EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 2257:2267, July, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 09-03-2025 • Accept Date : 06-05-2025 • Available online: 10-07-2025 • DOI : 10.21608/edj.2025.366856.3413

MARGINAL ACCURACY OF ULTRA-TRANSLUCENT ZIRCONIA AND MACHINABLE COMPOSITE LAMINATE VENEERS VERSUS LITHIUM DISILICATE VENEERS USING TWO MILLING PROTOCOLS

Nessma M. Atta *, Hany H. Nasr** *and* Sama N. Kotb**

ABSTRACT

Aim: to investigate the effect of two CAD/CAM milling protocols on the marginal accuracy of delicate thin margins of laminate veneers fabricated from different esthetic materials.

Materials and Methods: A typodont maxillary central incisor was prepared with a butt-joint incisal preparation design and 0.4 mm chamfer finish line to receive 36 laminate veneers constructed from (L) lithium disilicate (IPS e.max CAD), (Z) ultra-translucent zirconia (UTML KATANA), and (C) machinable composite (Brilliant Crios) (n=12). Each group was subdivided into 2 subgroups according to milling protocol used: fast and normal (n=6). The margins of each laminate veneer were measured under stereomicroscope. Three points were measured for each surface (mesial, distal, incisal and cervical). Each measurement was repeated three times then mean values were calculated. Data were analyzed statistically using One-Way Anova, post hoc test and Paired t-test.

Results: normal milling protocol, showed statistically significant difference between materials (P-value=0.01*). Ultra-translucent zirconia showed the lowest mean marginal gap. Regarding fast milling protocol, there was statistical significant difference between materials with (P-value= 0.012*). Machinable composite showed the lowest mean marginal gap. Finally, there was no statistically significant difference between fast and normal milling protocols except for with machinable composite.

Conclusion: Ultra-translucent zirconia and machinable composite can be considered as a great revolution in laminate veneers fabrication, also as substitutes for lithium disilicate. Ultra-translucent zirconia laminates exhibited the lowest marginal gaps in normal milling while, machinable composite exhibited the lowest marginal gaps in fast milling protocol. Also, Fast milling can substitute normal milling protocol.

KEY WORDS: laminate veneer, fast milling, normal milling, esthetic materials

* Department of Fixed Prosthodontics, Faculty of Dentistry, Ahram Canadian University
** Department of Fixed Prosthodontics, Faculty of Dentistry, Cairo University

INTRODUCTION

Laminate veneer is a thin labial restoration kept within enamel and considered as the most popular treatments for achieving a perfect smile [1,2,3]. Recent CAD/CAM ceramic systems have an demonstrated improved mechanical and superior physical properties which are essential for dental restorations especially in thin thicknesses [4,5,6].

Lithium disilicate has superb optical and improved mechanical properties. It has been widely regarded as a benchmark material for laminate veneers construction[7,8,9] . Zirconia is an esthetic ceramic material with an exceptional mechanical properties and high biocompatility. However, it naturally suffered from opacity [8,9,10]. Recently, monolithic translucent zirconia restorations have improved the ability to match the color and translucency of natural teeth without needing a porcelain overlay layer[5]. It even could be used as laminate veneer material restoring the aesthetics of the tooth structure in thin or ultrathin restoration with thickness down to 0.1 to 0.3 mm thanks to its high mechanical properties[11-16]. Recently introduced resin-based CAD/CAM blocks have emerged as alternatives to CAD–CAM glass ceramics. They are easier to mill, provide a smoother final surface, and require fewer steps [17-20]. Their high edge stability increases the accuracy of the milling process. Allowing for reduced thickness of the restoration without compromising marginal integrity, which can be an advantage over thin glass ceramic restorations [17,18,21,22,23].

Over the past 25 years, CAD/CAM technology has advanced signficantly. The development of CAD/CAM technology in dentistry had significantly altered treatment plans and the production of prostheses [16,24]. The use of CAD/CAM technology reduced construction time, allowing practitioners to choose from various designing and milling protocols. The normal milling option can be used for all materials and indications. The fast milling option accelerates the process, allowing quicker restoration fitting as claimed by the manufacturer [4,15].

Marginal fit is crucial for long-term success of dental restorations. Since laminate veneers are cemented using resin cement, they become a part of the tooth and subjected to functional forces, thermal changes, and the hydrolytic effect of water and oral environment [15,25-30]. Marginal discrepancies exposes the luting cement to oral environment causing increased rate of cement dissolution, secondary decay, microleakage, discoloration, esthetic problems or fracture of the restoration [16,17]. The clinically acceptanle marginal gap should not exceed 120µm for any restoration[31,32]. According to **Baig et al. (2024)** marginal gap around 50 µm are considered ideal for CAD/CAM restorations [24] From preparation to cementation many factors influence the accuracy and fit of the margins[33-36]. These factors include; the finish-line configuration and thickness [33,36,37,38], method of recording whether conventional impression or digital scanning intra or extra-oral [18,20,25,29,31,39,40], processing technique and fabrication [4,15,17,29,31,33,34,36,41,42], material type used[2,9,14,18,19,23 25,34,43 – 46] and cementation procedure [16,22,34].

Due to the insufficient researches related to the marginal accuracy of laminate veneers with different milling protocols, the aim of the present study was to evaluate and compare the marginal accuracy of three different CAD-CAM materials used for fabrication of laminate veneers utilizing two different milling speeds.

METHODOLOGY

Power analysis was constructed to ensure adequate power to test a statistical test for the null hypothesis that there will be no difference in marginal adaptation between Ultra-translucent zirconia, machinable composite and Lithium disilicate glass ceramic when milled into laminate veneers. Additionally, there would be no difference in marginal adaptation between laminate veneers after both normal and fast milling protocols. By adopting an alpha and beta levels of (0.05) i.e., power=95% and an effect size (f) of (0.899) calculated based on the results of previous studies [4,30]. The predicted sample size (n) was a total of (36) samples. Sample size calculation was performed using G*Power version 3.1.9.7 [47].

A number of 36 laminate veneers were constructed from 3 materials (n=12); **L:** Lithium disilicate [IPS e.max® CAD Blocks (Ivoclar Vivadent, Schaan, Liechtenstein)], **C:** Machinable resin composite [BRILLIANT Crios (Coltène Whaledent Feldwiesenstrasse, Altstätten, Switzerland)], and **Z:** Ultra-translucent zirconia [UTML Katana Zirconia (Kuraray Noritake, Tokyo, Japan)]. Half of each group was milled using normal milling speed subgroups (L_n, Z_n, C_n), the other half with fast milling speed subgroups L_f Z_f C_f (n=6).

Tooth preparation.

An upper right maxillary central incisor tooth of a typodont model (NISSIN Dental Model, Koyota, Japan) was selected to be prepared and serve as a die [34]. A butt-joint incisal preparation design was chosen for incisal edge by 1mm using a wheel stone (Frank, Germany). Labially depth grooves were obtained using 0.3 and 0.5 depth cutter diamond stones (Frank, Germany) in two planes. The preparation was done using tapered diamond stone with a round end (Frank, Germany) to obtain chamfer finish line 0.3-0.4mm thickness and 0.5mm supragingivally. Mesial and distal boundaries were extended 1 mm just before the contact point. Finishing diamond stones were used to finish the tooth and a prepared putty index section was used to evaluate and ensure the required amount of reduction [40] **Figure (1).**

Construction of laminate veneers.

Scanning was done using an intraoral scanner "Medit i500" (Medit, South Korea). Then the scan was sent to Exocad designing software (Exocad chairside 2.3 Matera software). The restoration shape was determined using the copy then mirror option, and cement gap was set at 50 μm and 1 mm away from the margins. The same final design was used to fabricate the full number of samples [36]. The design was electronically sent to the milling machine "Cerec MCx5" (sirona, dental, Benhshiem, Germany).

On the CAM software, after collection of data, and arrangement of the restoration, the final phase that gave the order of milling the restoration with milling speed set as required for the research once normal milling speed; with estimated time per unit; (L_n) 25:26 minutes, (C_n) 28:00 minutes, and (Z_n) 20:00 minutes. Then other time with fast milling speed with estimated time per unit; (L_f) 18:24 minutes, (C_f) 22:47 minutes, and (Z_f) 13:24 minutes.

According to manufacturer instructions, for group L combined crystallization/ glazing program was conducted in programat CS3 furnace (Ivoclar Vivadent, Schaan, Liechtenstein). Group C does not require a firing process but only polishing. Group

Fig. (1) Prepared tooth after finishing and polishing

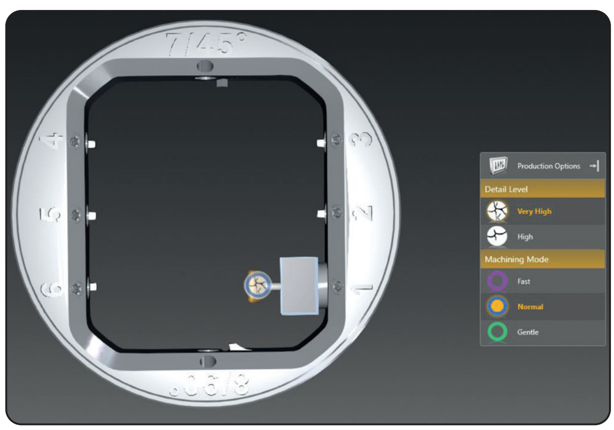

Fig. (2) Determinig the milling protocol on the CAM software

Z veneers were sintered in the inFire HTC speed furnace (sirona, dental, Benhshiem, Germany) then glazed and fired using glaze cycles in Programat CS3 furnace (Ivoclar Vivadent, Schaan, Liechtenstein).

Marginal accuracy Measurements

The vertical marginal gap was assessed by fixing veneers directly on the prepared tooth as a master die, with a drop of Te-Econom Bond adhesive (Ivoclar Vivadent, Schaan, Liechtenstein) without curing to form reversible seating between the die and veneers, then the restoration-tooth assembly were examined under digital stereomicroscope Lecia SAPO (Leica Microsystems, Bensheim, Germany) at magnification 45X. Images were processed by Leica application suites (LAS) version 4.0 software. Three predetermined point were selected on each surface with distances arbitrary detected at cervical (misocervical, midcervical, distocervical), mesial (cervicomesial, midmesial, incisomesial), distal (cervicodistal, middistal, incisodistal), incisal (misoincisal, midincisal, distoincisal) were selected on the typodont finish line and restoration margin then the software measures the perpendicular distance between both points. Then measurements were repeated 3 times for each point.

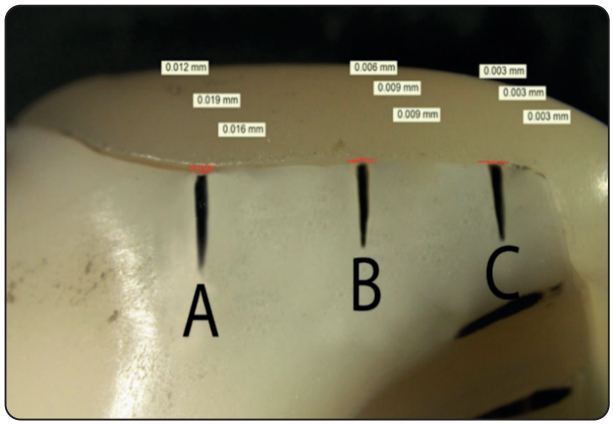

Fig. (3) Points of measurements at distal surface of Cf group

RESULTS

Comparison between the mean marginal gap values of the two milling speed groups (normal and fast) **[Table 1]** revealed that; **group L showed** no statistically significant difference between $\mathbf{L_n}$ and $\mathbf{L_f}$

TABLE (1) The Mean and standard deviation (SD) values of marginal accuracy (μm) of materials after fast and normal milling using a paired t-test.

	Normal Milling		Fast Milling		P-value
	Mean	**SD**	**Mean**	**SD**	
Group L					
Cervical	15.74[a]	2.19	15.76[a]	2.02	0.99ns
Mesial	14.22[a]	1.94	12.32[a]	1.03	0.54ns
Distal	15.06[a]	2.82	13.35[a]	1.76	0.15ns
Incisal	15.04[a]	0.72	17.06[a]	1.93	0.09ns
Group C					
Cervical	15.11[a]	1.24	11.74[b]	1.79	0.001*
Mesial	11.2[a]	1.58	9.76[a]	1.46	0.09ns
Distal	14.98[a]	1.35	11.76[b]	2.27	0.0*
Incisal	18.87[a]	3.65	18.93[a]	0.30	0.83ns
Group Z					
Cervical	12.78[a]	1.92	14.98[a]	1.52	0.17ns
Mesial	12.91[a]	1.85	10.22[a]	1.93	0.26ns
Distal	13.76[a]	2.28	13.63[a]	0.66	0.9ns
Incisal	13.76[a]	1.45	14.96[a]	0.53	0.14ns

Letters ***indicate statistical difference within the same row,*** ***;** ***significant ($p\leq 0.05$)*** **ns;** ***non-significant ($p>0.05$)***

groups in either all surfaces, **group C** showed no statistically significant difference between $\mathbf{C_n}$ and $\mathbf{C_f}$ groups in all surfaces except cervical surface where the P-value= **0.001**, **group Z** showed no statistically significant difference between $\mathbf{Z_n}$ and $\mathbf{Z_f}$ groups in either all surfaces.

Correlation between different groups in the same milling speed group: [Table 2]

Normal Milling in all three materials (L_n, C_n, and Z_n)

Cervical surfaces showed statistically significant difference was recorded between the groups (P-value= 0.032) with the lowest mean value recorded for Z_n group. Mesial surfaces showed statistically significant difference was recorded between the groups (P-value= 0.037) with the lowest mean value recorded for C_n group. Distal surface showed no statistically significant difference was recorded between the groups (P-value= 0.26). Incisal surface showed statistically significant difference was recorded between the groups (P-value= 0.001) with the lowest mean value recorded for Z_n group.

Fast Milling in all three materials (L_f, C_f, and Z_f)

Cervical Surface showed statistically significant difference between the groups (P-value=0.003) where the lowest mean value was for C_f group. **Mesial** Surface showed no statistically significant difference between the groups (P-value= 0.99). **Distal** Surface showed no statistically significant difference between the groups (P-value= 0.15). **Incisal** Surface showed statistically significant difference between the groups (P-value= 0.001) where the lowest mean value was for Z_f group.

Overall correlation for all surfaces after both fast and normal milling [Table 3]

There was no statistically significant difference between both milling protocols except for group C (P-value <0.001), with the lowest mean marginal gap was recorded at fast milling group.

Multiple comparisons, between each 2 groups of materials separately

For normal milling, group L was significantly higher than group Z (P-value= 0.02), and insignificantly lower than group C (P-value= 1) and group Z was significantly lower than group C (P-value= 0.02). Regarding fast milling protocol, group L was insignificantly higher than group Z (P-value= 0.58), and significantly higher than group C (Pvalue=0.01), group Z was insignificantly higher than group C (P-value= 0.11).

TABLE (2) One Way ANOVA test comparing the Mean and Standard deviation (SD) values of marginal accuracy (μm) of different groups after normal and fast milling.

	surface	L		C		Z		P-value
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Normal milling	**Cervical**	15.74^{b}	2.19	15.11^{b}	1.24	12.78^{a}	1.92	0.032*
	Mesial	14.22^{b}	1.94	11.2^{a}	1.58	12.91^{ab}	1.85	0.037*
	Distal	15.06^{a}	2.82	14.98^{a}	1.35	13.76^{a}	2.28	0.26ns
	Incisal	15.04^{b}	0.72	18.87^{c}	3.65	13.76^{a}	1.45	0.001*
Fast milling	**Cervical**	15.76^{b}	2.02	11.74^{a}	1.79	14.98^{ab}	1.52	0.003*
	Mesial	12.32^{a}	1.03	9.76^{a}	1.46	10.22^{a}	1.93	0.99 ns
	Distal	13.35^{a}	1.76	11.76^{a}	2.27	13.63^{a}	0.66	0.15 ns
	Incisal	17.06^{a}	1.93	18.93^{b}	0.30	14.96^{a}	0.53	0.001*

Letters *indicate statistical difference within the same row,* ***;** *significant (p≤ 0.05)* **ns;** *non-significant (p>0.05)*

TABLE (3) The Mean and standard deviation (SD) values of marginal accuracy (μm) of all materials after both fast and normal milling speeds

Groups	Normal Milling		Fast Milling		P-value
	Mean	**SD**	**Mean**	**SD**	
L	15.2^{Aa}	1.83	14.92^{Aa}	2.3	**0.68ns**
C	15.2^{Ab}	3.33	12.05^{Ba}	3	**<0.001***
Z	13.3^{Ba}	1.83	13.97^{ABa}	1.47	**0.2ns**
P-value	0.01*		0.012*		

Capital letters ***indicate statistical difference within the same column,***
Small letters ***indicate statistical difference within the same row.***
****; significant (p≤ 0.05) ns; non-significant (p>0.05)***

DISCUSSION

Lithium disilicate is considered the most widely used for laminate veneers fabrication due to its mechanical and optical properties (8,9)**.**

Zirconia has an outstanding strength, and biocompatility. However, its main problem was its opacity. Now with the invention of different translucencies of monolithic zirconia, it is possible to fabricate esthetic restorations with very thin sections and high strength (8,10,13).

Recently introduced composite resin CAD–CAM materials were used as alternatives to glass ceramics, with easier milling, repairability, and fewer steps (7,19,21).

Artificial tooth was selected to eliminate natural tooth variations, and a single operator prepared the typodont tooth for standardization (4,33). Tooth preparation was done according to the stated guidelines for laminate veneers preparation (35,50). A sectioned silicone putty index was used to ensure even and adequate reduction (4,17,37).

"Medit i500" scanner was chosen for acquisition because it does not need powder application which can affect the accuracy (40,51) with high trueness and precision as claimed by manufacturer (39). Designing was completed using Exocad software2 (52). Milling was done using a 5-axis milling machine 24,43. Milling process was accomplished with normal and fast milling speeds (4,15).

Measuring the vertical marginal gap was done directly on the prepared typodont tooth to eliminate variants that may occur during fabrication of new dies. As our scope was to examine the effect of material type and milling protocol on laminate veneers' margins thus, no cementation step was performed during examination **(34,44)** and laminate veneers restorations were seated on the typodont tooth using boning agent **(4).**

The vertical marginal gap is thought to be the most representative of restorations' marginal accuracy so it was employed in the present study and measured using stereomicroscope, at the national institution of researches, Egypt **(11).** Three predetermined points were marked for marginal gaps measurements for each surface's finish line (mesial, distal, incisal and cervical) **(27,28,29).**

Results of this study showed no significant difference in marginal accuracy between both milling speeds for lithium disilicate veneers. Also, there was no significant difference between any surface and its corresponding surface for both milling protocols with the highest marginal gap recorded for incisal edge at fast milling protocol**.** This was consistent with the results of **Hany& Taymour (2019)** [4] who reported no statistically signficant difference in marginal gap values after fast and normal milling of lithium disilicate veneers. Also **Lubauer et al. (2021)** [41] found no statistical significant difference in marginal integrity values after rough fast grinding and fine slow grinding of lithium disilicate restorations.

However, machinable composite showed a statistically significant difference among both milling protocols with normal milling showing the highest mean marginal gap. This could be attributed to differences in the resin matrix composition, size, and type of the particles used as fillers, the dispersed particles on the milled surface that could be easily washed away with the effect of water in wet milling. The wash away effect was also explained by **Goujat et al. (2018)** [45] who compared different types of machinable composites with different amounts of fillers and showed that the lowest filler content type of composites had the highest marginal gap. The wash away effect in our study might have been reduced when fast milling protocol is used with less friction and less exposure to water during milling.

For ultra-translucent zirconia there was no statistical significant difference between fast and normal milling protocols. Also, there was no significant difference between any surface and its corresponding after both protocols. This has been in accordance with **Wallum et, al. (2024)** [15] who examined three milling protocols for zirconia laminate veneers; super-fast, fine (fast) and extra fine (normal) and found no statistical difference between both fine and extra fine milling protocols which agrees with our study.

Normal milling showed, no statistical significant difference between lithium disilicate and machinable composite veneers. While ultra-translucent zirconia showed statistically significant difference when compared to lithium disilicate and machinable composite veneers. Particularly, zirconia laminate veneers showed the best marginal fit. The decreased gap values of zirconia could be explained by several factors; mainly CAD/CAM systems were initially used for milling polycrystalline materials, carbide milling tools were used to mill zirconia while diamond tools were used for the other two materials [42,53]**.** Also, sintering causes shrinkage of the material and in consequence reduces irregularities at marigns [42]. Another explanation could be attributed to the ultimate mechanical properties of zirconia material that reduces edge chipping and in turn better adaptation [46]**.**

Our results are matched by findings of **Naffah et al. (2019)** [19] who found no significant difference in marginal adaptation of machinable composite, and lithium disilicate crowns. Also, **de Paula et al., (2017)** [18] who found no statistically significant difference in the marginal fit of lithium disilicate and Lava Ultimate crowns.

While our results were in partial disagreement with **Kapler et al. (2020)** [25] who studied marginal adaptation of Lithium Disilicate, and two composite resin (Grandio and Brava) crowns. They found statistically insignificant differences between lithium disilicate and Grandio while there was significant difference between lithium disilicate compared to Brava. The difference of results of both composite materials could be due to the difference in organic content of blocks.

Results are in disagreement with, **Elsharkawy (2021)**[23] who found statistically significant difference between lithium disilicate and machinable composite for endocrowns with the lowest marginal gap recorded for composite. This could be explained due to the fact that endocrown restorations were easier to obtain more define margins during impression recording. Moreover, **Mohammed & Majeed, (2020)** [22] who measured marginal accuracy of lithium disilicate and composite overlays, reported a statistically significant difference. Composite recorded better marginal adaptation. This disagreement of results could be explained by the difference in properties between natural teeth used in this study and typodont tooth used in our research.

The results of zirconia marginal adaptation superiority over lithium disilicate goes with the findings of **Wahsh & Taha. (2020)** [12] who studied marginal gaps of lithium disilicate and high translucent zirconia and reported statistically significant difference favouring high translucent zirconia marginal adaptation. Another agreement with **Ferrini et al, (2023)** [14] who found that zirconia showed statistically significant difference when compared to Lithium Disilicate, and Composite crowns. While there was no significant difference between both lithium disilicate and composite materials. Zirconia crowns showed the lowest marginal gap value, followed by composite and lithium disilicate. Another agreement with **Nawafleh et al., (2023)** [11] who found a statistically significant difference between lithium disilicate and zirconia restorations with the least marginal gap values recorded for zirconia group. Also our results were in match with a study by **Basheer, et al. (2017)** [30] who compared the marginal accuracy of monolithic zirconia and lithium disilicate laminate veneers, and found that the former had the highest gap.

Our results was in contrast to Riccitiello et al., (2018) [42] whose Results revealed that no statistically significant difference between lithium disilicate and zirconia crowns. This may be explained due to different recording methods, as they used micro CT for measurement which records in black and white, while in our study we used a stereomicroscope with a colored records.

For fast milling protocol results showed that, there was statistically significant difference between lithium disilicate and machinable composite with p-value = 0.01. The composite veneers showed the lowest mean marginal gap. This could be due to edge stability of composite during milling. There was no statistically significant difference between zirconia compared to lithium disilicate or machinable composite with p-values= 0.58 and 0.11 respectively.

Based on the present results the null hypothesis was partially rejected, since ultra-translucent zirconia veneers showed superior marginal adaptation than both lithium disilicate glass ceramic and machinable composite veneers in normal milling. There were no significant differences in marginal adaptation of both ultra-translucent zirconia or lithium disilicate veneers when milled with either normal or fast milling speeds. While, with machinable composite veneers the fast milling offered significantly better marginal adaptation than normal milling.

LIMITATIONS

- The utilization of an acrylic typodont instead of natural teeth
- Lack of cementation although justification was previously discussed.
- In vitro study needing further clinical researches.

CONCLUSION

1. Fast milling protocol can be a substitute for normal milling without compromising marginal accuracy.
2. Although there were statistically significant difference between the three materials, all values fall within the clinically accepted range (<50 μm).
3. Ultra translucent zirconia exhibited the lowest marginal gap in normal milling and comparable marginal gaps to composite in fast milling, while machinable composite performed best with fast milling. Both materials may be viable alternatives to lithium disilicate, especially in ultra-thin veneer applications.

REFERENCES

1. Costa DC, C. M. de S. A. E. J. (2013). A Meta-Analysis of the Most Indicated Preparation Design for Porcelain Laminate Veneers. Article in J Adhes Dent. Vol 15, No 3,215-220.
2. Liu, M., Gai, K., Chen, J., & Jiang, L. (2018). Comparison of Failure and Complication Risks of Porcelain Laminate and Indirect Resin Veneer Restorations: A Meta-Analysis. IJOPRD, 32(1), 59–65.
3. Alenezi, A., Alsweed, M., Alsidrani, S., & Chrcanovic, B. R. (2021). Long-term survival and complication rates of porcelain laminate veneers in clinical studies: A systematic review. J. Clin. Med. 10, 5, 1–14.
4. Hany, C., & Taymour, M. (2019). Marginal Integrity of Glass Ceramic Laminate Veneers Produced Through Different CAD/CAM Milling Protocols: In-Vitro Study. Egypt. Dent. J., 65(3), 3007–3018.
5. Abdel-Nabi W., Ghazy, M, Dawood, Lamia.: Fracture Resistance and Marginal Adaptation of CAD/CAM Generated Monolithic Zirconia Laminate Veneers, In-Vitro Study. Mansoura J. Dent. Febrauary,2020; 6(20). 81-85.
6. Souza, R., Barbosa, F., Araújo, G., Miyashita, E., Bottino, M. A., Melo, R., & Zhang, Y. Ultrathin monolithic zirconia veneers: Reality or future? Report of a clinical case and one-year follow-up. Oper. Dent., 2018; 43-1, 3-1
7. Coldea, A., Swain, M. V., & Thiel, N.; Mechanical properties of polymer-infiltrated-ceramic-network materials. Dent. Mater., 2013. 29(4), 419–426.
8. Willard, A., & Gabriel Chu, T. M. (2018). The science and application of IPS e.Max dental ceramic. KJMS 34 (4) 238–242.
9. Zarone, F., Di Mauro, M. I., Ausiello, P., Ruggiero, G., & Sorrentino, R. Current status on lithium disilicate and zirconia: A narrative review. BMC Oral Health, 2019; 19(1), 1–14.
10. Zhang, Y., Lawn, B.(2017) Novel zirconia materials in dentistry. J. Dent. Res.; 97, 140–147.
11. Nawafleh, N. A., Mack, F., Evans, J., Mackay, J., & Hatamleh, M. M. (2013). Accuracy and reliability of methods to measure marginal adaptation of crowns and FDPs: A literature review. J. Prosthodont, 22(5), 419–428.
12. Wahsh Marwa & Taha Doaa. (2020). In vitro evaluation of the marginal integrity of monolithic ceramic crowns utilizing different machinable blocks fabricated for minimally invasive vertical preparation designs. Egypt. Dent. J. 66. 2597-2606.
13. Alqutaibi, A. Y., Ghulam, O., Krsoum, M., Binmahmoud, S., Taher, H., Elmalky, W., & Zafar, M. S. (2022). Revolution of Current Dental Zirconia: A Comprehensive Review. In Molecules 27, 5.
14. Ferrini, F., Paolone, G., Di Domenico, G. L., Pagani, N., & Gherlone, E. F. (2023). SEM Evaluation of the Marginal Accuracy of Zirconia, Lithium Disilicate, and Composite Single Crowns Created by CAD/CAM Method: Comparative Analysis of Different Materials. Materials, 16(6), 2413.
15. Wallum, A. J., Raimondi, C., Lien, W., Hoopes, W. L., & Vandewalle, K. S. (2024). Effect of Milling Speed on the Properties of Zirconia Restorations. J Clin Exp Dent, 16(1), e84.
16. Bennani, V., Aarts, J. M., & Veerasamy, A. (2025). Cement Thickness of CAD/CAM Zirconia Laminate Veneers: Impact of Preparation Design. European Journal of Prosthodontics & Restorative Dentistry, 33(1).
17. Aboushelib, M. N., Elmahy, W. A., & Ghazy, M. H. (2012). Internal adaptation, marginal accuracy and microleakage of a pressable versus a machinable ceramic laminate veneers. J. of Dent., 40(8), 670–677.
18. De Paula Silveira, A. C., Chaves, S. B., Hilgert, L. A., & Ribeiro, A. P. D. (2017). Marginal and internal fit of CAD-CAM-fabricated composite resin and ceramic crowns scanned by 2 intraoral cameras. Journal of Prosthetic Dentistry, 117(3), 386–392
19. Naffah, N., Ounsi, H., Ozcan, M., Bassal, H., & Salameh, Z. Evaluation of the adaptation and fracture resistance of three CAD-CAM resin ceramics: An in vitro study. J. Contemp. Dent. Pract. May, 2019; 20(5), 571–576.
20. Kapler, R., Oliveira, M. V., de Oliveira Bandeira, I., Metzker, T. C., Carvalho, A. O., & Lima, E. M. C. X. (2020). Analysis of the marginal adaptation of different crowns fabricated with computer-aided technology using an intraoral digital scanner. Braz. J. Oral Sci., 19, e200537-e200537.
21. Reymus, M., Roos, M., Eichberger, M., Edelhoff, D., Hickel, R., & Stawarczyk, B. (2019). Bonding to new CAD/CAM resin composites: influence of air abrasion and conditioning agents as pretreatment strategy. Clin. Oral Investig., 23(2), 529–538.

22. Mohammed, Z. H., & Majeed, M. A. (2020). Effect of cementation protocol on the marginal adaptation of indirect overlay restorations fabricated from two different all-ceramic CAD/CAM materials. J. Res. Med. Dent. Sci., 8(7), 518-525.

23. Elsharkawy, A. (2021). Marginal Adaptation And Fracture Resistance Of Endocrown Restorations Constructed From Two Cad/Cam Blocks. Egypt. Dent. J., 67(4), 3547–3560.

24. Baig, M. R., Qasim, S. S. B., & Baskaradoss, J. K. (2024). Marginal and internal fit of porcelain laminate veneers: A systematic review and meta-analysis. The JPD, 131(1), 13–24.

25. Elbasty, R. S., Nabil, O., Elgohary, M. S., & Taymour, M. (2025). Comparison of vertical marginal gap and internal fit of chairside laminate veneers fabricated from advanced versus conventional lithium disilicate ceramics: An in vitro study. The Journal of Prosthetic Dentistry.

26. Tuğcu, E., Vanlıoğlu, B., Özkan, Y., & Aslan, Y. (2018). Marginal Adaptation and Fracture Resistance of Lithium Disilicate Laminate Veneers on Teeth with Different Preparation Depths. The International Journal of Periodontics & Restorative Dentistry, 38, s87–s95.

27. Aldafeeri, H. R., Abd, W., Al-Zordk, E.-G., & Ghazy, M. H. (2019). Marginal Accuracy of Machinable Monolithic Zirconia Laminate Veneers. IOSR-JDMS, 18, 67–74.

28. Baig, M. R., Akbar, A. A., Sabti, M. Y., & Behbehani, Z. (2022). Evaluation of Marginal and Internal Fit of a CAD/CAM Monolithic Zirconia-Reinforced Lithium Silicate Porcelain Laminate Veneer System. J. Prosthodont, 31(6), 502–511.

29. Kang S, Lee H, Kim J, Kim W. (2018). Evaluation of marginal discrepancy of pressable ceramic veneer fabricated using CAD-CAM system: Additive and subtractive manufacturing. J Adv Prosthodont.,10:347-56

30. Basheer, R., Elsayed, S., & Bahgat, S. (2017). Assessment of accuracy of different CAD/CAM fabricated porcelain laminate veneers. Egypt. Dent. J., 63 (4) , 3767-3781.

31. Abdel-Azim, T., Rogers, K., Elathamna, E., Zandinejad, A., Metz, M., & Morton, D. (2015). Comparison of the marginal fit of lithium disilicate crowns fabricated with CAD/CAM technology by using conventional impressions and two intraoral digital scanners. JPD, 114(4), 554–559.

32. Son K, Lee K-B. (2021). Marginal and Internal Fit of Ceramic Prostheses Fabricated from Different Chairside CAD/CAM Systems: An In Vitro Study. Applied Sciences, 11(2), 857.

33. Najim, B. A. E.-S., & Al-Rawi, I. I. (2015). The Influence of Different Fabrication Techniques and Preparation Designs on the Marginal Adaptation of Ceramic Veneers : An in Vitro Comparative Study. JBCD, 27(4), 8–14.

34. Al-Dwairi, Z. N., Alkhatatbeh, R. M., Baba, N. Z., & Goodacre, C. J. (2019). A comparison of the marginal and internal fit of porcelain laminate veneers fabricated by pressing and CAD-CAM milling and cemented with 2 different resin cements. JPD, 121(3), 470–476.

35. Farias-Neto A, de Medeiros FCD, Vilanova L, Simonetti Chaves M, Freire Batista de Araújo J. (2019). Tooth preparation for ceramic veneers: when less is more. International Journal of Esthetic Dentistry,14(2):156-164.

36. Saker, S., & Ozcan, M. (2021). Marginal discrepancy and load to fracture of monolithic zirconia laminate veneers: The effect of preparation design and sintering protocol. Dent Mater J., 40(2)

37. Brunton, P. A., Aminian, A., & Wilson, N. H. F. (2000). Tooth preparation techniques for porcelain laminate veneers. Br. Dent. J.189, (5).

38. Shillingberg HT, Hobo S and Fisher TW (2003): Preparation design and margin distortion in porcelain fused to metal restorations. J of Prosthet Dent; 89:527-532.

39. Ji-Man Park (2018). Accuracy comparison analysis on scan data of single tooth, quadrant, and full arch between two types of intraoral scanner, i500 and Trios 3” by in vitro was conducted by Yonsei University College of Dentistry.

40. Al-Dwairi, Ziad N., Moataz Al-Sardi, Brian J. Goodacre, Charles J. Goodacre, Khaled Q. Al Hamad, Mutlu Özcan, Nadin Al-Haj Husain, and Nadim Z. Baba (2023). “Evaluation of Marginal and Internal Fit of Ceramic Laminate Veneers Fabricated with Five Intraoral Scanners and Indirect Digitization” Materials 16, no. 6: 2181

41. Lubauer, J., Belli, R., Schünemann, F. H., Matta, R. E., Wichmann, M., Wartzack, S., Völkl, H., Petschelt, A., & Lohbauer, U. (2021). Inner marginal strength of CAD/CAM materials is not affected by machining protocol. Biomater. investig. dent., 8(1), 119–128.

42. Riccitiello, F., Amato, M., Leone, R., Spagnuolo, G., & Sorrentino, R. (2018). In vitro Evaluation of the Marginal Fit and Internal Adaptation of Zirconia and Lithium Disilicate Single Crowns: Micro-CT Comparison between

Different Manufacturing Procedures. The Open Dentistry Journal, 12(1), 160–172.

43. Goujat, A., Abouelleil, H., Colon, P., Jeannin, C., Pradelle, N., Seux, D., & Grosgogeat, B. (2019). Marginal and internal fit of CAD-CAM inlay/onlay restorations: A systematic review of in vitro studies. The JPD, 121(4), 590–597.

44. Tinschert J, Natt G, Mautsch W, Spiekermann H, and Anusavice KJ (2001): Marginal Fit of Alumina and Zirconia Based Fixed Partial Dentures Produced by a CAD/CAM System. Oper Dent; 26: 367-374.

45. Goujat, A., Abouelleil, H., Colon, P., Jeannin, C., Pradelle, N., Seux, D., & Grosgogeat, B. (2018). Mechanical properties and internal fit of 4 CAD-CAM block materials. The JPD, 119(3), 384–389.

46. Spitznagel, F. A., Boldt, J., & Gierthmuehlen, P. C. (2018). CAD/CAM Ceramic Restorative Materials for Natural Teeth. J. Dent. Res., 97(10), 1082–109.

47. Faul, Franz, et al. "G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences." Behavior research methods 39.2 (2007): 175-191.

48. Cho, Y. E., Lim, Y. J., Han, J. S., Yeo, I. S. L., & Yoon, H. I. Effect of yttria content on the translucency and masking ability of yttria-stabilized tetragonal zirconia polycrystal. Materials, November, 2020; 13(21), 1–10.

49. El-Ashkar, A. S., Ahmed, O. N., Taymour, M. A., & El-Tannir, A. M. (2021). One-year clinical evaluation of monolithic zirconia crowns restoring endodontically treated molars with two finish line designs. Int. J. Health Sci, (IV), 1960-1967.

50. Chai, S. Y., Bennani, V., Aarts, J. M., Lyons, K., & Lowe, B. (2020). Effect of incisal preparation design on load-to-failure of ceramic veneers. JERD., 32(4), 424–432.

51. Tamimi, S., Essam, E., & El Guindy, J. (2017). Effect of Different Preparation Designs on the Fracture Load of Two Machinable Laminate Veneers. AJDS 4(1), 63-70.

52. Al Hendi, K. D. (2023). Comparative Evaluation of Fitness and Compressive Strength of Temporary Crowns Designed from 3Shape and Exocad Software: An In Vitro Study. IJOPRD, 13(4), 216-221.

53. Park SH. and Lee KB.(2008). A comparison of the fidelity between various cores fabricated with CAD/CAM system. J Kor Acad Prosthodont ; 43: 269-78.