ORIGINAL RESEARCH

Internal Fit and Marginal Adaptation of Posterior CAD/CAM Crowns Fabricated from Fully Crystallized Lithium Disilicate Compared to Partially Crystallized Lithium Disilicate with Two Finish Line Thicknesses: An *In Vitro* Study

Menna ElGendy[1], Rana Sherif[2], Karim Rabie[3]

Received on: 30 August 2024; *Accepted on*: 25 October 2024: *Published on*: 26 November 2024

Abstract

Aim: This study aimed to evaluate internal fit and marginal adaptation of posterior CAD/CAM crowns fabricated from partially crystallized lithium disilicate and fully crystallized lithium disilicate with two finish line thicknesses (0.5 mm chamfer and 1 mm round shoulder).

Methodology: In this *in vitro* study, 20 sound extracted human molar teeth were collected. The teeth were prepared using a dental surveyor. Teeth were divided into main groups: Group I partially crystallized e.max CAD (Em) and Group II fully crystallized Initial LiSi (Li). Each group was subdivided according to finish line thicknesses into 0.5 mm chamfer and 1 mm round shoulder finish lines. All samples were tested for internal fit by triple scanning technique and the marginal adaptation was measured by stereomicroscope before cementation.

Results: The results showed that the finish line thicknesses (0.5 mm chamfer,1 mm round shoulder) had no statistically significant effect on mean internal fit ($p = 0.954$). Ceramic types: Em and Li had no statistically significant effect on mean internal fit ($p = 0.902$). Regarding the marginal adaptation, Em showed statistically significantly higher mean marginal gap distance than Li ($p < 0.001$).

Conclusion: The finish line thicknesses did not affect the internal fit or marginal adaptation values. Ceramic types did not affect the internal fit values. The marginal adaptation of Em was lower than Li.

Clinical significance: GC Initial Lisi produced comparable results to the gold standard IPS e.max CAD, thus it can be used due to its clinically acceptable internal fit and marginal adaptation.

Keywords: Finish line, Internal fit, Lithium disilicate, Marginal adaptation.

The Journal of Contemporary Dental Practice (2024): 10.5005/jp-journals-10024-3744

Introduction

Ceramic restorations have been developed, offering benefits such as biocompatibility, color stability, enhanced wear resistance, low thermal conductivity, and excellent light transmission. Along with esthetic and mechanical properties, achieving proper internal fit and marginal adaptation are essential for clinical success.[1,2] Glass-based materials are non-metallic inorganic ceramic materials that contain a glassy phase.[3] Lithium disilicate ceramic is categorized under this group. IPS e.max CAD is a lithium disilicate available in a partially crystallized block which will need additional crystallization step after milling. Its long-term success is attributed to its improved esthetics and enhanced physical characteristics with flexural strength ranging from 370 to 460 MPa, making it highly approved for both anterior and posterior restorations.[4]

Recently, numerous brands have been engaged in the development of lithium disilicate ceramics. The new GC Initial LiSi Block is a fully crystallized lithium disilicate block that delivers optimum physical properties without any need for firing. This block features GC's exclusive high-density micronization (HDM) technology for CAD/CAM dentistry, which provides exceptional durability, precise margins, and esthetically pleasing outcomes. This feature makes it a perfect and efficient choice for chairside treatments that may be completed in a single visit.[5,6]

Internal fit and marginal adaptation are crucial factors that are used to assess the clinical acceptability of permanent restorations and their long-term success throughout future evaluations.[7] Quantitative criteria for the highest permissible gaps at the tooth-restoration interface are not well-established. However, Mclean and Von Fraunhofer suggest that from 100 to 120 µm for crowns is generally deemed clinically acceptable.[8,9]

Several studies have examined various factors that may influence the precision of ceramic crowns, such as material properties,

[1]Department of Fixed Prosthodontics, Faculty of Dentistry, Cairo University; Department of Fixed Prosthodontics, Faculty of Oral and Dental Medicine, Egyptian Russian University, Cairo, Egypt

[2,3]Department of Fixed Prosthodontics, Cairo University, Cairo, Egypt

Corresponding Author: Menna ElGendy, Department of Fixed Prosthodontics, Faculty of Dentistry, Cairo University; Department of Fixed Prosthodontics, Faculty of Oral and Dental Medicine, Egyptian Russian University, Cairo, Egypt, Phone: +0021093302027, e-mail: mennaelgendy@dentistry.cu.edu.eg

How to cite this article: ElGendy M, Sherif R, Rabie K. Internal Fit and Marginal Adaptation of Posterior CAD/CAM Crowns Fabricated from Fully Crystallized Lithium Disilicate Compared to Partially Crystallized Lithium Disilicate with Two Finish Line Thicknesses: An *In Vitro* Study. J Contemp Dent Pract 2024;25(8):740–744.

Source of support: Nil

Conflict of interest: None

the measurement techniques adopted, and modifications in the preparation design.[10–13] Fully crystallized lithium disilicate “GC Initial LiSi” has been recently introduced with claims that it delivers optimal physical and esthetic properties without the need for additional firing step. Nevertheless, there is currently no definitive information about its impact on the accuracy of the fit. Accordingly, more studies are needed to discover the biomechanical behavior of this new material when used as crowns.

The first null hypothesis of this study: There will be no differences in internal fit between partially crystallized lithium disilicate and fully crystallized lithium disilicate with two finish line thicknesses (0.5 mm chamfer, 1 mm round shoulder). The second null hypothesis: There will be no differences in marginal adaptation between partially crystallized lithium disilicate and fully crystallized lithium disilicate with two finish line thicknesses (0.5 mm chamfer, 1 mm round shoulder).

Materials and Methods

Study Design

This *in vitro* study was conducted at the Department of Prosthodontics, Cairo University from December 2023 till August 2024, after receiving approval from the Institutional Ethics Committee of Cairo University, number 1102022.

Sample Size Calculation

The power analysis is for 2 × 2 factorial design using an internal gap as the primary outcome. The first factor is the material types, and the second factor is the finish line thicknesses. Based upon the results of Baig et al.,[10] the effect sizes (f) were 8.39 and 4.59 for the two factors, respectively. Using alpha (α) level of (5%) and Beta (β) level of (20%) i.e., power = 80%; the minimum estimated sample size was 5 specimens per subgroup. Sample size calculation was performed using IBM® SPSS® SamplePower® Release 3.0.1. (Corporation, NY, USA.)

Sample Grouping

Group I is partially crystallized lithium disilicate (IPS e.max CAD, Ivoclar Vivadent, Liechtenstein, Germany) crowns ($n = 10$). Group II is fully crystallized lithium disilicate (Initial LiSi, GC, Tokyo, Japan) crowns ($n = 10$). Each group was subdivided into two subgroups, five samples according to the finish line thicknesses as follows:

- Subgroup I: Crowns with 0.5 mm chamfer finish line ($n = 5$).
- Subgroup II: Crowns with 1 mm round shoulder finish line. ($n = 5$)

Teeth Preparation

This *in vitro* study collected 20 sound extracted human first molar teeth free of caries, cracks, and fractures. Each tooth was immersed into epoxy resin block to a level of 2 mm below cementoenamel junction (CEJ) for proper margin visualization assessment. For standardization of teeth during preparation, a diamond stone mounted onto a dental surveyor (Paraskop M surveyor, BEGO) was used. The occlusal surface was made flat for all teeth.[14] Ten teeth were prepared with 0.5 mm circumferential chamfer finish line using diamond stone on a straight hand piece (850 018 SC HP, okoDENT GmbH & Co), while the other 10 teeth were prepared for a 1 mm circumferential round shoulder finish line using diamond (850 023 SC HP, okoDENT GmbH & Co) with 6° taper per wall.

Computer-aided Designing/Computer-aided Manufacturing (CAD/CAM)

Samples were digitized using the desktop scanner (Sirona InEos x5, Dentsply Sirona, Germany). The crown design was selected from the built-in tooth library in exocad (exocad Dental CAD2.2 software, Valletta, Germany) with a thickness of 2 mm occlusally, 1 mm axially, and 0.5 mm/1 mm at the margin. The milling was done using (VHF S1 5 axis, vhf camfacture AG, Ammerbuch, Germany) following the manufacture’s instructions. Since GC Initial Lisi is fully crystallized thus, crystallization was carried out for IPS e.max CAD only. The crystallization took place in Programat EP 3010 calibrated ceramic furnace under vacuum following the manufacturer’s instructions. For surface finishing a (DIAPRO HP finishing and polishing kit, EVE, Keltern, Germany) was used sequentially following the manufacturer’s recommendations. Glazing was carried out for both groups using Noritake FC paste glaze (Kuraray Noritake Dental, Japan) in the programat EP 3010 furnace (Ivoclar Vivadent AG, Schaan Liechtenstein, Germany) according to manufacturing instructions.

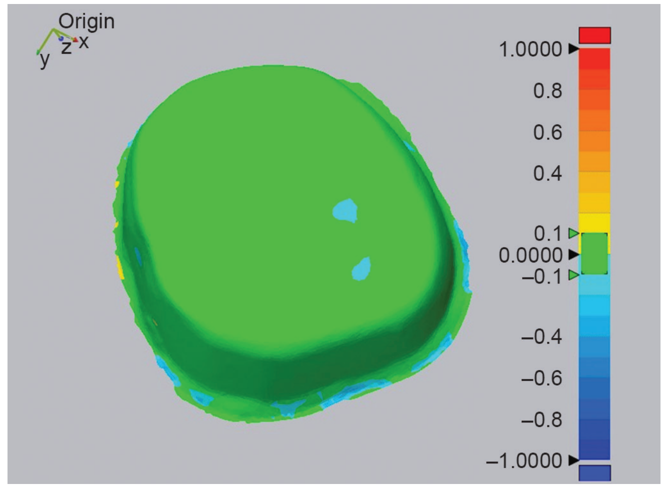

Fig. 1: Representing the internal fit of the crown in color map where blue color represents space and green color represents perfect adaptation

Internal Fit Measurements (Primary Outcome)

A triple scanning technique was used to measure the internal fit of the crowns.[13] The digitalization of the samples was conducted by using intraoral scanner (Medit i500, Medit, Seoul, South Korea). Three scans were obtained: The first scan was taken for the prepared abutments; the second scan for the crown’s internal and external surfaces; and the third scan was for the adapted crown over the prepared tooth abutment (combined scan). The STL files were imported into 3D inspection and metrology software (Geomagic control X2022 1.0). The two STL files representing the separate crown, and the separate tooth abutment were superimposed on the third STL file representing the crown fully seated on the tooth abutment using the initial alignment software tool followed by best-fit alignment. The STL file representing the crown fully seated on the tooth abutment was then deleted, leaving the other two STL files duplicating the relation between the crown and the tooth abutment. The STL file representing the tooth abutment was set as a reference for the upcoming comparisons.

The qualitative data of internal fit was represented using a color map of green, yellow, red, and blue colors, where green colors represent zero deviation, and blue, yellow, and red colors represent deviation values. Blue and dark blue colors represent space between the crown and the prepared abutment while orange to red colors represents pressure area between the crown and the prepared abutment as in Figure 1.

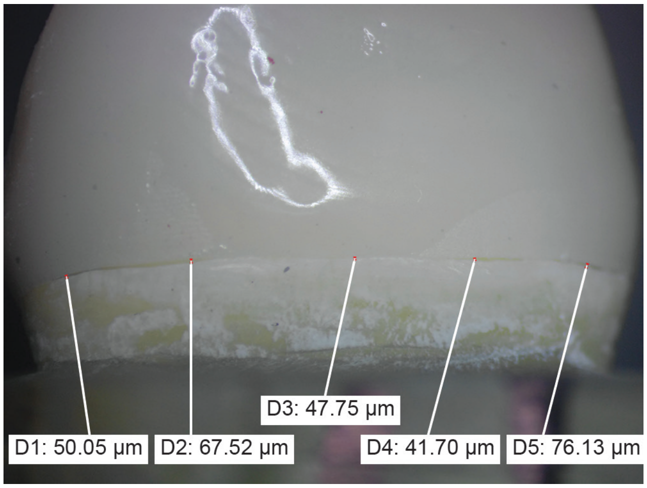

Fig. 2: Points located at the midline, line angles, and a midpoint in between the midline and each line angle

Marginal Adaptation Measurements (Secondary Outcome)

Marginal adaptation was carried out before and after cementation using a stereomicroscope (Nikon SMZ745T, Nikon Europe B.V). The software (Omnimet image analysis software, Buehler, USA) measured and evaluated the marginal adaptation between the outer extremities of the preparation finish line and the restoration's margin. Five predetermined equally distributed points were taken at each axial surface. The points were located at the midline, line angles, and a midpoint between the midline and each line angle. This was done using the grid feature in the software where a total of 20 points were recorded per crown[15] as in Figure 2.

Statistical Analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov–Smirnov and Shapiro–Wilk tests). Marginal gap distance data showed normal (parametric) distribution. Data were presented as mean and standard deviation (SD) values. Two-way analysis of variance (ANOVA) was used to study the effect of finish line thickness, ceramic type, and their interactions on mean gap distance. Repeated measures ANOVA was used to study the effect of finish line thickness and ceramic type and their interactions on mean marginal gap distance. Bonferroni's *posthoc* test was used for pair-wise comparisons when ANOVA test was significant. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Results

Internal Fit Results (Root Mean Square)

The results showed that the finish line thicknesses regardless of the ceramic types had no statistically significant effect on mean internal fit. The ceramic types regardless of finish line thicknesses had no statistically significant effect on mean internal fit as shown in Table 1.

Table 1: The mean, standard deviation (SD) values, and results of the two-way ANOVA test for comparison between internal fit (RMS) with different interactions of variables

Ceramic type	*0.5 mm*		*1 mm*		*p-value*	*Effect size*
	Mean	*±SD*	*Mean*	*±SD*		
Em	0.0868	0.0266	0.1287	0.0211	0.083	0.176
Li	0.1297	0.0453	0.0897	0.044	0.097	0.163
p-value	0.076		0.105			
Effect size *(Partial Eta Squared)*	0.183		0.156			

*Significant at $p \leq 0.05$

Table 2: The mean, standard deviation (±SD) values, and results of repeated measures ANOVA test for comparison between marginal gap distances (µm) of the finish line thicknesses regardless of ceramic types

0.5 mm		*1 mm*			
Mean	*±SD*	*Mean*	*±SD*	*p-value*	*Effect size*
89.4	27.1	80.9	26.7	0.091	0.169

*Significant at $p \leq 0.05$

Table 3: The mean, standard deviation (±SD) values, and results of repeated measures ANOVA test for comparison between marginal gap distances (µm) of the two ceramic types regardless of finish line thicknesses

Em		*Li*			
Mean	*±SD*	*Mean*	*±SD*	*p-value*	*Effect size (partial Eta squared)*
96	29.6	74.3	19.1	<0.001*	0.571

*Significant at $p \leq 0.05$

Marginal Adaptation Results in µm

The finish line thicknesses had no statistically significant effect on the mean marginal gap distance. (*p*-value = 0.091, Effect size = 0.169) as shown in Table 2.

The ceramic types had a statistically significant effect on the mean marginal gap distance. (*p*-value < 0.001, Effect size = 0.571) as shown in Table 3. IPS e.max CAD showed a statistically significantly higher mean marginal gap distance than GC Initial Lisi.

Comparison between the finish line thicknesses and the two ceramic types. There was no statistically significant difference between the two finish line thicknesses (*p*-value = 0.059, Effect size = 0.206) and (*p*-value = 0.456, Effect size = 0.035), respectively. With 0.5 mm finish line thickness, IPS e.max showed statistically significantly higher mean marginal gap distance than LiSi (*p*-value = 0.009, Effect size = 0.355). While with 1 mm thickness, there was no statistically significant difference between the two ceramic types (*p*-value = 0.872, Effect size = 0.002) as shown in Table 4.

Discussion

The increase in esthetic demands nowadays has led to improvements in both dental techniques and materials.[16] Ceramic materials are used in various dental applications and are characterized by their favorable mechanical properties, esthetics, and biocompatibility.[17] In the present study, IPS e.max CAD was selected. It is partially crystallized lithium disilicate ceramic, a highly esthetic dental

Table 4: The mean, standard deviation (±SD) values, and results of repeated measures ANOVA test for comparison between marginal gap distances (μm) of the two finish line thicknesses with different interactions of variables

Ceramic type	*0.5 mm*		*1 mm*			
	Mean	*±SD*	*Mean*	*±SD*	*p-value*	*Effect size*
Em	87.8	16.5	66.7	21.7	0.059	0.206
Li	57	5.6	65	17.4	0.456	0.035
p-value	0.009*		0.872			
Effect size *(Partial Eta Squared)*	0.355		0.002			

*Significant at $p \leq 0.05$

restorative material that has unbeatable nature-mimicking esthetics and clinically satisfactory strength. Moreover, studies have proved that it has a superior fit and thus can be used for long-term successful restorations.[3]

GC Initial LiSi was chosen in the present study. It is a newly developed ceramic material composed of fully crystallized lithium disilicate. It contains 10–30% lithium silicate and 5–20% additional oxides. It is based on the proven HDM technology (High Density Micronization). Its ultrafine crystals simplify the milling of the ceramic in a fully crystallized phase. Moreover, it does not require a crystallization step therefore, less time is needed, and can be delivered on the same visit.[5,6]

The internal fit and marginal adaptation are crucial factors for the long-term viability of a restoration, considering both biological and mechanical perspectives. Poor marginal fit can lead to several potential outcomes, including cement dissolution, marginal discoloration, microleakage, hypersensitivity, increased plaque retention, and secondary caries.[18]

McLean and von Fraunhofer concluded that the marginal gap should ideally fall within the range of 100–120 μm to be considered clinically acceptable.[8]

Internal Fit Results

All the internal fit results fell within the accepted range, which is from 50 to 100 μm. The results showed that the finish line thicknesses did not have a significant impact on the precision of fit for partially crystallized IPS e.max CAD and fully crystallized GC Initial Lisi crowns. This could be attributed to the cement space which allowed proper adaptation of the crown.[19–21] These results are consistent with several other studies that also found no significant differences between the two margin configurations, shoulder and chamfer finish lines concerning internal fit.[10,22]

There was no statistically significant difference between the mean internal fit of the two ceramic types. These results could be attributed to the similarity between the two materials' microstructures. For partially crystallized lithium disilicate IPS e.max CAD made of 60% lithium disilicate, while fully crystallized GC Initial Lisi consists of 55–80% silicon dioxide (SiO2), and 10–30% lithium oxide (Li2O).[6] Based on the previous findings, the first null hypothesis was accepted.

Marginal Adaptation Results

The mean marginal gap distance in the present study for 0.5 mm and 1 mm finish line thicknesses; were below the reference value (120 μm), which was considered as a clinically acceptable threshold for ceramic crowns.[8] These findings were in agreement with a previous study, which found that neither the finish line thicknesses of chamfer 0.5 nor round shoulder 1 mm affect the marginal gap distance.[23] However, the results for the present study disagreed with a previous study that found that 0.2 feather edge margins showed superior margin adaptation to those fabricated with 1 mm deep chamfer margins, they attributed their findings to the feather margin configuration where it forms an acute angle with the tooth providing a shorter distance between the tooth and restoration.[11] IPS e.max CAD showed a statistically significantly higher mean marginal gap distance than GC Initial LiSi. These results could be attributed to crystallization shrinkage of IPS e.max CAD as GC Initial Lisi being fully crystallized, it does not require additional crystallization step. This phenomenon can be described due to the presence of lithium metasilicate (partially crystallized) material before crystallization, with particle sizes ranging from 0.2 m to 1 μm. Upon crystallization, the particle size increases to 5 μm with 0.2% linear contraction, and this alteration has the potential to increase the marginal gap distance.[24] These findings come in agreement with a previous study that found that crystallization firing can result in a significant increase in the marginal gap distance of CAD/CAM lithium disilicate crowns.[25] Based on the previous findings, the second null hypothesis was rejected.

However, this significant difference was found in 0.5 mm finish line thickness; e.max showed statistically significantly higher mean marginal gap distance than LiSi. This could be attributed to the brittleness index which measures the material's relative sensitivity to deform and fracture and is claimed to be directly connected to dental ceramic machinability which ranges from 3 to 9 $\mu m^{-1/2}$ and the tendency for edge chipping damage which is increased when used in thin sections (0.5 mm). This behavior is considered a consequence of reducing the amorphous phase and increasing the number of elongated lithium disilicate crystals in the material.[26]

Limitations

The Limitations of This Study Include

- While *in vitro* experiments are useful for exploring fundamental dental processes and assessing material properties under controlled conditions, they do not fully replicate the complexities of the oral environment.
- The need for dynamic interactions and mechanical stresses such as thermocycling and fatigue to simulate the oral conditions.
- Being *in vitro* may not assess the long-term effects or biological variability in human subjects.
- The study focused on specific finish line thicknesses and designs, which may not encompass the full range of clinical scenarios encountered in dental practice.
- Limited number of ceramic materials used in this study will not capture the diverse properties and performance characteristics of other ceramic options available in the market.

Conclusion

Within the limitations of this study, the following can be concluded:

- The finish line thickness whether 0.5 chamfer or 1 mm round shoulder did not affect the internal fit or marginal adaptation.
- The use of partially crystallized or fully crystallized lithium disilicate did not affect the internal fit values.

- Marginal adaptation of IPS e.max CAD is lower than GC Initial Lisi; however, it is considered clinically acceptable ≤120 µm.

Clinical Recommendations and Implications

GC Initial Lisi produced comparable results to the gold standard IPS e.max CAD, thus it can be used due to its clinically acceptable internal fit and marginal adaptation. Moreover, long-term clinical trials are an important addition before any material or technique can be safely recommended for clinical practice.

Orcid

Menna ElGendy https://orcid.org/0009-0006-0581-9754
Rana Sherif https://orcid.org/0000-0003-3033-4100
Karim Rabie https://orcid.org/0000-0001-9179-0543

References

1. Saleh O, Amin R, Abdellatif M. Effect of different pattern construction techniques on the marginal adaptation, internal fit and fracture resistance of Ips-emax press crowns. Egyptian Dental Journal 2016;62(1):1141–1152. DOI: 10.21608/edj.2016.95432.
2. Li RW, Chow TW, Matinlinna JP. Ceramic dental biomaterials and CAD/CAM technology: State of the art. Journal of prosthodontic research 2014;58(4):208–216. DOI: 10.1016/j.jpor.2014.07.003.
3. Gracis S, Thompson V, Ferencz J, et al. A new classification system for all-ceramic and ceramic-like restorative materials. Int J Prosthodont 2016;28(3):227–235. DOI: 10.11607/ijp.4244.
4. Zarone F, Di Mauro MI, Ausiello P, et al. Current status on lithium disilicate and zirconia: A narrative review. BMC Oral Health 2019;19:1–4. DOI: 10.1186/s12903-019-0838-x.
5. Phark JH, Duarte Jr S. Microstructural considerations for novel lithium disilicate glass ceramics: A review. J Esthet Restor Dent 2022;34(1):92–103. PMID: 34995008.
6. Jurado CA, Yeh JS, Vidal CM, et al. Fracture load of chairside CAD-CAM veneers fabricated with pre-and fully crystalized lithium disilicate ceramics. J Prosthodont 2024. DOI: 10.1111/jopr.13867.
7. Sadid-Zadeh R, Li R, Miller LM, Simon M. Effect of fabrication technique on the marginal discrepancy and resistance of lithium disilicate crowns: An in vitro study. J Prosthodont 2019;28(9):1005–1010. DOI: 10.1111/jopr.13014.
8. McLean JW, Von F. The estimation of cement film thickness by an in vivo technique. Br Dent J 1971;131(3):107–111. DOI: 10.1038/sj.bdj.4802708.
9. Nawafleh N, Hatamleh M, Janzeer Y, et al. Marginal discrepancy of five contemporary dental ceramics for anterior restorations. Eur J Dent 2023;29;17(4):1114–1149. DOI: 10.1055/s-0042-1758787.
10. Baig MR, Akbar AA, Embaireeg M. Effect of finish line design on the fit accuracy of CAD/CAM monolithic polymer-infiltrated ceramic-network fixed dental prostheses: An in vitro study. Polymers (Basel) 2021;13(24). DOI: 10.3390/polym13244311.
11. Nassar H, Abo El-Mal E. In Vitro evaluation of the marginal adaptation of monolithic ceramic crowns fabricated with different margin designs using novel CAD/CAM material after thermomechanical aging. Egypt Dent J 2024;70(1):575–585. DOI: 10.21608/edj.2023.256264.2830.
12. Son K, Lee S, Kang SH, et al. A comparison study of marginal and internal fit assessment methods for fixed dental prostheses. J Clin Med 2019;8(6). DOI: 10.3390/jcm8060785.
13. Li R, Chen H, Wang Y, et al. Suitability of the triple-scan method with a dental laboratory scanner to assess the 3D adaptation of zirconia crowns. The J Prosthet Dent 2021;125(4):651–666. DOI: 10.1016/j.prosdent.2020.02.010.
14. Nabil O, Halim CH, Mokhtar AH. Fracture resistance and 3D finite element analysis of machined ceramic crowns bonded to endodontically treated molars with two planes versus flat occlusal preparation designs: An in vitro study. F1000Research 2021;8:1020. DOI: 10.12688/f1000research.19455.2.
15. Groten M, Axmann D, Pröbster L, et al. Determination of the minimum number of marginal gap measurements required for practical in vitro testing. J Prosthet Denti 2000;83(1):40–49. DOI: 10.1016/s0022-3913(00)70087-4.
16. Alikhasi M, Yousefi P, Afrashtehfar KI. Smile design: Mechanical considerations. Dental Clinics 2022;66(3):477–487. DOI: 10.1016/j.cden.2022.02.008.
17. Brandt S, Winter A, Lauer HC, et al. IPS e. max for all-ceramic restorations: clinical survival and success rates of full-coverage crowns and fixed partial dentures. Materials 2019;12(3):462. DOI: 10.3390/ma12030462.
18. Y F, M T, G EN. Marginal adaptation and internal fit of all ceramic crowns fabricated with pressed versus milled zirconia reinforced lithium silicate (An In-vitro study). Acta Scientific Dental Sciences 2022;68–75.
19. Shim JS, Lee JS, Lee JY, et al. Effect of software version and parameter settings on the marginal and internal adaptation of crowns fabricated with the CAD/CAM system. Journal of Applied Oral Science 2015;23(5):515–522. DOI: 10.1590/1678-775720150081.
20. Halawani S, Al-Harbi S. Marginal adaptation of fixed prosthodontics. International Journal of Medicine in Developing Countries 2017; 78–84. DOI: 10.24911/IJMDC.1.2.7.
21. Dauti R, Lilaj B, Heimel P, Moritz A, et al. 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):1929–1938. DOI: 10.1007/s00784-019-03053-1.
22. Baig MR, Tan KB, Nicholls JI. Evaluation of the marginal fit of a zirconia ceramic computer-aided machined (CAM) crown system. J Prosthet Dent 2010;104(4):216–227. DOI: 10.1016/S0022-3913(10)60128-X.
23. El-Damaty MF, Abdel-Aziz MH, El-Kouedi AMY, et al. 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. DOI: 10.14295/bds.2020.v23i3.1908.
24. Ghadeer FK, Alwan LE, Al-Azzawi AKJ. Crystallization firing effect on the marginal discrepancy of the IPS.emax CAD crowns using two different CAD/CAM systems. Journal of Baghdad College of Dentistry 2023;35(1):49–57. DOI: 10.26477/jbcd.v35i1.3316.
25. Azarbal A, Azarbal M, Engelmeier RL, et al. Marginal fit comparison of CAD/CAM crowns milled from two different materials. J Prosthodont 2018;27(5):421–428. DOI: 10.1111/jopr.12683.
26. Almohammed SN, Alshorman B, Abu-Nabaa LA. Mechanical Properties of five esthetic ceramic materials used for monolithic restorations: A comparative in vitro study. Ceramics 2023;6(2):1031–1049. DOI: 10.3390/ceramics6020061.