Tikrit Journal for Dental Sciences 12(2) (2024) 463-471
https://doi.org/10.25130/tjds.12.2.22

Tikrit Journal
for
Dental Sciences
https://tjds.tu.edu.iq
ISSN:2073-1213

IRAQI Academic Scientific Journals
Tikrit Journal for Dental Sciences

The Effect of Shoulderless Versus Chamfer Finishing Line Designs with Different Cement Space Settings on the Marginal Fit of Monolithic Zirconia Crowns (in-vitro study)

Kazhan M. Omer [1] *
Abdulsalam R. Kudid Al-Zahawi [2]
[1,2] Department of Conservative, College of Dentistry, University of Sulaimani, Sulaimani, Iraq

Keywords:
CAD/CAM, Zirconia, Shoulderless finishing line

Article Info.:

Article History:
Received: 22/9/2023
Received in revised form: 30/9/2023.
Accepted: 2/10/2023
Final Proofreading: 2/10/2023
Available Online: 1/12/2024

© THIS IS AN OPEN ACCESS ARTICLE UNDER THE CC BY LICENSE

https://creativecommons.org/licenses/by/4.0/

Citation: **Omer KM, Al-Zahawi AR. The Effect of Shoulderless Versus Chamfer Finishing Line Designs with Different Cement Space Settings on the Marginal Fit of Monolithic Zirconia Crowns (in-vitro study). Tikrit Journal for Dental Sciences 2024; 12(2): 463-471.**
https://doi.org/10.25130/tjds.12.2.22

***Corresponding Author:**
Email:
kazhan.omer@univsul.edu.iq

Department of Conservative, College of Dentistry, University of Sulaimani, Sulaimani, Iraq

Abstract
The objective was to examine the effect of various finishing line designs and modified cement space settings on the marginal fit of monolithic zirconia crown restorations. Material and methods: - Extracted sound upper first premolar tooth was prepared sequentially with two different finishing lines, a shoulderless and a chamfer. Each preparation was scanned with an intra-oral scanner. The scan data was used to create 45 milled Chrome-Cobalt (Cr-Co) alloy copies and to design crowns with two cement space settings using CAD software (Exocad version 3.1). Three groups were designed (n=15). (1) group A: shoulderless finishing line and crowns with (0 µm marginal and 35 µm occlusal-axial) cement space setting; (2) group B: shoulderless finishing line and crowns with modified cement space setting (0 µm occlusal to the 2.4 mm axial and 35 µm marginal); (3) group C: chamfer finishing line and crowns with (0 µm marginal and 35 µm occlusal-axial) cement space setting. The marginal gap was measured in microns (µm) with the impression replica technique. Data were statistically analyzed using the Student's T-test, one-way ANOVA, and Bonferroni tests at a significance level of 0.05. Results: - The lowest mean values were recorded by group A, followed by group B, and the highest mean values were recorded by group C. The result revealed highly significant differences between groups. Conclusion: - Within this in-vitro study limits, all groups' marginal gap variables were clinically acceptable. Modifying the crown cement space setting for shoulderless preparation resulted in a larger marginal gap.

Introduction:

Construction of a full-coverage crown might be necessary when the tooth is weak or heavily fractured (1). Over the years, horizontal finishing lines (chamfer and shoulder) have become preferred for all-ceramic full-coverage crown restorations. However, these margins can be considered invasive due to removing healthy tooth structures to create a clear finishing line, which is essential from biological and esthetic perspectives (2).

Owing to the development of dental technologies, monolithic restorations, and the growing demand for minimally invasive dentistry, vertical finishing lines (shoulderless, feather-edge, and knife-edge) have become more popular as they can be considered more conservative due to preserving more of the sound tooth structure essential for reducing stress on the tooth being restored with a full-coverage crown restoration (3).

Monolithic zirconia restorations have recently become more frequent due to the advancement of CAD-CAM technology, in which various restoration parameters, such as restorative material thicknesses and cement spacing, can be modified in the designing phase, making fabrication faster and less expensive (4).

During crown manufacturing, a cement space should be created to lessen the cementing material's flow resistance, reducing the hydraulic pressure that exists between the cement and the restoration, allowing for complete seating of the restoration, reducing marginal discrepancies, and extruding extra cement from all preparation margins (5,6).

According to Holmes et al.(7) the marginal gap can be defined as the "Distance from the margin of the restoration to the margin of the tooth preparation". A maximum marginal disparity of less than 120 µm has been advocated in several studies (8), in contrast, others believe 100 µm should be the cutoff (9). An inadequate prosthesis margin might result in a gap between the prepared tooth and the restoration, while cement can fill the marginal discrepancies, it might degrade due to its porous and rough nature when exposed to the oral cavity. Bacteria can build up and endanger the treatment's effectiveness (10). On the other hand, the tighter the marginal gap, the harder it becomes for cement to exit due to early marginal seal, which could potentially result in higher cement buildup on the occlusal seating area (11–14).

There are many strategies for marginal gap measurement; one of the most popular methods is the impression replica technique because it is straightforward, non-destructive, economical, clinically applicable, and repeatable (15–18). The coping will be placed on the abutment after injection of light body silicone and embedded with heavy body silicone; after removing from the abutment, the replica will be sectioned and analyzed (19).

Several studies indicated crowns with vertical finishing lines exhibit superior marginal fit compared to those with horizontal finishing lines (11,12,20–22). According to some investigations, this fit could potentially result in early marginal seal and prevent seepage of accessory luting cement during cementation, which might otherwise hinder proper restoration seating and cause excessive cement accumulation on the occlusal seat (11,12).

Considering the aforementioned reasons, this study aimed to investigate (inverted cement space) setting (0 µm cement space at the occlusal surface up to more than half of the axial walls and a 35 µm cement space setting for the remaining marginal areas) on the marginal fit for monolithic zirconia crowns fabricated for shoulderless preparation and to assess how this modified cement space setting might impact the marginal fit.

Materials and Methods

1. Tooth preparations

Extracted sound upper first premolar tooth for orthodontic purposes was selected, free from carious lesions and restorations. The sample tooth received two preparations sequentially with the aid of a modified dental surveyor and a high-speed handpiece. The first preparation form had a shoulderless finishing line using a round safe-end taper fissure bur (857 016M-FG NTI, Kahla, Germany). The preparation's total convergence angle was set to 6 degrees depending on the bur's taperness. The occlusal reduction was 1.5 mm, determined with a depth cutter bur (MADC15 NTI, Kahla, Germany), then a planar occlusal surface was prepared using a Burrell-shaped diamond bur (K899-031M-FG NTI, Kahla, Germany). The prepared sample's axial height was 4 mm, measured from the buccal surface to the finishing line. An intra-oral scanner (Cerec Omnicam, Sirona, Bensheim, Germany) was used to capture a digital impression of the first preparation.

The finishing line area of the prepared sample was then marked carefully with a permanent marker, and with the aid of a modified dental surveyor and a high-speed handpiece a 0.5 mm chamfer finishing line was prepared using a round-end taper fissure bur with a guided pin (998 016F-FG, NTI, Kahla, Germany); the second preparation had the same total convergence angle and axial height as the first preparation. No further adjustments were made to the occlusal surface except for the smoothing of sharp edges Fig. (1). A digital impression of the second preparation was subsequently taken using the same intra-oral scanner.

2. Duplication of preparations

The scan data were used to construct 45 milled Cr-Co copies (n=15), which were milled with a 5-axis CAD/CAM milling machine (In-Laboratory MC×5, Sirona, Bensheim, Germany) using Cr-Co disk. 30 copies for both groups A and B with shoulderless finishing line (15 each), and 15 copies for group C with chamfer finishing line. The milled Cr-Co copies were embedded 2 mm apical to the finishing line area with the aid of a modified dental surveyor in a specially designed cuboid rubber mold (2.0 cm height × 1.3 cm width × 1.3 cm length) filled with a freshly mixed cold cure acrylic.

3. Crown fabrication

The scan data obtained from both preparations were used to design monolithic zirconia crowns with identical contours and occlusal thicknesses for each group using CAD software (Exocad version 3.1). Regarding the cement space settings, groups A and C were designed with a 0 µm cement space from the margin to 1 mm and a 35 µm cement space setting for the rest of the internal fitting surfaces. In contrast, the cement space setting for group B was modified with 0 µm from the occlusal surface to the 2.4 mm axial wall and a 35 µm cement space for the remaining marginal areas to compensate for an inverted cement space setting. Fig. (2).

The crowns were milled with a 5-axis CAD/CAM machine using zirconia blanks (IPS e.max ZirCAD LT; Ivoclar Digital, Schaan, Liechtenstein). The milled crowns were then exposed to the sintering process in order to achieve their original size, strength, and color. This was accomplished using the In Fire HTC Speed Sintering Furnace (Sirona, Bensheim, Germany) at a temperature of 1,450°C.

The crowns were glazed using a brush to apply a glaze paste (FLUO Ivoclar glaze paste; Ivoclar Vivadent, Schaan, Liechtenstein). The Programat EP 5010 furnace (Ivoclar, Schaan, Liechtenstein) was used for glaze firing at 840°C for 20 minutes. The intaglio surface of each crown was then sandblasted using the sandblasting machine (Renfert, Hilzingen, Germany) for 10 seconds with 1 bar of 50 µm aluminum oxide particles placed 10 mm from the restoration (23). Crowns for each group were distributed randomly on the corresponding milled Cr-Co alloy copies.

4. Marginal gap measurements

Marginal gap measurements were evaluated by a non-destructive technique, using the impression replica technique described by Boening et al (24) Each fabricated crown was injected with light body fast set vinylpolysiloxane impression material and seated with finger pressure on the Cr-Co copy, then a constant occlusal load of 5 kg was applied for 5 minutes with the aid of a modified dental surveyor (25). The crown was carefully removed from the Cr-Co copy with a thin layer of light body impression material representing the cement gap. A heavy body fast set vinylpolysiloxane impression material of different colors was carefully injected inside the crown to stabilize and fix the light body in place; after complete polymerization, the replica was carefully removed from the crown and cut in the occlusal-gingival direction into four sections.

Each section was placed beside the Neubauer chamber grid, and an image was captured under a stereo microscope. Images were assessed utilizing image processing software (Image J version 1.53t) to measure the yellowish color of the light body at the marginal area. Four marginal points (mid-buccal, mid-mesial, mid-distal, and mid-palatal) were calculated, and the mean was gathered, representing the marginal gap measurement for one sample. For standardization purposes and to avoid errors two operators took the marginal gap measurements at different times.

5. Statistical analysis

Statistical analysis was done using the Statistical Package for Social Science (SPSS version 25). The normal distribution of variables was evaluated with the Shapiro-Wilk test; the Student's T-test was employed to compare the marginal gap measurements taken by two operators; the one-way ANOVA test was used to assess the significance of the mean differences of the marginal gap measurements among the three groups; and Bonferroni correction was used for multiple comparisons across the groups.

Results

Shapiro-Wilk test revealed that the data were normally distributed ($p > 0.05$). The inter-examiner results showed a statistically non-significant difference ($p>0.05$) between the two measurements. The descriptive statistics in Table (1) include the three groups' minimum, maximum, mean, and standard deviation of the three groups.

The lowest mean value of the marginal gap measurements was recorded by group A (44.08 µm) with shoulderless finishing line and crowns with (0 µm marginal and 35 µm occlusal-axial) cement space setting, followed by group B (55.46 µm) with shoulderless finishing line and crowns with inverted cement space setting (0 µm occlusal to the 2.4 mm axial and 35 µm marginal). The largest mean value of the marginal gap was recorded by group C (66.47 µm) with a chamfer finishing line and crowns with (0 µm marginal and 35 µm occlusal-axial) cement space setting Fig. (3).

The one-way ANOVA test was used to compare the marginal gap measurements among the three groups at a significance level of 0.05 and revealed statistically significant differences among groups ($p<0.05$) Table (2).

The Bonferroni test was used to determine differences across the groups; the result showed statistically significant differences between the three groups when compared with each other Table (3).

Discussion

Tooth preparation for full-coverage crowns is invasive and irreversible, so research seeking more conservative preparation has never stopped. Shoulderless preparation can be considered the most conservative approach toward dental structure (2,26).

The marginal fit is crucial for determining the restoration's long-term viability in fixed prosthodontics. Most clinicians prefer a marginal gap of ≤ 60 µm, while 120 µm or less can be considered clinically acceptable (6). Additionally, there is a positive correlation between the size of the marginal gap and the emergence of secondary caries (18,27). Because of the mentioned reasons, researchers and prosthodontists are still interested in prosthesis adaption (28,29).

Due to the superior mechanical properties of zirconia, it is possible to endorse the use of thinner monolithic zirconia crowns in the posterior area, facilitating a more conservative preparation design(23,30,31). Additionally, monolithic zirconia restorations eliminate the problem of chipping off the ceramic layer (26). A systematic review revealed that the chipping of porcelain fused to zirconia was statistically higher than that of porcelain fused to metal in fixed partial dentures (32). On the other hand Maha Fouad, in her marginal adaptation study, found that feather-edge finishing line with super translucent multilayered zirconia crowns (Katana Kurary, Noritake Japan) showed better marginal adaptation than zirconia-reinforced lithium silicate ceramic crowns (Celtra Duo, Dentsply Sirona) (22).

The inner surfaces of all zirconia crowns underwent sandblasting to enhance mechanical interlocking between the fitting surface and the light body silicon material. In the pilot study, it was found sandblasting the fitting surface of zirconia to be beneficial in preventing silicon deformation when the crown is taken off from the abutment.

There are many methods for marginal gap measurement (Direct optical microscopy, Cross-section of cemented crowns, Impression replica technique, Scanning electron microscopy, Optical coherence tomography, and dye penetration) (33); one of the most popular approaches is the impression replica technique since it is simple, non-destructive, inexpensive, and reliable (15–18). Additionally, Wu et al.(34), in their study found a positive correlation between the impression replica technique and optical coherence tomography.

In the current study, the mean values of the marginal gap measurements in all groups were within the clinically acceptable range despite the highly statistically significant differences. It is worth mentioning, to the authors' knowledge, no previous studies are available yet in the literature regarding modifying monolithic zirconia crowns' cement space setting for shoulderless finishing line with an inverted cement space setting; Hence, it was not feasible to directly compare the results obtained in the current study with those of other studies.

The study's findings indicate that the crowns constructed for a shoulderless finishing line in groups A and B, regardless of the cement space setting, demonstrated a significantly smaller marginal gap than the crowns of group C with a chamfer finishing line. These findings support Comlekoglu et al.(20) finding that zirconia copings with feather-edge offered reduced absolute marginal discrepancy and marginal opening than chamfers.

Several factors contribute to this outcome; firstly, thicker restoration margins of zirconia restorations were thought to be more susceptible to creep and deformation during sintering than thinner restoration margins (20,27). Furthermore, the chamfer's curved marginal geometry might make machining the crown restoration more complicated in CAD/CAM and reduce the marginal fit (35). Moreover, the constrained size and form of the milling bur are other reasons for the subtractive milling process restriction. Therefore, concave shapes with small details might not be milled accurately (36).

Nemane et al. (11), in their in vitro study, tested six different finishing lines (90-degree shoulder, Rounded shoulder, 45-degree sloped shoulder, Chamfer, Long chamfer, and Feather edge) regarding marginal seal and occlusal seat, using full cast metal crowns with stainless steel metal dies, they found the shoulder margin provided a poor seal which allowed good occlusal seating, whereas the feather edge margin sealed earlier and did not allow the cement to escape and hence did not seat completely.

According to Eldamaty et al. (37), Monolithic zirconia crowns with chamfer and knife edge finishing lines did not significantly differ in marginal accuracy, which disagrees with the current study's finding; this discrepancy could be due to the placement of flat occlusal surfaces on their metal abutment copies.

El Eneen et al. (38) disagreed with the current study, showing a non-significant difference in the marginal fit of zirconium-reinforced lithium silicate (Vita Suprinity) crowns with chamfer and feather edge margins. This could be explained by the different mechanical properties of the tested materials in the two studies.

Cetik et al. (39) discovered a comparable internal and marginal adaptation with the chamfer and knife-edge finishing lines in

their scanning electron microscopy analysis while having superior adaptation than the shoulder margin.
The reason for modifying the monolithic zirconia crowns cement space setting with inverted cement space for the shoulderless finishing line was to create more space in the marginal area for accessory cement to escape and to prevent early marginal seal, which might result in more cement accumulation at the occlusal surface (11,12). The findings of the current study indicate that in group B, the marginal gap measurements were statistically larger than those in group A. This discrepancy may result in increased available space within the marginal area, potentially facilitating the escape of excess cement for crowns fabricated for the shoulderless finishing line. On the other hand, group B still had a smaller marginal gap compared to group C with the chamfer finishing line and crowns with 0 µm marginal cement space setting. However, the few numbers of marginal gap measurement points in this study should be considered when evaluating the findings concerning clinical acceptability.

Conclusions

Within the limitations of this *in vitro* study, the following conclusions could be drawn; the marginal gap for the crowns in all groups was within the clinically acceptable range. The crowns for both shoulderless finishing line groups regardless of cement space setting showed statistically better marginal fit than those of the chamfer finishing line group. The crowns of the modified cement space setting with inverted cement space for shoulderless preparation had a statistically larger marginal gap than those without this setting.

Acknowledgments
The authors express their sincere gratitude to Dr. Pasquale Venuti, for all his support.

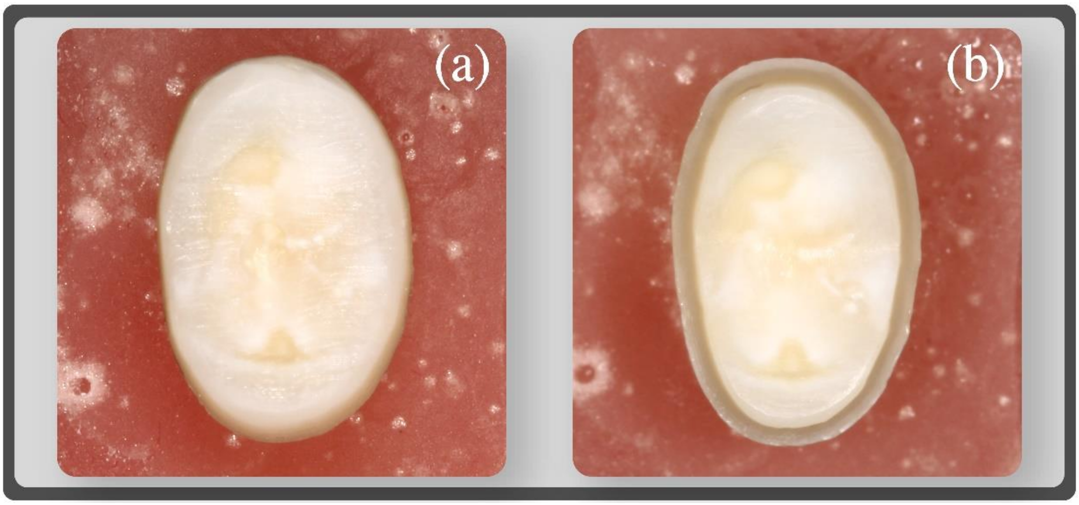


Figure (1): Both preparation designs on the same sample tooth: (a) shoulderless preparation, (b) chamfer preparation

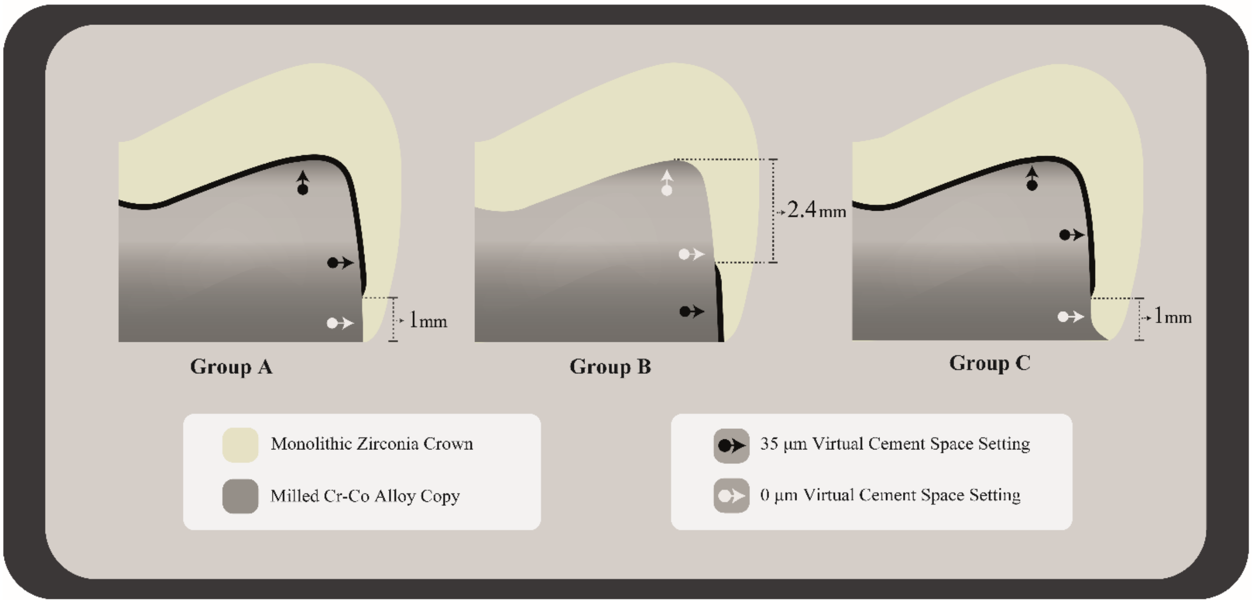
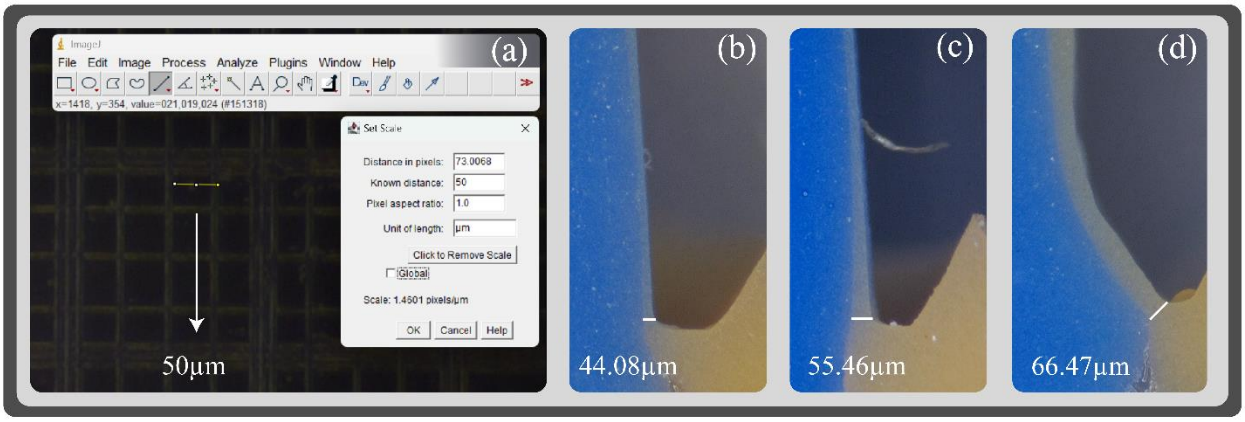


Figure (2): Illustration of the study groups: group A: shoulderless preparation and crowns with (0 µm marginal and 35 µm occlusal-axial) cement space setting; group B: shoulderless preparation and crowns with inverted cement space setting (0 µm occlusal to the 2.4 mm axial and 35 µm marginal); group C: chamfer preparation and crowns with (0 µm marginal and 35 µm occlusal-axial) cement space setting.



Average measurement of the marginal gap in group A, (c) Average measurement of the marginal gap in group B, (d) Average measurement of the marginal gap in group C.

Table 1 Descriptive statistics

Groups	N	Minimum	Maximum	Mean	Std. Deviation
A	15	38.93	50.04	44.0831	3.15493
B	15	45.38	61.75	55.4676	4.53124
C	15	59.09	76.58	66.4788	5.52321

Abbreviations, N: Number of samples, Std. deviation: standard deviation

Table 2 One-way ANOVA for comparison among the three groups

ANOVA	Sum of squares	df	Mean square	F	Sig.
Between groups	3762.115	2	1881.058	92.524	0.001
Within groups	853.883	42	20.331		
total	4615.998	44			

Abbreviations, df: degree of freedom, F: variation between sample means, Sig.: significance level

Table 3 Bonferroni test to compare across the three groups

Variance (I)	Variance (J)	Mean difference (I-J)	Std. error	Sig.
A	**B**	11.38455	1.64643	0.001
	C	22.39573	1.64643	0.001
B	**C**	11.01118	1.64643	0.001

Abbreviations, Std. error: standard error, Sig.: significance level

References

1. Alfaro DP, Ruse ND, Carvalho RM, Wyatt CC. Assessment of the internal fit of lithium disilicate crowns using micro-CT. J Prosthodont. 2015;24(5):381–6.
2. Ramos R M, Mazza, M., Venuti, P., Maiolino, M., Kopanja, S., Cirimpei, V., et al. The shoulderless approach: a new rationale in prosthetic dentistry. TT Journal. 2017;1:1–29.
3. Łabno P, Drobnik K. Comparison of horizontal and vertical methods of tooth preparation for a prosthetic crown. J Pre-Clin Clin Res. 2020;14(1):25–8.
4. Hussien IM, Ibraheem AF. The Effect of Different Marginal Cement Space Thickness on the Fracture Strength of Monolithic Zirconia Crowns Using Different Luting Agents. J res med dent sci. 2022;10(4):48–52.
5. Mule SA, Dange SP, Khalikar AN, Vaidya SP. Effect of varying layers of two die spacers on Precementation space of full coverage restorations. J Indian Prosthodont Soc. 2014;14:67–75.
6. 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.
7. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthet Dent. 1989;62(4):405–8.
8. Karatasli Ö, Kursoglu P, Capa N, Kazazoglu E. Comparison of the marginal fit of different coping materials and designs produced by computer aided manufacturing systems. Dent Mater J. 2011;30(1):97–102.
9. 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.
10. Contrepois M, Soenen A, Bartala M, Laviole O. Marginal adaptation of ceramic crowns: A systematic review. J Prosthet Dent. 2013;110(6):447-54.
11. Nemane V, Akulwar RS, Meshram S. The Effect of Various Finish Line Configurations on the Marginal Seal and Occlusal Discrepancy of Cast Full Crowns After Cementation - An In-vitro Study. J Clin Diagn Res. 2015;9(8):18–21.
12. Gavelis JR, Morency JD, Riley ED, Sozio RB. The effect of various finish line preparations on the marginal seal and occlusal seat of full crown preparations. J Prosthet Dent. 2004;92(1):1–7.
13. Pilo R, Cardash HS, Baharav H, Helft M. Incomplete seating of cemented crowns: A literature review. J Prosthet Dent. 1988;59(4):429–33.
14. Hammond ED, Ibraheem AF. Evaluate and compare the effect of different marginal cement space parameter setting in the CAD software on the marginal and internal fitness of monolithic zirconia crowns with different types of luting agents (a comparative in vitro study). J res med dent sci. 2020;8(1):74–80.
15. Abdelhafiz SH, Abdelkader SH, Azer A. Marginal and internal fit evaluation of metal copings

fabricated by selective laser sintering and CAD/CAM milling techniques: in-vitro study. Alex dent j. 2022;47(2):134–9.
16. Sharma A, Abraham D, Gupita A, Singh A, Sharma N. Comparative evaluation of the marginal fit of inlays fabricated by conventional and digital impression techniques: A stereomicroscopic study. Contemp Clin Dent. 2020;11(3):237–44.
17. Yadav P, Sharma V, Paliwal J, Meena KK, Madaan R, Gurjar B. An In Vitro Comparison of Zirconia and Hybrid Ceramic Crowns with Heavy Chamfer and Shoulder Finish Lines. Cureus. 2023;15(1):1–9.
18. Savencu CE, Șerban C, Porojan L. Adaptability evaluation of metal-ceramic crowns obtained by additive and subtractive technologies. Appl Sci. 2020;10(16):1–14.
19. Xu D, Xiang N, Wei B. The marginal fit of selective laser melting–fabricated metal crowns: An in vitro study. J Prosthet Dent. 2014;112(6):1437–40.
20. Comlekoglu M, Dundar M, Özcan M, Gungor M, Gokce B, Artunc C. Influence of Cervical Finish Line Type on the Marginal Adaptation of Zirconia Ceramic Crowns. Oper Dent. 2009;34(5):586–92.
21. Almahdy RM, Mandour MH, El Sharkawy ZR. Marginal accuracy of monolithic zirconia crowns with vertical and horizontal margin configurations after thermomechanical fatigue. Al-Azhar dent j girls. 2022;9(1):55–60.
22. Fouad M. Marginal adaptation related to margin design of CAD/CAM ceramic crowns. Egypt Dent J. 2023;69(1):447–55.
23. Abdulazeez MI, Majeed MA. Fracture Strength of Monolithic Zirconia Crowns with Modified Vertical Preparation: A Comparative In Vitro Study. Eur J Dent. 2022;16(1):209–14.
24. Boening KW, Wolf BH, Schmidt AE, Kästner K, Walter MH. Clinical fit of Procera AllCeram crowns. J Prosthet Dent. 2000;84(4):419–24.
25. Cunali RS, Saab RC, Correr GM, Cunha LF da, 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.
26. Mitov G, Anastassova-Yoshida Y, Nothdurft FP, Von See C, Pospiech P. Influence of the preparation design and artificial aging on the fracture resistance of monolithic zirconia crowns. J Adv Prosthodont. 2016;8(1):30–6.
27. Ahmed WM, Abdallah MN, McCullagh AP, Wyatt CC, Troczynski T, Carvalho RM. Marginal discrepancies of monolithic zirconia crowns: The influence of preparation designs and sintering techniques. J Prosthodont. 2019;28(3):288–98.
28. Riccitiello F, Amato M, Leone R, Spagnuolo G, Sorrentino R. In vitro evaluation of the marginal fit and internal adaptation of zirconia and lithium disilicate single crowns: micro-CT comparison between different manufacturing procedures. Open Dent J. 2018;12:160–72.
29. Dahl BE, Dahl JE, Rønold HJ. Digital evaluation of marginal and internal fit of single-crown fixed dental prostheses. Eur J Oral Sci. 2018;126(6):512–7.
30. Jasim HH, Findakly MB, Mahdi NA, Mutar MT. Effect of reduced occlusal thickness with two margin designs on fracture resistance of monolithic zirconia crowns. Eur J Dent. 2020;14(02):245–9.
31. Ozer F, Naden A, Turp V, Mante F, Sen D, Blatz MB. Effect of thickness and surface modifications on flexural strength of monolithic zirconia. J Prosthet Dent. 2018;119(6):987–93.
32. Heintze SD, Rousson V. Survival of zirconia-and metal-supported fixed dental prostheses: a systematic review. Int j prosthodont. 2010;23(6):493–502.
33. Memari Y, Mohajerfar M, Armin A, Kamalian F, Rezayani V, Beyabanaki E. Marginal adaptation of CAD/CAM all-ceramic crowns made by different impression methods: A literature review. J Prosthodont. 2019;28(2):536–44.
34. Wu J, Xie H, Sadr A, Chung KH. Evaluation of internal fit and marginal adaptation of provisional crowns fabricated with three different techniques. Sensors. 2021;21(3):1–15.
35. Atlas A, Isleem W, Bergler M, Fraiman HP, Walter R, Lawson ND. Factors Affecting the Marginal Fit of CAD-CAM Restorations and Concepts to Improve Outcomes. Curr Oral Health Rep. 2019;6:277–83.
36. Li R, Chen H, Wang Y, Zhou Y, Shen Z, Sun Y. Three-dimensional trueness and margin quality of monolithic zirconia restorations fabricated by additive 3D gel deposition. J Prosthodont Res. 2020;64(4):478–84.
37. Eldamaty M, Abdel-Aziz M, El-Kouedi A, Hamza T. Effect of finish line design and cement space thickness on the marginal accuracy of monolithic zirconia crowns. Braz Dent Sci. 2020;23(3):1–8.
38. El Eneen MA, El-Naggar G, Taymour M. Marginal accuracy of zirconium reinforced lithium silicate (Vita Suprinity) crowns with two marginal designs before and after cementation under thermo mechanical cycling. Int J Appl Dent Sci. 2019;5(4):382–90.
39. 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):208–16.