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RESEARCH AND EDUCATION

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

Ziad N. Al-Dwairi, BDS, MFDSRCS(Eng), MFDSRCS(Glasg), MFDSRCS Ed, PhD,[a]
Rana M. Alkhatatbeh, BDS, MClinDent,[b] Nadim Z. Baba, DMD, MSD,[c] and Charles J. Goodacre, DDS, MSD[d]

ABSTRACT

Statement of problem. The marginal and internal adaptations of porcelain laminate veneers (PLVs) are key elements in their long-term success. However, the marginal and internal fit obtained with a pressable material compared with computer-aided design and computer-aided manufacturing (CAD-CAM) needs further investigation as does the choice of cement used.

Purpose. The purpose of this in vitro study was to evaluate the marginal and internal fit of PLVs fabricated using pressing and CAD-CAM milling and cemented using 2 types of composite resin cement.

Material and methods. Twenty PLVs were fabricated from VITA PM9 pressable material, and 20 veneers were milled using VITA Blocs Mark II. Veneers were cemented to composite resin dies using either RelyX Veneer cement or Variolink-N cement. Specimens were embedded in clear resin and sectioned incisogingivally and mesiodistally. Marginal discrepancy at the incisal and cervical positions and the internal gap at 6 different locations were evaluated by using a scanning electron microscope. Two-way ANOVA followed by Tukey multiple comparisons were used to examine difference among groups (α=.05).

Results. The cement and fabrication methods did not show any significant effect for absolute marginal gap (AMG) at the incisal edge, AMG at the cervical margin or marginal gap at the incisal edge. However, both had a significant effect on marginal gap at the cervical margin (P=.038 for the fabrication method and P=.050 for the cement used). Also, both cement and fabrication methods had a significant effect on internal gap average (P<.001). The lowest gap values were reported for veneers fabricated from VITA PM9 by using the press technique and cemented with RelyX Veneer cement. When the position of gap measurements was taken into consideration, it was the only significant factor (P<.001 for the effect of position on AMG and P<.001 for the effect of position on marginal gap). Gaps at the cervical position were significantly lower than gaps at the incisal position.

Conclusions. Smaller marginal and internal discrepancies were recorded for PLVs fabricated by using the pressing technique and cemented using RelyX Veneer cement compared with milled veneers and Variolink-N cement. Larger discrepancies were present incisally than cervically. (J Prosthet Dent 2019;121:470-6)

Successful porcelain laminate veneers (PLVs) depend on factors such as mechanical strength, bonding properties,[1] and marginal and internal fit.[2-4] Fit is measured by the intimate contact between the veneer and the prepared tooth.[5-11] Intimate contact is recommended because composite resin cements are the weakest link in the porcelain veneer-resin cement-tooth complex.[12] The polymerization shrinkage of the luting composite resin generates internal stresses[13] that form microcracks that might propagate under mechanical loading and result in restoration fracture.[14,15] In addition, the composite resin wears with time, especially with larger marginal discrepancies, and, if exposed to oral fluids, it will absorb water which may result in deterioration of the resin matrix.[16-20] In addition, the difference in the coefficient of

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[a]Professor, Department of Prosthodontics, Jordan University of Science and Technology (JUST), Irbid, Jordan.
[b]Graduate student, Department of Prosthodontics, Jordan University of Science and Technology (JUST), Irbid, Jordan.
[c]Professor, Advanced Specialty Education Program in Prosthodontics, Loma Linda University, School of Dentistry, Loma Linda, Calif.
[d]Distinguished Professor, Advanced Specialty Education Program in Prosthodontics, Loma Linda University, School of Dentistry, Loma Linda, Calif.

Clinical Implications

In this study, all gap measurements were within the clinically acceptable values, and, therefore, both fabrication techniques and both cements are acceptable for the fabrication and cementation of porcelain laminate veneers. However, fit was better with pressing than with milling.

thermal contraction of the bonded surfaces may result in a marginal discrepancy after temperature changes in the oral cavity.[21] Therefore, as close an adaptation of the porcelain veneer to the tooth preparation as possible is recommended to reduce the luting cement component and its exposure to the oral environment.[12]

Farrell et al[3] considered marginal discrepancies of gold inlays in the range of 34 to 119 μm as acceptable for subgingival margins and marginal discrepancies in the range of 2 to 51 μm as acceptable for supragingival margins.[22] Other investigators considered margins less than 120 μm as clinically acceptable,[22] while still others considered margins up to 150 μm as clinically acceptable.[23] Others reported marginal fit values to range between 7.5 μm and 206.3 μm.[24,25] This wide range might be due to variations in the definition of fit, the methods used to measure the fit, and the ceramic material being tested.[26-28]

To the best of the authors' knowledge, few studies have investigated the combined effect of the type of fabrication method—pressing versus computer-aided design and computer-aided manufacturing (CAD-CAM)—and the type of composite resin cement on the marginal and internal fit of PLVs. Differences in the marginal and internal discrepancy values between different cements have been reported.[10,29-35] Therefore, the purpose of this in vitro study was to compare the marginal and internal fit of PLVs fabricated by pressing and CAD-CAM and cemented using 2 types of composite resin cement. The null hypothesis was that neither the fabrication technique nor the cement used would influence the marginal and internal fit of PLVs.

MATERIAL AND METHODS

A maxillary left central incisor ivorine typodont tooth (860 Series Dentoform; Columbia Dentoform Teaching Solutions) was used to create a master PLV preparation. A conventional veneer preparation was made with a preparation rotary instrument set (Ceramic Veneer System for porcelain veneers; Komet Dental). Depth orientation grooves were prepared followed by reduction with tapered diamond rotary instruments and finishing stones. The reduction at the facial surface of the tooth was 0.4 mm in the cervical third with a chamfer finish line. The preparation ended 1.0 mm occlusal to the cemento-enamel junction. At the middle and occlusal thirds, the reduction was 0.5 mm. Proximally, the preparation extended lingually without removing the proximal contact area. The prepared tooth was scanned using CAD-CAM technology (Ceramill Map 400+ scanner; Amann Girrbach AG), and 40 composite resin dies were made from photopolymerized acrylic resin (Ceramill Gel; Amann Girrbach AG) using a stereolithographic 3D printer (Formlabs 2; Formlabs Inc).

Twenty veneers were fabricated from a feldspathic glass-ceramic (VITA PM9; VITA Zahnfabrik) by pressing the veneers using the lost-wax technique according to the manufacturer's instructions. An additional 20 veneers were fabricated from a fine-structure feldspar ceramic (VITA-BLOCS Mark II; VITA Zahnfabrik) using a CAD-CAM milling machine (Ceramill Motion II; Amann Girrbach AG) according to the manufacturer's instructions. A series of different diameter grinding tools were used to mill the veneers. A grinding point of 1.8 was mounted at position 1, a grinding point of 1.4 was mounted at position 2, and a grinding point of 1.0 was mounted at position 3.

Ten veneers from each ceramic material were cemented to their corresponding composite resin dies using a composite resin cement (RelyX Veneer cement; 3M) by 1 operator (R.M.A.). The intaglio surface of each veneer was treated with a 9.5% hydrofluoric acid solution (Vista Dental; Ada Product Co, Inc) for 60 seconds, washed with water, dried with oil-free air, and treated with a silane coupling agent (Bis-Silane; Bisco) for 20 seconds. The resin dies were treated with 37% phosphoric acid (Super Etch; SDI) for 15 seconds, washed with water, and dried for 10 seconds. A universal adhesive (Scotchbond Universal adhesive; 3M) was painted on the dies for 20 seconds and air dried for 5 seconds. Finally, an adequate amount of resin cement to cover the intaglio surface of each veneer was applied using a plastic instrument before the veneer was placed on its corresponding die using finger pressure. A microbrush moistened with bonding agent was then used to remove excess cement. The cement was light polymerized from 4 directions (mesial, distal, buccal, and incisal) for 40 seconds in each direction. The margins were finished with fine finishing and polishing rubber rotary instruments (Dental Polishers; KENDA AG).

The same cementation protocol was followed for the Variolink-N cement group (Variolink-N; Ivoclar Vivadent AG) except that the manufacturer's bonding agent (Te-Econom Bond; Ivoclar Vivadent AG) was used. All cementation procedures were performed at room temperature.

The veneers were classified into 4 groups based on the method of fabrication and type of composite resin cement used (Table 1). The specimens were placed in the center of prefabricated plastic molds and invested with clear chemically polymerizing acrylic resin (mega SIN ORTHO; megadental GmbH) to form blocks. The

Table 1. Study groups

Group	Fabrication Method	Cement Type
CR (CAD-CAM/RelyX)	CAD-CAM (Ceramill Motion II; Amann Girrbach AG)	RelyX Veneer
PR (Press/RelyX)	Press fabrication technique	RelyX Veneer
CV (CAD-CAM/Variolink)	CAD-CAM	Variolink-N Veneer
PV (Press/Variolink)	Press fabrication technique	Variolink-N Veneer

specimens were then sectioned mesiodistally and incisogingivally at the center of each tooth surface and perpendicular to the margins using a sectioning machine (IsoMet 1000 Precision Cutter; Buehler).[36]

The sectioned specimens were examined with a scanning electron microscope (Quanta 450 FEG; Thermo Fisher Scientific Inc) at ×200 magnification. The thickness of the resin cement was measured at 8 points to obtain 2 marginal and 6 internal measurements. For assessment of the marginal fit, 2 parameters were obtained: marginal gap (MG) and absolute marginal gap (AMG). The definitions stated by Holmes et al[37] were followed for MG and AMG. AMG is the distance from the internal edge of the coping margin to the preparation finish line and was measured at the cervical and incisal margins. MG is the perpendicular distance from the internal surface of the coping to the margin of the preparation and was measured at the cervical and incisal margins.

For the internal fit evaluation, the internal gap (IG) was also defined according to Holmes et al[37] as the perpendicular distance from the internal surface of the coping to the axial wall of the preparation. For each veneer, 6 internal measurements were located at the following distances: at a distance of 1.0 mm from the incisal margin, at the middle of the tooth incisogingivally (incisal quadrant), at a distance of 1.0 mm from the middle point toward the incisal, at the middle of the tooth incisogingivally (cervical quadrant), at a distance of 1.0 mm from the middle point toward the cervical, and at a distance of 1.0 mm from the cervical margin. Figure 1 shows the points of measurements on one of the specimens.

Four digital images that represent the locations of measurements for each specimen were made (Fig. 2). AMG at the incisal edge (AMGI), marginal gap at the incisal edge (MGI), AMG at the cervical margin (AMGC), marginal gap at the cervical margin (MGC), and IG at 6 different locations were measured for each specimen and tabulated. Statistical analysis software (Minitab v17; Minitab Inc) was used for data analysis. Two-way ANOVA followed by Tukey multiple comparisons were used to examine difference among groups (α=.05). Cement and fabrication techniques were set as the independent variables, and the gaps were considered the dependent variables. In addition, 3-way ANOVA was used to study the effect of position (incisal versus cervical) on the marginal discrepancies.

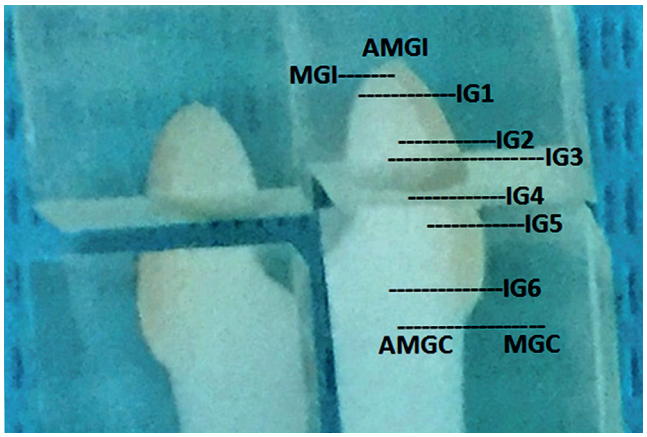

Figure 1. Points of marginal and internal gaps measurements. AMGC, absolute marginal gap at cervical margin; AMGI, absolute marginal gap at incisal edge; IG1, internal gap at distance of 1.0 mm from incisal margin; IG2, at middle of tooth incisogingivally (incisal quadrant); IG3, at distance of 1.0 mm from middle point toward incisal edge; IG4, at middle of tooth incisogingivally (cervical quadrant); IG5, at distance of 1.0 mm from middle point toward cervical margin; IG6, at distance of 1.0 mm from cervical margin; MGC, marginal gap at cervical margin; MGI, marginal gap at incisal edge.

RESULTS

The lowest mean AMGI value was reported in the CV group (CAD-CAM/Variolink) and was 164.2 ±131.3 μm, whereas the highest mean AMGI value was reported in the PR group (Press/RelyX) and was 266.4 ±108.7 μm. Neither the type of the composite resin cement (*P*=.105) nor the fabrication method (*P*=.432) had a significant effect on the mean AMGI value. Also, the interaction between the type of composite resin cement and fabrication methods showed no significant effect on the mean AMGI value (*P*=.972) (Table 2).

The lowest mean AMGC value was 89.5 ±48.8 μm in the CR group (CAD-CAM/RelyX), while the highest mean AMGC value was 111.4 ±57.8 μm in the CV group (CAD-CAM/Variolink). No statistical significant effects of the type of composite resin cement (*P*=.290), fabrication method (*P*=.423), and cement-fabrication method interaction (*P*=.966) were reported on the mean AMGC value (Table 3).

The lowest mean MGC value was 28.6 ±19.2 μm and was reported in the PR group (Press/RelyX), whereas the highest mean was 84.4 ±49.4 μm and was reported in the CV group (CAD-CAM/Variolink). The results showed that the mean MGC value was affected significantly by both fabrication method (*P*=.038) and the type of composite resin cement used (*P*=.050) (Table 4).

The lowest mean IG value was 62.5 ±24.5 μm in the PR group, whereas the highest mean IG value was 207.9 ±40.4 μm in the CV group. Both the type of the

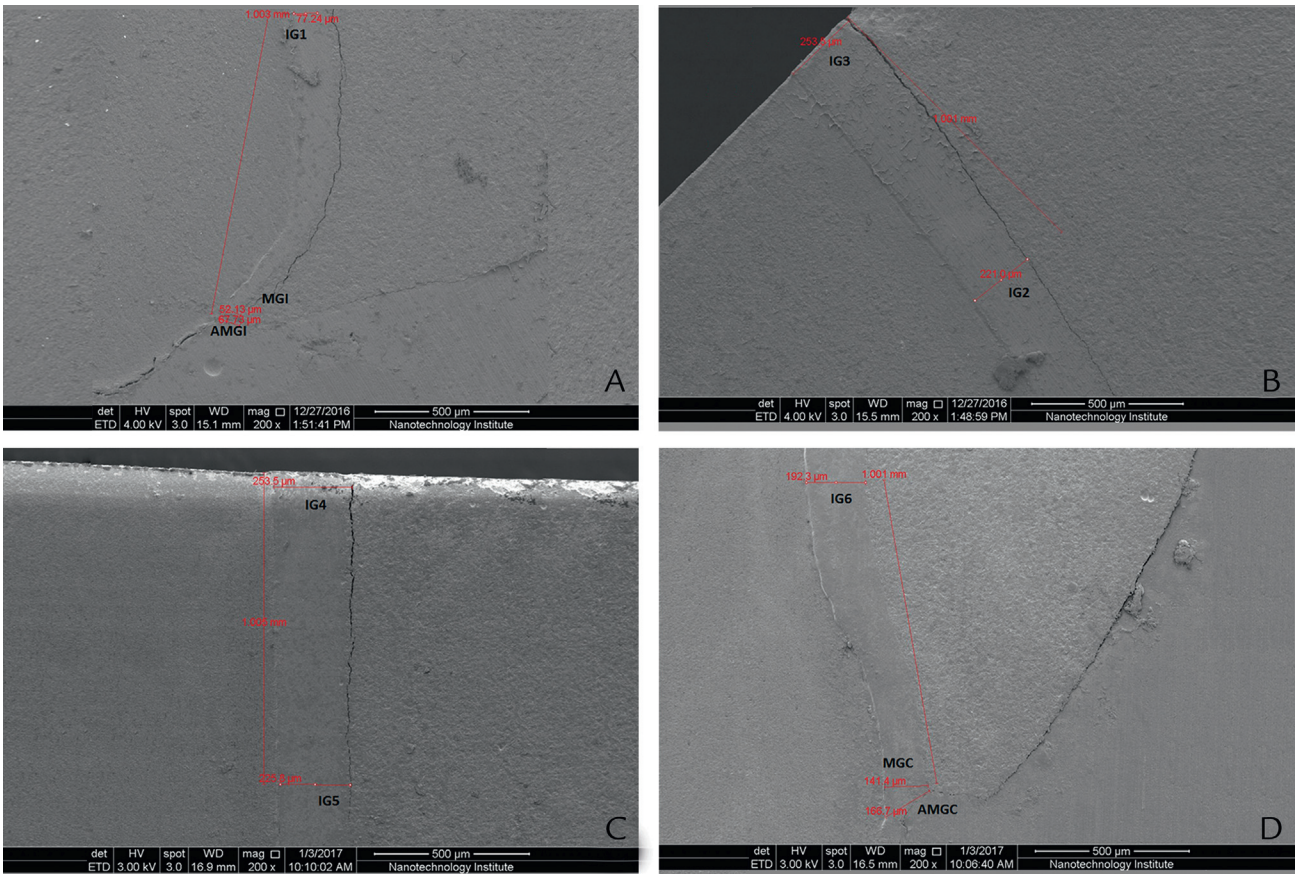

Figure 2. Digital images of gaps measurements. A, At incisal edge. B, At incisal midline section. C, At cervical midline section. D, At cervical margin. Original magnification ×200. AMGC, absolute marginal gap at cervical margin; AMGI, absolute marginal gap at incisal edge; IG1, Internal gap at distance of 1.0 mm from incisal margin; IG2, at middle of tooth incisogingivally (incisal quadrant); IG3, at distance of 1.0 mm from middle point toward incisal edge; IG4, at middle of tooth incisogingivally (cervical quadrant);IG5, at distance of 1.0 mm from middle point toward cervical margin; IG6, at distance of 1.0 mm from cervical margin; MGC, marginal gap at cervical margin; MGI, marginal gap at incisal edge.

Table 2. Means and standard deviations (μm) of tested groups

	Measurement			
	AMGI	AMGC	MGC	IG
Experimental group	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
CAD-CAM/RelyX	234.9 ±154.9	89.5 ±48.8	81.0 ±48.2	147.6 ±49.6
Press/RelyX	266.4 ±108.7	74.4 ±84.0	28.6 ±19.2	62.5 ±24.5
CAD-CAM/Variolink	164.2 ±131.3	111.4 ±57.8	84.4 ±49.4	207.9 ±40.4
Press/Variolink	198.7 ±119.2	94.6 ±46.5	78.9 ±44.5	112.8 ±43.9

AMGI, absolute marginal gap at incisal edge; AMGC, absolute marginal gap at cervical margin; MGC, marginal gap at cervical margin; IG, internal gap; SD, standard deviation.

composite resin cement and fabrication method significantly affected the mean values of the IG (P<.001) (Table 2).

Tables 3 and 4 show the mean values of AMG and MG at cervical and incisal positions. A 3-way ANOVA test indicated that position (incisal or cervical) was the only factor that significantly influenced the mean AMG and MG values (P<.001) and that the combination of the type of resin cement and position had no significant effect on the mean AMG values (P=.053).

Table 3. Three-way ANOVA results for testing the effect of cement, fabrication method, and position on AMG

Source	*df*	Sum Squares	Mean Squares	F	*P*
Model	7	369 129	52 733	5.13	<.001
Cement	1	11 282	11 282	1.1	.298
Fabrication method	1	1425	1425	0.14	.711
Position	1	296 978	296 978	28.89	<.001
Cement×fabrication method	1	2	2	0	.989
Cement×position	1	39 673	39 673	3.86	.053
Fabrication method×position	1	11 662	11 662	1.13	.290
3-way interactions	1	26	26	0	.960
Cement×fabrication method×position	1	26	26	0	.960
Error	70	719 535	10 279		
Total	77	1 088 663			

AMG, absolute marginal gap.

DISCUSSION

The marginal and internal fits investigated in this in vitro study identified the thickness of the composite resin cement film and reflected the real adaptation of the

Table 4. Three-way ANOVA results for testing effect of cement, fabrication method, and position on MG

Source	*df*	Sum Squares	Mean Squares	F	*P*
Model	7	246 250	35 179	4.35	<.001
Cement	1	298	298	0.04	.848
Fabrication method	1	5590	5590	0.69	.409
Position	1	184 948	184 948	22.87	<.001
Cement×fabrication method	1	25 496	25 496	3.15	.080
Cement×position	1	18 434	18 434	2.28	.136
Fabrication method×position	1	2806	2806	0.35	.558
3-way interactions	1	3148	3148	0.39	.535
Cement×fabrication method×position	1	3148	3148	0.39	.535
Error	70	566 122	8087		
Total	77	812 372			

MG, marginal gap.

restoration to its corresponding die.[10,30] Accordingly, the null hypothesis that the marginal and internal fit of PLVs would not be influenced by the PLVs fabrication technique or the cement used was rejected.

Resin dies fabricated from photopolymer resin were selected as teeth analogs for cementation of the veneers because of their uniform dimensions, homogenous structure that offers a reproducible medium for bonding, and the ability of composite resin cements to adhere efficiently to the surface of the dies.[30] However, natural teeth have different dimensions, different ages, different storage times, and different storage media after extraction. Therefore, bonding ability at the enamel- or dentin-cement interface could be affected.[38]

In the present study, evaluation of the fit of PLVs was performed after cementation of the veneers to their corresponding dies to reflect the actual adaptation in the mouth because higher marginal discrepancies were observed after the cementation procedure.[27,28] In addition, cementation may lead to chipping of the thin ceramic at the margin of the veneer as a result of the seating pressure which may significantly affect the marginal discrepancy measurements.[36]

The results of this study are consistent with studies that reported better fit of restorations fabricated with the use of the pressing technique over CAD-CAM fabricated copings.[31,38] Aboushelib et al[31] found that vertical and horizontal marginal discrepancies, internal discrepancies, and microleakage were significantly less in the pressable PLVs group than in the CAD-CAM group. Similarly, Lin et al[29] found smaller vertical gaps in conventionally sintered feldspathic PLVs than in the CAD-CAM PLVs.

The lowest mean vertical gap was recorded at the incisal surface, and the highest mean vertical gap was recorded at the mesial surface. This could be attributed to differences in the fabrication technique. The pressing technique permits accurate reproduction of fine details and provides more control over the fabrication of the wax pattern, which is built directly on the working die and can be easily shaped, modified, or adapted to the margins. The pressing process was performed under controlled pressure and temperature. However, with the CAD-CAM technique, the size of the grinding points in particular may result in difficulties in milling fine details such as the 0.5-mm finish line of the PLVs. In addition, chipping of thin porcelain margins due to vibration during milling could lead to marginal discrepancies that are larger on the opposite side of the sprue where vibration is likely to be higher.[29] Furthermore, the possible change in the surface of the virtual model after scanning of the dies may eliminate any irregularities in the surface to facilitate the milling process. CAD-CAM–fabricated zirconia copings showed significantly less marginal discrepancies and microleakage than heat-pressed lithium disilicate or cast Co-Cr copings.[39]

The few studies that have investigated the effect of using different composite resin luting agents on the fit of PLVs have reported no significant effect on the fit or microleakage values of PLVs.[10,31] However, in the present study, RelyX Veneer cement was associated with less marginal discrepancy than Variolink-N cement, and this may be attributed to reported differences in the viscosity and the degree of polymerization of these cements.[32] A composite resin cement with high viscosity may result in limited penetration time and consequently in a thick cement layer if insufficient pressure has been applied.[32] The degree of polymerization of the resin cement when subjected to light influences their mechanical properties, and this varies among different types of composite resin cements.[33,34] Marginal integrity may also be affected by factors such as polymerization shrinkage, water absorption, plasticity or hygroscopic expansion of the cement, thermocycling, occlusal stresses, and the bonding agent and its placement.[33,35,40]

In the present investigation, fabrication technique and the type of resin cement significantly affected the MGC, and both the AMG and MG were higher at the incisal aspect than at the cervical position, which is consistent with previous investigations.[10,11,41,42] A previous study that compared the marginal integrity of composite and ceramic veneers cemented using different types of cements reported mean marginal discrepancies from 105 μm at the cervical margin to 182 μm at the incisal margin. The mean marginal discrepancy (represented by AMG in the present study) varied from 125 μm at the proximal margin to 402 μm at the incisal margin.[10] In spite of variable gap widths between different fabrication techniques and luting material, the mean values observed for different groups in the present study were within a range of 164 to 266 μm for AMGI, 89.5 to 111 μm for AMGC, 126 to 210 μm for MGI, 28 to 84 μm for MGC, and 62 to 207 μm for IG. The recommended values of acceptable marginal adaptation vary based on several

factors such as whether the prosthetic restorations were cemented or not cemented and whether aging procedure was performed after cementation, location of measurement, kind of abutment, and kind of microscope.[27,29]

Clinically, the lack of accurate marginal fit may result in the ingress of bacteria and oral fluids under the cemented restoration leading to microleakage, staining, postoperative sensitivity,[6] recurrent caries, or pulpal inflammation. Optimum fit of dental restorations will maintain the biological health of its surrounding periodontal tissue and enhances the esthetic and mechanical properties of the dental restoration.[43]

The limitations of this study include the cementation of PLVs was performed under finger pressure, which does not guarantee complete, uniform seating of the veneers but is representative of the procedure used clinically. In future studies, the use of a special device to standardize the amount of pressure applied over each veneer during the cementation procedure is suggested. In addition, thixotropic characteristics are different between different types of composite resin cements, which could affect the ability to achieve a thin film thickness. Marginal integrity may also be affected by thermocycling, occlusal stresses, and the bonding agent and its placement.[44] It is recommended to perform further assessment of the marginal discrepancies after artificial aging.

CONCLUSIONS

Within the limitation of this in vitro study, the following conclusions were drawn:

1. The type of ceramic material, its fabrication method, and the type of composite resin cement significantly affected the mean marginal discrepancy at the cervical and mean IG values. RelyX Veneer cement-press combination had the lowest marginal discrepancy at the cervical and IG means. No statistically significant difference was found in gap measurements among the other 3 groups.
2. When the position of gap measurement is taken into consideration, it was the only factor that influenced the means of absolute marginal discrepancy and marginal discrepancy. Cervical margins had the lowest absolute marginal discrepancy and marginal discrepancy.

REFERENCES

1. Sailer I, Pjetursson BE, Zwahlen M, Hammerle CH. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part II: fixed dental prostheses. Clin Oral Implants Res 2007;18:86-96. Review. Erratum in: Clin Oral Implants Res 2008;19:326-8.
2. Moretti LA, Barros RR, Costa PP, Oliveira FS, Ribeiro FJ, Novaes AB Jr, et al. The influence of restorations and prosthetic crowns finishing lines on inflammatory levels after non-surgical periodontal therapy. J Int Acad Periodontol 2011;13:65-72.
3. Farrell CV, Johnson GH, Oswald MT, Tucker RD. Effect of cement selection and finishing technique on marginal opening of cast gold inlays. J Prosthet Dent 2008;99:287-92.
4. AL-Makramani BM, Razak AA, Abu-Hassan MI. Evaluation of load at fracture of Procera AllCeram copings using different luting cements. J Prosthodont 2008;17:120-4.
5. Amaal CM, Peris AR, Ambrosano GM, Pimenta LA. Microleakage and gap formation of resin composite restorations polymerized with different techniques. Am J Dent 2004;17:156-60.
6. Hekimoglu C, Anil N, Yalcin E. A microleakage study of ceramic laminate veneers by autoradiography: effect of incisal edge preparation. J Oral Rehabil 2004;31:265-9.
7. Albert FE, El-Mowafy OM. Marginal adaptation and microleakage of Procera AllCeram crowns with four cements. Int J Prosthodont 2004;17:529-35.
8. Aristidis GA, Dimitra B. Five-year clinical performance of porcelain laminate veneers. Quintessence Int 2002;33:185-9.
9. Höland W, Schweiger M, Watzke R, Peschke A, Kappert H. Ceramics as biomaterials for dental restoration. Expert Rev Med Devices 2008;5:729-45.
10. Celik C, Gemalmaz D. Comparison of marginal integrity of ceramic and composite veneer restorations luted with two different resin agents: an in vitro study. Int J Prosthodont 2002;15:59-64.
11. Morimoto S, Albanesi RB, Sesma N, Agra CM, Braga MM. Main clinical outcomes of feldspathic porcelain and glass-ceramic laminate veneers: a systematic review and meta-analysis of survival and complication rates. Int J Prosthodont 2016;29:38-49.
12. Peumans M, Meerbeek BV, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent 2000;28:163-77.
13. Nagem FH, Nagem HD, Francisconi PA, Franco EB, Mondelli RF, Coutinho KQ. Volumetric polymerization shrinkage of contemporary composite resins. J Appl Oral Sci 2007;15:448-52.
14. Stappert CF, Ozden U, Gerds T, Strub JR. Longevity and failure load of ceramic veneers with different preparation designs after exposure to masticatory simulation. J Prosthet Dent 2005;94:132-9.
15. Peumans M, De Munck J, Fieuws S, Lambrechts P, Vanherle G, Van Meerbeek B. A prospective ten-year clinical trial of porcelain veneers. J Adhes Dent 2004;6:65-76.
16. Petridis HP, Zekeridou A, Malliari M, Tortopidis D, Koidis P. Survival of ceramic veneers made of different materials after a minimum follow-up period of five years: a systematic review and meta-analysis. Eur J Esthet Dent 2012;7:138-52.
17. Krämer N, Lohbauer U, Frankenberger R. Adhesive luting of indirect restorations. Am J Dent 2000;13:60D-76D.
18. D'Arcangelo C, De Angelis F, Vadini M, D'Amario M. Clinical evaluation on porcelain laminate veneers bonded with light-cured composite: results up to 7 years. Clin Oral Investig 2012;16:1071-9.
19. Yeo IS, Yang JH, Lee JB. In vitro marginal fit of three all-ceramic crown systems. J Prosthet Dent 2003;90:459-64.
20. Shiratsuchi H, Komine F, Kakehashi Y, Matsumura H. Influence of finish line design on marginal adaptation of electroformed metal-ceramic crowns. J Prosthet Dent 2006;95:237-42.
21. Chun YH, Raffelt C, Pfeiffer H, Bizhang M, Saul G, Blunck U, et al. Restoring strength of incisors with veneers and full ceramic crowns. J Adhes Dent 2010;12:45-54.
22. Osman SA, McCabe JF, Walls AW. Film thickness and rheological properties of luting agents for crown cementation. Eur J Prosthodont Restor Dent 2006;14:23-7.
23. Eliasson A, Arnelund CF, Johansson A. A clinical evaluation of cobalt-chromium metal-ceramic fixed partial dentures and crowns: a three- to seven-year retrospective study. J Prosthet Dent 2007;98:6-16.
24. Kohorst P, Brinkmann H, Li J, Borchers L, Stiesch M. Marginal accuracy of four-unit zirconia fixed dental prostheses fabricated using different computer-aided design/computer-aided manufacturing systems. Eur J Oral Sci 2009;117:319-25.
25. Quintas AF, Oliveira F, Bottino MA. Vertical marginal discrepancy of ceramic copings with different ceramic materials, finish lines, and luting agents: an in vitro evaluation. J Prosthet Dent 2004;92:250-7.
26. Nawafleh NA, Mack F, Evans J, Mackay J, Hatamleh MM. Accuracy and reliability of methods to measure marginal adaptation of crowns and FDPs: a literature review. J Prosthodont 2013;22:419-28.
27. Contrepois M, Soenen A, Bartala M, Laviole O. Marginal adaptation of ceramic crowns: a systematic review. J Prosthet Dent 2013;110:447-44.
28. Limkangwalmongkol P, Chiche GJ, Blatz MB. Precision of fit of two margin designs for metal-ceramic crowns. J Prosthodont 2007;16:233-7.
29. Lin TM, Liu PR, Ramp LC, Essig ME, Givan DA, Pan YH. Fracture resistance and marginal discrepancy of porcelain laminate veneers influenced by preparation design and restorative material in vitro. J Dent 2012;40:202-9.
30. Aboushelib MN, Elmahy WA, Ghazy MH. Internal adaptation, marginal accuracy and microleakage of a pressable versus a machinable ceramic laminate veneers. J Dent 2012;40:670-7.

31. Ibarra G, Johnson GH, Geurtsen W, Vargas MA. Microleakage of porcelain veneer restorations bonded to enamel and dentin with a new self-adhesive resin-based dental cement. Dent Mater 2007;23:218-25.
32. Gu XH, Kern M. Marginal discrepancies and leakage of all-ceramic crowns: influence of luting agents and aging conditions. Int J Prosthodont 2003;16:109-16.
33. De Munck J, Vargas M, Van Landuyt K, Hikita K, Lambrechts P, Van Meerbeek B. Bonding of an auto-adhesive luting material to enamel and dentin. Dent Mater 2004;20:963-71.
34. Rosentritt M, Behr M, Lang R, Handel G. Influence of cement type on the marginal adaptation of all-ceramic MOD inlays. Dent Mater 2004;20:463-9.
35. Aleisa K, Al-Dwairi ZN, Alghabban R, Goodacre CJ. Effect of luting agents on the tensile bond strength of glass fiber posts: an in vitro study. J Prosthet Dent 2013;110:216-22.
36. Mitchell CA, Pintado MR, Douglas WH. Nondestructive, in vitro quantification of crown margins. J Prosthet Dent 2001;85:575-84.
37. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthet Dent 1989;62:405-8.
38. 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;104:216-27.
39. Yuksel E, Zaimoglu A. Influence of marginal fit and cement types on microleakage of all-ceramic crown systems. Braz Oral Res 2011;25:261-6.
40. Khoroushi M, Ehteshami A. Marginal microleakage of cervical composite resin restorations bonded using etch-and-rinse and self-etch adhesives: two dimensional vs. three dimensional methods. Restor Dent Endod 2016;41:83-90.
41. Bhowmik H, Parkhedkar R. A comparison of marginal fit of glass infiltrated alumina copings fabricated using two different techniques and the effect of firing cycles over them. J Adv Prosthodont 2011;3:196-203.
42. Ranganathan H, Ganapathy DM, Jain AR. Cervical and incisal marginal discrepancy in ceramic laminate veneering materials: a SEM analysis. Contemp Clin Dent 2017;8:272-8.
43. Celik N, Yapar MI, Taşpınar N, Seven N. The effect of polymerization and preparation techniques on the microleakage of composite laminate veneers. Contemp Clin Dent 2017;8:400-4.
44. Tuğcu E, Vanlıoğlu B, Özkan YK, Aslan YU. Marginal adaptation and fracture resistance of lithium disilicate laminate veneers on teeth with different preparation depths. Int J Periodontics Restorative Dent 2018;38(Suppl):s87-95.

Corresponding author:
Dr Ziad N. Al-Dwairi
Department of Prosthodontics
Faculty of Dentistry
Jordan University of Science and Technology (JUST)
PO Box 3030 code 22110
Irbid
JORDAN
Email: Ziadd@just.edu.jo

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Noteworthy Abstracts of the Current Literature

Immediate versus delayed loading of dental implants supporting fixed full-arch maxillaryprostheses: A 10-year follow-up report

Pera P, Menini M, Pesce P, Bevilacqua M, Pera F, Tealdo T

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Purpose. To compare clinical outcomes of immediate vs delayed implant loading in edentulous maxillae with full-arch fixed prostheses.

Material and methods. Two patient groups were identified for this study: (1) the test group (TG), which included 34 patients (19 women, 15 men; mean age 56.7 years) treated with the Columbus Bridge Protocol with 4 to 6 post-extractive implants loaded within 24 hours (163 implants total); and (2) the control group (CG), which included 15 patients (6 women, 9 men; mean age 59.96 years) treated with a traditional two-stage delayed loading rehabilitation using 6 to 9 implants inserted in healed sites (97 implants total). All patients were rehabilitated with full-arch fixed prostheses in the maxilla.

Results. At the 10-year follow-up, no difference in the implant cumulative survival rate between the TG (93.25%) and CG (94.85%) was found. Mean bone loss was significantly lower in the TG (mean: 2.11 mm) compared to the CG (mean: 2.65 mm). All original prostheses were maintained and functioning satisfactorily.

Conclusions. Maxillary full-arch immediate loading represents a valid alternative to the traditional delayed loading rehabilitation.

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