with two different CAD/CAM systems. Dent Mater J 2008;27:422-6.
30. Kuni 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 2007;26:820e6.
31. Kohorst P, Brinkmann H, Dittmer MP, Borchers L, Stiesch M. Influence of the veneering process on the marginal fit of zirconia fixed dental prostheses. J Oral Rehabil 2010;37:283e91.

Copy right © Sara Tavakolizadeh

32. Vigolo P, Fonzi F. An in vitro evaluation of fit of zirconium-Oxide-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;17:621e6.
33. 29. 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;31:601-9.
34. Daou EE, Ounsi H, Özcan M, Al-Haj Husain N, Salameh Z. Marginal and internal fit of pre-sintered Co-Cr and zirconia 3-unit fixed dental prostheses as measured using microcomputed tomography. J Prosthet Dent. 2018;120(3):409-414.
35. 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):890-895.
36. Diker B, Erkut S. The influence of zirconia coping designs on maximum principal stress distribution in all-ceramic premolar crowns: A finite element analysis. Am J Dent. 2019;32(5):255-259.
37. Rekow ED, Harsono M, Janal M, Thompson VP, Zhang G. Factorial analysis of variables influencing stress in all-ceramic crowns. Dent Mater. 2006;22(2):125–132.
38. Vijay Venkatesh K., Vidyashree Nandimi V., Direct metal laser sintering: a digitised Metal casting technology, J. Indian Prosthodont Soc 2013, 13 (4):389-392.
39. Chan C, Haraszthy G, Gerstorfer JG, Weber H, Huettemann H. Scanning electron microscopic studies of the marginal fit of three esthetic crowns. Quintessence Int J 1989;20:189e93.
40. Fairhurst CW, Anusavice KJ, Hashinger DT, Ringle RD, Twiggs SW. Thermal expansion of dental alloys and porcelains. J Biomed Mater Res 1980;14:435-46.
41. Isgrò G, Kleverlaan CJ, Wang H, Feilzer AJ. Thermal dimensional behavior of dental ceramics. Biomaterials 2004;25: 2447-53.
42. Goldin E, Boyd NW, Goldstein GR, Hittelman EL, Thompson VP. Marginal fit of leuciteeglass pressable ceramic restorations and ceramic pressed-to-metal restorations. J Prosthet Dent 2005;93:143e7.
43. Sulaiman F, Chai H, Jameson LM, Wozniak WT. A comparisonof the marginal fit of in-ceram, IPS empress, and procera crowns. Int J Prosthodont 1997;10:478e84.
44. 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;26:582e93.
45. Att W, Komine F, Gerds T, Strub JR. Marginal adaptation of three different zirconium dioxide three-unit fixed dental prostheses. J Prosthet Dent 2009;101:239e47.
46. Lins L, Bemfica V, Queiroz C, et al: In vitro evaluation of the internal and marginal misfit of CAD/CAM zirconia copings. J Prosthet Dent 2015;113:205-211.
47. P Fasih, S Tavakolizadeh, MS Monfared, A Sofi, A Yari. Marginal fit of monolithic versus layered zirconia crowns assessed with 2 marginal gap methods. J Prosthet Dent 130(2), 250, 2023.
48. Boitelle P, Tapie L, Mawussi B, Fromentin O. Evaluation of the marginal fit of CAD-CAM zirconia copings: Comparison of 2D and 3D measurement methods. J Prosthet Dent. 2018;119(1):75-81.
49. Borba M, Cesar PF, Griggs JA, Della Bona A. Adaptation of all-ceramic fixed partial dentures. Dent Mater 2011;27:1119-26.
50. Kim KB, Kim JH, Kim WC, Kim JH. Three-dimensional evaluation of gaps associated with fixed dental prostheses fabricated with new technologies. J Prosthet Dent 2014;112:1432

Copy right © Sara Tavakolizadeh