Cement Thickness of CAD/CAM Zirconia Laminate Veneers: Impact of Preparation Design

Keywords

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ABSTRACT

Introduction: This study assessed cement thickness of three veneer preparation designs: feather edge, shoulder, and shoulder with wings. Objectives: The aim was to evaluate whether the modified shoulder with wings design produced a similar cement thickness compared to the traditional shoulder and feather edge designs. Methods: The study measured vertical, horizontal, and overall cement thickness of 60 veneer cemented (20 per group) on typodont teeth. Ceramic veneers were fabricated using CAD/CAM with each veneer assessed for fit before cementation. Ten specimens were cut vertically, and 10 were cut horizontally in each group. The cement thickness was measured for each cross-section with scanning electron microscopy. Descriptive data analysis and hypothesis testing were conducted using the nonparametric Kruskal Wallis test (α=.05). Results: In vertical dimension, shoulder with wings design showed the smallest cement thickness. When comparing horizontal and overall cement thickness, the shoulder and shoulder with wings designs were similar. Both shoulder designs produced less overall cement thickness than the feather edge design. Conclusions: Shoulder with wings preparation produced the thinnest cement layer in vertical dimension and a comparable overall cement thickness to the shoulder design. Clinical Relevance: Modified shoulder with wings could enhance veneer longevity by reducing vertical cement thickness.

INTRODUCTION

Advances in dental ceramic materials and adhesive bonding systems have improved the long-term survival of veneers; however, their clinical performance still relies on marginal integrity and internal adaptation.[1-3] Excessive cement thickness is still an issue and can result in microleakage and secondary caries.[4,5] Boitelle *et al.*[6] and Goujat *et al.*[7] also suggest that the cause of these failures is excessive cement thickness, which is linked to the stress relief occurring between the cement and veneer. This is contributed by several mechanisms, such as bonding failure, microfracture of cement, and water absorption. Fracture resistance is also influenced by uneven cement layers, as highlighted by Ha *et al.*[8], who emphasize the role of water absorption in reducing resin cement strength, more concentrated stresses and increased cement wash-out.[8-10] Water absorption significantly diminishes the flexural strength of resin cement working as a plasticizer of the cement and increasing the chance of restoration fracture under mastication forces.[8] Luting cements can act as a barrier to microbial leakage but if there is leakage, bacterial growth can occur along the interface between the restoration and the tooth. This can even progress into the dentinal tubules irritating the pulp causing inflammatory pulpal lesions.[9] Therefore, clinicians should keep the cement film as thin as possible.[11]

The two most common tooth preparation designs for veneers are the feather edge and incisal shoulder *(Figure 1A and B)*.[12,13] The feather edge preparation does not overlap the incisal edge, and this design has been reported to be difficult to seat correctly.[14-17] The shoulder preparation overlaps the incisal edge and has been reported to improve esthetics and facilitate veneer placement.[14,15,18-20] The incisal preparation design for veneers has been widely discussed with a consensus that shoulder preparations are superior.[14,15,21] Key recommendations are that an interproximal extension be incorporated producing an interproximal wraparound, while also maintaining the natural tooth interproximal contact. A major advantage to the interproximal extension is that it can mask tooth discoloration, and it also enables significant changes in morphology to be achieved when indicated.[22-24] To design a veneer that maintains the proximal contact, there are 2 design options. The veneer's proximal margin can be positioned labially to the natural interproximal contact, or the preparation of the veneer can extend 50% into the interproximal contact area.[25]

The modified veneer design being tested in this research is a modified shoulder preparation that has had additions cut into the gingival interproximal area of the preparation. A "C" shape is prepared that extends into the gingival interproximal area on both sides of the tooth as shown in Figure 1C. The extension effectively adds an additional interproximal wrapping element to the veneer preparation. The impact of the modified veneer preparation design on margin discrepancy and marginal overhang has been recently explored by Bennani *et al*.[26]. However, the effect of this design on the resulting cement thickness remains unclear and warrants further investigation. This study aims to build upon the previous research by Bennani *et al*.[26] to determine whether this preparation design influences the thickness of the cement layer.

The null hypothesis was that no statistically significant difference would be found in an alternative tooth-preparation design for veneers in relation to cement thickness.

METHODS

An *in vitro* study design was used to determine the effect of preparation design on internal cement thickness. The methods described below follow the methods published in a recent study investigating the effect of laminate veneer preparation design on absolute margin discrepancy.[26] The specimens were divided into 3 groups (n=20): feather edge (FE), shoulder (S), and shoulder with wings (SW) *(Figure 1)*. The sample size was established based on a previous study that compared the marginal and internal fit of porcelain laminate veneers fabricated using pressing and CAD-CAM milling.[27] Variables were controlled by using a standardized preparation tooth, a single ceramic material, a single luting agent, and a standardized cementation procedure. A single maxillary left central incisor typodont tooth (A252A-UL 19B; Nissin Dental Products, Kyoto, Japan) was prepared with an FE veneer preparation design with a 0.5-mm-labial reduction that did not extend lingually to the proximal contact *(Figure 1A)*. This tooth was duplicated using a polyvinyl siloxane impression material (Light and Regular body Exahiflex; GC, Tokyo, Japan) and poured into a resin die material (Exakto-Form; Bredent, Chesterfield, England). The resin die material was selected for its dimensionally and structurally stable and for its homogeneous and uniform bonding surface.[28] Zirconia (3M Lava Esthetic; 3M, Maplewood, MN, USA) ceramic material was used to produce the veneers which were milled using CAD-CAD techniques (Ceramill Map 400, Ceramill Mind CAD software; Amann Girrbach AG, Pforzheim, Germany). The veneer was then cemented onto the prepared typodont teeth with a dual-polymerized adhesive cement (Rely X ultimate; 3M, Maplewood, MN, USA).

For the subsequent shoulder preparation group the incisal edge of the same typodont tooth was then reduced by 1.5 mm to simulate the S incisal preparation using a diamond disk (Thin-flex; Premier, Plymouth, PA, U.S.A) and sharp edges were rounded with a silicone point (Silicone Polishing Point, X-Fine; Shofu, Kyoto, Japan) to avoid stress concentrations in the veneers *(Figure 1B)*.[12,18] All modifications were carried out by 1 operator. For customization of the S group, the shoulder

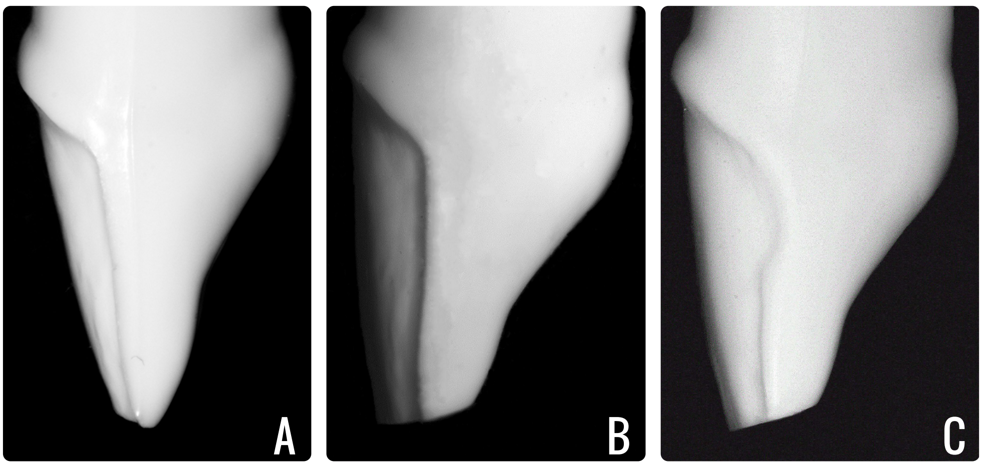

Figure 1: A) Feather edge preparation. B) Shoulder preparation. C) Shoulder with wing preparation.

master specimen was then duplicated by following the same methodology as for group FE and then further modified by placing a mesial and distal C shape wing using a chamfer diamond rotary instrument (770.10, Two Striper; Premier Dental, Plymouth, PA, U.S.A) as shown in Figure 1C. The SW master specimen was then duplicated using the same methodology as previously described. All specimens were evaluated for consistency by using a master matrix made from laboratory putty and confirmed with electronic calipers (Digital Ip54 Caliper; Moore & Wright, Sheffield, England).

One specimen for each group was scanned (Ceramill Map 400; Amann Girrbach AG, Pforzheim, Germany), and veneers were designed using CAD software (Ceramill Mind CAD; Amann Girrbach AG, Pforzheim, Germany). All 3 groups of ceramic veneers were designed with a 0.5 mm labial thickness, and an internal cement spacer of 50 µm was incorporated into the design, with no marginal gaps. On the surface of the veneers, 0.5×0.5-mm-raised dimples were placed to act as guides when doing the vertical and horizontal sectioning *(Figure 2A)*. All the veneers were evaluated for marginal fit by a single operator by seating them with finger pressure and using an optical light microscope (Alphaphot-2 YS2; Nikon, Tokyo, Japan). If a gap was observed a stereomicroscope (Nikon SMZ800N; Nikon, Tokyo, Japan), was used to measure the gap and, if it exceeded 50 µm, the veneer was discarded. The intaglio of each veneer was airborne-particle abraded (Basic master; Renfert, Hilzingen, Germany) with 50-µm aluminum oxide at 0.2 MPa for 2 seconds at 10 cm from the specimen and the prepared teeth and veneer were steamed clean (Wasi steam; Wassermann, Hamburg, Germany) and dried. Scotchbond Universal; 3M adhesive was applied to the prepared tooth and veneer surfaces (Scotchbond Universal; 3M, Maplewood, MN, USA), and the excess was gently dispersed with oil-free air flow for 5 seconds. A dual-polymerized adhesive cement (Rely X ultimate; 3M, Maplewood, MN, USA) was applied to the intaglio, and the veneer was seated on the tooth using its path of insertion (vertical path for FE and S and rotational path for SW). A custom-made device was then used to apply sustained uniform pressure during cementation.[25] A disposable micro-applicator brush was used to remove excess cement (Microbrush; Microbrush International, Grafton, Wisconsin, USA) and initial placement was secured by light polymerizing a small area for 3 seconds using a polymerization light on 650 mW/cm^2 mode (Bluephase; Ivoclar AG, Schaan, Liechtenstein). Immediately afterwards, the margins were covered with glycerin gel (Liquid Strip; Ivoclar AG, Schaan, Liechtenstein) and the light-polymerizing process was repeated for 20 seconds on all surfaces. The specimen was then left for 6 minutes to allow complete auto-polymerization and then placed in distilled water at room temperature for 48 hours. For each group, 10 veneered teeth were sectioned vertically and the other 10 were sectioned horizontally as shown in Figure 2A. All the sectioning was done with a slow-speed diamond-coated saw (LECO VC-50 Model 801–900; LECO, Stockport, England) under constant water irrigation to Ø0.3-mm precision. One operator sectioned the specimens and two other members of the research team evaluated the sections for quality. Any sectioned veneers showing signs of fractures, cracks, cement voids, or porosities were discarded. The cut surfaces were polished using 0.05-µm grain size disks (LaboPol-21; Struers, Hovedstaden, Denmark) until the exact center of the specimen. The sectioned veneered teeth were then stored in distilled water at room temperature for 24 hours before measuring. The cement thickness was measured under a scanning electron microscope (SEM) (JEOL JSM-6700F; JEOL, Tokyo, Japan) in both the horizontal and vertical planes.

The cement thickness in the horizontal and vertical planes were calculated on the cross-sections by measuring the distance between the laminate veneer and the abutment at 5 points after sectioning *(Figure 2B and C)*. The measurement points were selected based on the literature, with a point located in the center of the buccal surface, a point 1 mm from the margins (incisal and cervical margins for the vertical sections, mesial and distal margins for the horizontal sections), and a point at the mid-distance between the center of the buccal surface and the margins on each side.[27] As seen in figure 2B the thicknesses measured on the vertical sections were as follow: V1 cement thickness 1mm from the incisal margin; V2 cement thickness 1mm from the cervical margin; V3 cement

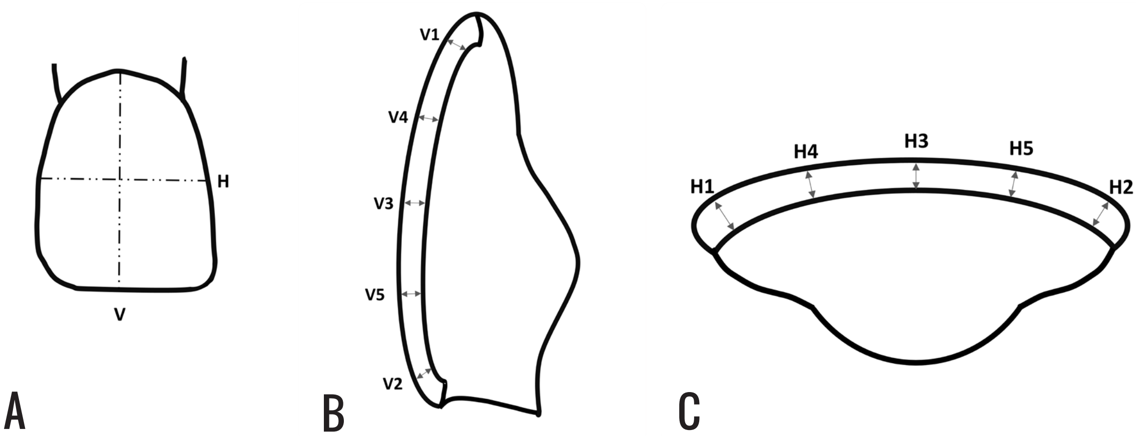

Figure 2: A) Frontal view locating the center of laminate veneer in the horizontal and vertical planes. B) Sagittal side view identifying the measuring points on the vertical section: V1-V5. C) Axial incisal view identifying the measuring points on the horizontal sections: H1-H5.

thickness midway between V1 and V2; V4 cement thickness midway between V1 and V3; V5 cement thickness at mid-distance between V3 and V2. Figure 2C illustrates, the thicknesses measured on the horizontal sections as follows: H1 cement thickness 1 mm from the mesial margin; H2 cement thickness 1 mm from the distal margin; H3 cement thickness midway between H1 and H2; H4 cement thickness midway between H1 and H3; H5 cement thickness midway between H3 and H2.

The overall cement thickness was obtained by combining the values recorded for each point on the vertical and horizontal sections. Two researchers observed the SEM measurement data to avoid errors in interpretation. If any issue with the measurement quality was found, the data and specimen were coded and sent to an SEM data specialist to redo the measurements. The final data were entered into a spreadsheet (Excel; Microsoft, Redmond, Washington) by 1 operator and were then checked by a second researcher to confirm the proper transfer of data.

The data were transferred to a statistical software program (IBM SPSS Statistics, v27; IBM, Armonk, New York). The cement thickness measurements were taken from both vertical and horizontal sections. In each section, the five specific points chosen for measurement were considered and the data was transferred to IBM SPSS Statistics v27 for analysis. The multiple cement thickness measurement points were computed, and the mean value was calculated separately for vertical and horizontal sections. Later, the mean of all measurements from 60 samples was calculated, and further descriptive and comparative analyses were conducted to see the differences.

RESULTS

Descriptive analyzes were performed to identify missing data, errors, and outliers for vertical, horizontal, and overall mean cement thickness. The central tendency data, mean, standard deviation, confidence interval, and range are presented in Table 1. Later, the mean cement thickness on vertical, horizontal, and overall means were compared across three groups. The descriptive analysis showed that the cement thickness of the FE preparation design was consistently higher than the mean cement thickness of SW and S. Further bivariate analysis was conducted to identify the better-performing preparation design concerning cement thickness between groups.

Table 1. Descriptive analysis of average cement thickness.

	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Mean cement thickness in vertical sections							
Shoulder with wings	10	68.55	11.228	60.51	76.58	54.89	86.75
Feather edged	10	101.19	28.089	81.10	121.29	56.02	145.60
Shoulder	10	86.85	31.278	64.47	109.22	54.71	163.30
Total	30	85.53	27.790	75.15	95.91	54.71	163.30
Mean cement thickness in horizontal sections							
Shoulder with wings	10	75.25	23.538	58.41	92.09	49.74	117.42
Feather edged	10	80.17	19.069	66.53	93.82	53.31	109.32
Shoulder	10	67.58	20.005	53.26	81.89	36.77	102.61
Total	30	74.33	20.900	66.53	82.14	36.77	117.42
Mean cement thickness of all samples							
Shoulder with wings	10	71.90	13.062	62.55	81.24	54.06	98.26
Feather edged	10	90.68	13.911	80.73	100.64	71.40	112.26
Shoulder	10	77.21	18.186	64.20	90.22	55.26	111.36
Total	30	79.93	16.743	73.68	86.18	54.06	112.26

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A normality test was conducted to investigate the assumptions for one-way ANOVA analysis. A factor level Shapiro Wilk normality test (P>.05) suggested no evidence of non-normality for the variables, mean cement thickness in the horizontal average. Hence, an ANOVA test was conducted for this variable. A Kruskal Wallis test was conducted for other nonnormal data, vertical mean, and overall mean.

A test for homogeneity of variance was conducted before the ANOVA test, and the assumption was met to proceed further with the ANOVA test for mean cement thickness in the horizontal section. The ANOVA test suggested the overall F statistics were insignificant (F=0.918, df=2, P>.05, η^2=0.064); hence, pairwise comparison by Tukey's Honestly significant test was not performed. The eta effect size was moderate for these results *(Table 2)*.

The nonparametric multiple comparison tests suggested a statistically significant difference in mean ranks between groups when measured in vertical sections and combined mean cement thickness, as shown in Table 3. The means rank for SW was lower than S and FE. However, Dunn's Post hoc pairwise comparison suggested a statistically significant difference between SW and FE but not between SW and S, and S and FE *(Table 4)*. These results had a very high effect size (η^2=0.239).

DISCUSSION

Based on the findings of this study using milled zirconia veneers, the null hypothesis that no statistically significant difference would be found in the cement thickness of the 3 tooth-preparation designs for veneers was rejected, as the SW

Table 2. ANOVA test results for normal data.

	Sum of Squares	df	Mean Square	F	Sig.	Effect size
Mean cement thickness in horizontal section						
Between Groups	806.211	2	403.106	.918	.412	
Within Groups	11860.947	27	439.294			0.064*
Total	12667.158	29				

*Medium effect size

Table 3. Non-Parametric test results.

	N	Mean Rank
Mean cement thickness in vertical section	H=8.385; df=2; p<0.015; Effect size= 0.102	
Shoulder with wings	10	9.80
Feather edged	10	21.20
Shoulder	10	15.50
Mean of both vertical and horizontal	H=6.483; df=2; p<039 Effect size = 0.239	
Shoulder with wings	20	25.10
Feather edged	20	38.45
Shoulder	20	27.95

Table 4. Dunn's pairwise comparison.

	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Shoulder with wings-Feather edged for mean cement thickness overall	-13.350	5.523	-2.417	.016	.047
Shoulder with wings-Feather edged for mean cement thickness in vertical section	-11.400	3.937	-2.896	.004	.011

[a]. Significance values have been adjusted by the Bonferroni correction for multiple tests.

and S designs performed better than the FE design. The results indicated that the SW and S were comparable while the FE was not as ideal. The superior performance of the SW and S designs over the FE design suggests that the former two provide a more consistent and optimal cement thickness, which is crucial for the longevity and stability of zirconia veneers. The SW and S designs likely offer better marginal integrity and resistance to mechanical stresses, which are critical factors in the clinical success of dental restorations. The FE design, while potentially more conservative in terms of tooth reduction, appears to compromise the uniformity of cement thickness, potentially leading to weaker bonding and an increased risk of veneer failure.[3-7,26]

Various studies have highlighted the importance of preparation design in the success of zirconia restorations. For instance, a systematic review and meta-analysis by Baig *et al*. (2024) emphasized preparations with specific geometry significantly improve the fit of zirconia veneers. Additionally, a study by Chai *et al*. (2021) concluded that a butt joint (BJ) incisal preparation design provides a more uniform stress distribution within the ceramic veneer-tooth system compared to a feathered edge (FE) design and that this could potentially enhance the longevity and durability of ceramic veneers. A recent study introduced the modified shoulder preparation design incorporating a wing in the interproximal area.26 The modified S design incorporates a modified "C" shape wings into the interproximal region of a traditional S design. This has been reported to enhance the positioning of the veneer in 3 dimensions, but the cement thickness also needed assessment. That study reported that the SW preparation design produced the smallest cervical absolute margin discrepancy (AMD) and overhang. The SW preparation design was also proven to have comparable AMD and overhangs in the mesial and distal proximal areas when compared with the BJ preparation design.[26] These above studies align with our findings that the SW and S designs, which involve more defined preparation geometries, perform better than the FE design.

This study elaborates further on findings from a previous study on the modified laminate veneer S design published in 2023 by evaluating whether a modified shoulder veneer preparation would influence the vertical, horizontal, and overall cement thickness.[26]

Limitations of the study included the *in vitro* design, which may not fully replicate the clinical situation. Therefore, the new design concept needs clinical testing. The study examined one specific combination of cement and veneer material and cannot be entirely applied to all materials or situations. The use of typodont teeth allowed for improved standardization of the test specimens and limited the variables but cannot be directly applied to the bonding properties of a zirconia veneer to a natural tooth. However, since bond strength was not a parameter investigated in this study, this aspect does not influence these results. Furthermore, the use of typodont teeth versus natural teeth allowed standardization of tooth specimens and tooth preparation, limiting the variables in the study, and therefore increasing the reliability of the results.

The Dunn's Post hoc pairwise comparison *(Table 4*) suggests a statistically significant difference between SW and FE but not between SW and S, and not between S and FE. This again illustrates that the SW design is comparable with an S design and superior to an FE design in terms of overall cement thickness and the mean vertical dimension. This suggests the clinical viability of the SW and demonstrates a slight improvement in both the overall measured cement thickness and the vertical dimension when compared to FE and S designs.

A possible reason for these results is that the FE design only provides a single surface/plane for 1-dimensional positioning guidance during cementation. An S preparation design, on the other hand, has 2 surfaces/planes for 2-dimensional positioning guidance during placement, while the SW design provides 3 surfaces/planes for 3-dimensional positioning assistance during placement of the veneer, potentially resulting in improved cementation thicknesses.[15,24,26] These findings support the conclusions of an earlier study on the SW design laminate veneer preparation. The study demonstrated that integrating wing elements into the shoulder laminate veneer preparation improves the ease of veneer positioning during cementation.[26] This enhancement leads to improved adaptation and a decrease in cervical overhang, all achieved with minimal removal of additional tooth structure.[26] The interproximal wrapping created by the SW preparation design also facilitates esthetics in the interproximal area and helps produce a progressive emergence of the interdental extension.[23,29,30] The SW design has a modified interproximal wrap-around that has curved wings cut into the interproximal cervical third while still maintaining the natural tooth's interproximal contact area and marginal ridges of the tooth.[29] The curve incorporated into the SW design is intended to provide additional surfaces for locational feedback during veneer placement. This addition to a standard S design essentially provides 3-dimensional guidance during veneer cementation, with the C curve assisting in the vertical placement of the veneer. Incorporating wing elements into the shoulder laminate veneer preparation indicates enhanced assistance in veneer positioning during cementation. This leads to improved marginal adaptation, reduced cervical overhang, and a thinner cement layer in the vertical direction compared to the S and FE designs.[26]

This study underscores the importance of preparation design in the performance of milled zirconia veneers. The results reinforce that preparation geometry can assist the clinician and that the preparation design is essential for achieving the best clinical result. Future research should continue to explore the nuances of preparation designs to further refine these results.

CONCLUSIONS

Based on the findings of this *in vitro* study, the following conclusions were drawn:

- The SW and S preparation designs are statistically comparable in terms of horizontal, and overall mean cement thickness.
- The SW preparation design produced the smallest cement thickness on the vertical dimension.

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DECLARATION OF INTEREST

None

REFERENCES

1. Akbar, J.H., Petrie, C.S., Walker, M.P., Williams, K. and Eick, J.D. Marginal adaptation of Cerec 3 CAD/CAM composite crowns using different finish line preparation designs. *J Prosthodont*. 2006; **15**:155-163.
2. Alghazzawi, T.F., Lemons, J., Liu, P.R., Essig, M.E. and Janowski, G.M. The failure load of CAD/CAM generated zirconia and glass-ceramic laminate veneers with different preparation designs. *J Prosthet Dent*. 2012; **108**:386-393.
3. Baig, M.R., Qasim, S.S. and Baskaradoss, J.K. Marginal and internal fit of porcelain laminate veneers: A systematic review and meta-analysis. *J Prosthet Dent*. 2024; **131**:13-24
4. Kusaba, K., Komine, F., Honda, J., Kubochi, K. and Matsumura, H. Effect of preparation design on marginal and internal adaptation of translucent zirconia laminate veneers. *Eur J Oral Sci*. 2018; **126**:507-511.
5. Alenezi, A., Alsweed, M., Alsidrani, S. and Chrcanovic, B.R. Long-term survival and complication rates of porcelain laminate veneers in clinical studies: A systematic review. *J Clin Med*. 2021; **10**:1074-1093.
6. Boitelle, B., Mawussi, L. and Tapie, O. Fromentin. A systematic review of CAD/CAM fit restoration evaluations. *J Oral Rehabil*. 2014; **41**:853-857.
7. Goujat, A., Abouelleil, H., Colon, P., Jeannin, C., Pradelle, N., Seux, D., *et al*. Marginal and internal fit of CAD-CAM inlay/onlay restorations: A systematic review of *in vitro* studies. *J Prosthet Dent*. 2019; **121**:590-597.
8. Ha, S.R., Kim, S.H., Lee, J.B., Han, J.S., Yeo, I.S., Yoo, S.H., *et al*. Biomechanical three-dimensional finite element analysis of monolithic zirconia crown with different cement thickness. *J Adv Prosthodont*. 2015; **7**:475-483.
9. Sener, I., Turker, B., Valandro, L.F. and Ozcan, M. Marginal gap, cement thickness, and microleakage of 2 zirconia crown systems luted with glass ionomer and MDP-based cements. *Gen Dent*. 2014; **62**:67-70.
10. Reich, S., Uhlen, S., Gozdowski, S. and Lohbauer, U. Measurement of cement thickness under lithium disilicate crowns using an impression material technique. *Clin Oral Investig*. 2011; **15**:521-526.
11. May, L.G., Kelly, J.R., Bottino, M.A. and Hill, T. Effects of cement thickness and bonding on the failure loads of CAD/CAM ceramic crowns: multi-physics FEA modeling and monotonic testing. *Dent Mater*. 2012; **28**:e99–109.
12. Chai, S.Y., Bennani, V., Aarts, J.M., Lyons. and, Das, R. Stress distribution within the ceramic veneer-tooth system with butt joint and feathered edge incisal preparation designs. *J Esthet Restor Dent*. 2021; **33**:496-502.
13. Christensen, G.J. Have porcelain veneers arrived? *J Am Dent Assoc*. 1991; **122**:81.
14. Calamia, J.R. Clinical evaluation of etched porcelain veneers. *Am J Dent*. 1989; **2**:9-15.
15. Chai, S.Y., Bennani, V., Aarts, J.M. and Lyons, K. Incisal preparation design for ceramic veneers: A critical review. *J Am Dent Assoc*. 2018; **149**:25-37.
16. Clyde, J.S. and Gilmour, A.S. Porcelain veneers: a preliminary review. *Br Dent J*. 1988; **164**:9-14.
17. Gilmour, A.S. and Stone, D.C. Porcelain laminate veneers: a clinical success? *Dent Update*. 1993; **20**:167-169.
18. Chai, S.Y., Bennani, V., Aarts, J.M., Lyons, K. and Lowe, B. Effect of incisal preparation design on load-to-failure of ceramic veneers. *J Esthet Restor Dent*. 2020; **32**:424-432.
19. Sirous, S., Navadeh, A., Ebrahimgol, S. and Atri, F. Effect of preparation design on marginal adaptation and fracture strength of ceramic occlusal veneers: A systematic review. *Clin Exp Dent Res*. 2022; **8**:1391-1403.
20. Tsouknidas, A., Karaoglani, E., Michailidis N., Kugiumtzis D., Pissiotis A. and Michalakis, K. Influence of preparation depth and design on stress distribution in maxillary central incisors restored with ceramic veneers: A 3D finite element analysis. *J Prosthodont*. 2020; **29**:151-160.
21. Edelhoff, D. and Sorensen, J.A. Tooth structure removal associated with various preparation designs for anterior teeth. *J Prosthet Dent*. 2002; **87**:503-509.
22. Abuzenada, B., Alanazi, A., Saydali, W., Elmarakby, A., Koshak, H. and Alharthi, A. Current classification and preparation techniques of dental ceramic laminate veneers (Review article). *Int J Adv Res*. 2017; **5**:1973-1979.
23. Belser, U.C., Magne, P. and Magne, M. Ceramic laminate veneers: continuous evolution of indications. *J Esth Dent*. 1997; **9**:197-207.
24. Shetty, A., Kaiwar, A., Shubhashini, N., Ashwini, P., Naveen, D., Adarsha, M. *et al*. Survival rates of porcelain laminate restoration based on different incisal preparation designs: An analysis. *J Conserv Dent*. 2011; **14**:10-15.
25. Peumans, M., De Munck, J., Fieuws, S., Lambrechts, P., Vanherle, G. and Van Meerbeek, B. A prospective ten-year clinical trial of porcelain veneers. *J Adhes Dent*. 2004; **6**:65-76.
26. Bennani, V., Aarts, J.M. and Senthilkumar, A. Effect of a modified laminate veneer preparation design on absolute margin discrepancy and marginal overhang. *J Prosthet Dent*. 2024; **131**:252.e1-252.e8.
27. Al-Dwairi, Z.N., Alkhatatbeh, R.M., Baba, N.Z. and Goodacre, C.J. 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. *J Prosthet Dent*. 2019; **121**:470-476.
28. Chu, J., Bennani, V., Aarts, J.M., Chandler, N. and Lowe, B. The effect of different geometric shapes and angles on the fracture strength of IPS e.max computer-aided designed ceramic onlays: An *in vitro* study. *J Conserv Dent*. 2018; **21**:210-215.
29. Magne, P. and Douglas, W.H. Cumulative effects of successive restorative procedures on anterior crown flexure: intact versus veneered incisors. *Quintessence Int*. 2000; **31**:5-18.
30. Nattress, B.R., Youngson, C.C., Patterson, C.J., Martin, D.M. and Ralph, J.P. An *in vitro* assessment of tooth preparation for porcelain veneer restorations. *J Dent*. 1995; **23**:165-170.

