Original Article

pISSN, eISSN 0125-5614
M Dent J 2017; 37 (2) : 135-144

Marginal and internal gaps of crown and bridge substructure of two all-ceramic systems

Bundhit Jirajariyavej, Daungjan Siangsiaw, Chuchai Anunmana

Department of Prosthodontics, Faculty of Dentistry, Mahidol University

Objective: The objectives of this study were to compare the marginal and internal gaps of two ceramic systems as well as the marginal and internal gaps between single crowns and three-unit fixed dental prostheses (FDPs) substructures.

Materials and Methods: Ceramic substructures were fabricated using CAD/CAM (Lava™ Zirconia) and heat-press technique (IPS e.max® Press) as premolar and molar single crowns and three-unit FDPs (4 groups, n=10). Marginal and internal gap widths were determined and measured using silicone replica technique. Results were analyzed using Mann Whitney U-test (α= 0.05), and data were described as median and interquartile range.

Results: For IPS e.max® Press, there was no significant difference of marginal adaptation between the crown and bridge groups, except at the mesial marginal gap of premolar (Crown; 39 µm, Bridge; 106 µm). For Lava™ Zirconia, differences were found at several locations of the premolar and one point of the molar. Significant differences of marginal gap between IPS e.max® Press and Lava™ Zirconia crown substructures were found only in premolar. There were also significant differences of marginal fit of FDPs between two systems in both abutments. Significant differences of internal fit were mostly found in the axial wall and the cusp tip areas.

Conclusions: Most marginal and internal gaps of IPS emax® Press were greater than those of Lava™ Zirconia except at the occlusal locations. In addition, three-unit FDPs revealed larger gap widths than those of single crowns in both ceramic groups.

Key words: all-ceramic, CAD/CAM, glass-ceramic, internal fit, marginal fit, zirconia,

How to cite: Jirajariyavej B, Siangsiaw D, Anunmana A. Marginal and internal gaps of crown and bridge substructure of two all-ceramic systems. M Dent J 2017; 37:135-144

Introduction

Materials for fixed dental restoration can generally be classified into 3 types: all-metal, metal-ceramic and all-ceramic materials. Cast metal restoration exhibits high strength and toughness without risk of fracture; however, it can only be used in unaesthetic zone. Metal-ceramic crown and bridge meet patient's esthetic more than metallic restorations; nonetheless, the optical properties of this restoration do not mimic the natural teeth. In addition, the opacity of metal under glass veneer may sometimes be problematic. Moreover, the metallic pigmentation of gingiva may occur near the margin of the porcelain fused to metal restoration. [1] Some patients may also be allergic to metal alloys in contrast to all-ceramic materials that are more biocompatible. [2]

For decades, dental ceramic has been used for dental fixed restoration. [3] Interest in all-ceramic application is increasing, both for the anterior and posterior regions. Esthetics is major concern of patients and dentist for the anterior region. In the posterior region, the main purpose is to resist the masticatory force; therefore, the strength of the material is necessary. Ceramics that have been developed for fixed dental restorations include inlays, onlays, crowns, fixed dental prostheses, and implant-supported

Corresponding author: Chuchai Anunmana Department of Prosthodontics, Faculty of Dentistry, Mahidol University 6 Yothi St, Rajthevi, Bangkok 10400, Thailand Tel. (66)2-2007818 Fax. (66)2-2007816
Received : 21 March 2017 Accepted : 9 May 2017

restorations. [2] Metal under veneering glass provides high strength but is inferior in esthetics; therefore, high-strength all-ceramic materials have been developed. Ceramic substructure materials such as lithium disilicate, aluminium oxide, and zirconium oxide for all-ceramic fixed dental prostheses have been developed for more than 10 years and have become more popular in recent years. [3]

To consider the long-term clinical success of all-ceramic restorations, one of the most important factors for restoration longevity is the marginal and internal gaps. The presence of large marginal gap is prone to dental caries, periodontal disease, cement dissolution, and discoloration of the margin. [4,5] Internal gap (occlusal and axial spaces) should provide the optimal luting space, which affects the clinical strength of crown-cement system. [6] Moreover, good internal fit provides appropriate retention and resistance form. [7] The acceptable marginal gap for restoration in the range of 100-150 µm has been proposed. [4] There are many factors that influence the fit of ceramic restoration such as the type of fabrication systems, span length, veneering, finish line configuration, angulation of the preparation, cement space, and zirconia ageing. [4]

Marginal and internal adaptations of various ceramic materials have been widely studied. [8-10] There were many studies that compared the marginal and internal adaptation of CAD/CAM fabricated and heat-pressed ceramic materials. In one study, it was found that the ZrO_2 fabricated from CAD/CAM technique had smaller marginal gap than that of heat-pressed ceramic technique. [8] On the other hand, heat-pressed ceramics exhibited smaller marginal gap than those of CAD/CAM fabricated zirconia ceramics (Cercon® and LAVA™) in other studies. [9,10] Differences of marginal opening between single crown and fixed dental prostheses were also investigated in many studies. [11-13] Most studies found that long-span fixed dental prostheses exhibited greater marginal opening than that of single-unit restoration. [11-13]

However, there were very few studies comparing the marginal and internal fit between zirconia and lithium disilicate substructures, therefore, the purpose of this study was to compare the marginal and internal gaps between single crown and three-unit substructures fabricated from two all-ceramic systems, Lava™ Zirconia and IPS e.max® Press.

Materials and Methods

Plastic maxillary teeth (Columbia Dentoform Corp, NY, USA) were embedded in type III dental stone platform (Comet 3, Ultima, Thailand) simulating a maxillary second premolar and maxillary second molar for three-unit fixed dental prostheses abutments. A putty-type silicone impression (Express, 3M ESPE, St.Paul, MN, USA) was made as a silicone index prior to abutment preparation to ensure uniformed reduction of abutment teeth. The abutment teeth were prepared as all-ceramic single crown and three-unit fixed dental prostheses (FDPs). The preparation guideline was as follows: 1 mm wide circumferential chamfer, 2 mm occlusal reduction, and 8-degree angle of total occlusal convergence (TOC). The approximate height of each prepared tooth was 4 mm with rounded line angle. TOC was verified using dental surveyor (Paraflex, Bego, Breman, Germany) to ensure the approximate 8 degrees of tooth preparation.

After the preparation was completed, the plastic abutment teeth in dental stone platform were duplicated using polyvinylsiloxane impression material (Wirosil®, Bego, Germany) and casted for a standardized Co-Cr model. The casted model was cleaned, polished, and finished by one operator. The finished standardized Co-Cr model is shown in Figure 1.

Forty impressions were taken on standardized Co-Cr model using customized

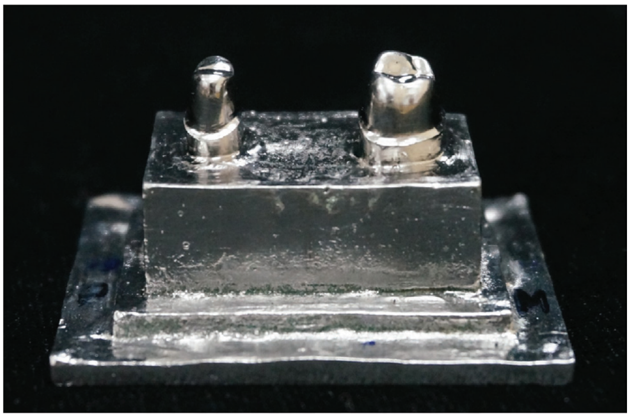

Figure 1. A standardized Co-Cr model

perforated plastic tray and polyether impression material (Impregum™, 3M ESPE, St. Paul, MN, USA). All impressions were poured with type IV die stone (Velmix Kerr Lab, California, USA) as working casts. Forty working casts were randomly assigned according to ceramic materials (Lava™ Zirconia and IPS e.max® Press) and types of restorations (single crown and three-unit FDPs), therefore, ten working casts were prepared for ceramic restorations within four experimental groups as shown in Table 1.

Marginal and internal gaps were determined using silicone replica technique. First, the fitting surface of substructures were filled with low-viscosity polyvinylsiloxane (Express XT, 3M ESPE, St. Paul, MN, USA) and subsequently placed on the abutment teeth of standard Co-Cr model under 50-N load for 10 minutes. After the low-viscosity silicone material set, the substructures were removed from standard Co-Cr model while the thin layer of light body silicone film still conspicuously remained on the abutment teeth. The thin silicone film, which represented the space between abutment tooth and substructure, was stabilized by high-viscosity impression material (Express XT, 3M ESPE, St. Paul, MN, USA) using customized perforated plastic tray. The silicone plastic trays were sectioned using a blade in buccal-lingual and mesial-distal direction on the cutting guide of the tray into four pieces for each abutment as shown in Figure 2. All silicone replicas were examined under optical light microscope (Nikon eclipse E400 POL, Japan) at 50X magnification, and the photograph of the gap was taken using a digital camera (Canon EOS 450D, Japan). Gap measurement was made using Image pro plus software version 7.0 (Media Cybernetics, MD, USA).

For each substructure, the following 6 positions as shown in Figure 3 were used as the references for measuring the marginal and internal gaps according to Holmes *et al.* [14]

Figure 2. Silicone replica technique : Low-viscosity silicone is loaded at the fitting

Table 1. The working casts were divided by material types and types of restorations

Types of materials	Types of restorations	Number of working cast
Lava™ Zirconia	Single crown	10 premolar and 10 molar crowns
Lava™ Zirconia	Three-unit bridge	10 Three-unit bridges
IPS e.max® Press	Single crown	10 premolar and 10 molar crowns
IPS e.max® Press	Three-unit bridge	10 Three-unit bridges

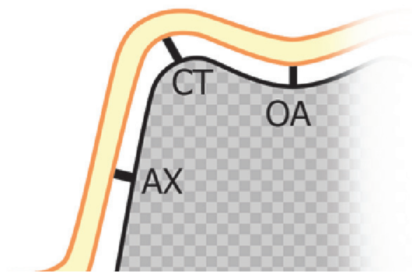

Figure 3. The reference points of the marginal and internal gaps

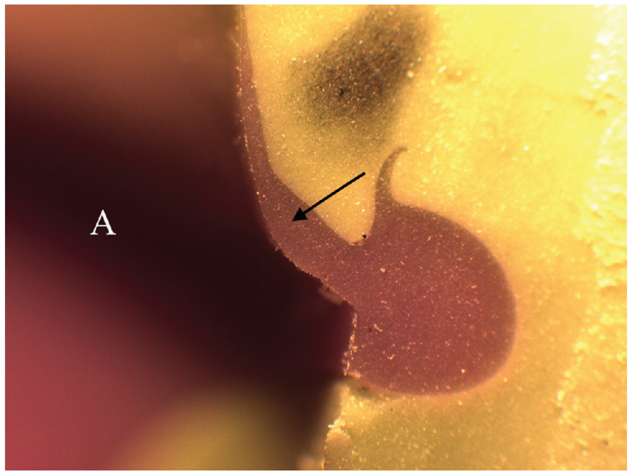

Figure 4. Optical micrograph of representative gap (arrow), A = abutment

The data were reported as median and 25th, 75th percentile values. The differences of marginal and internal gaps were determined by Mann-Whitney U-test statistic at a significant level of 0.05.

Results

1. Marginal adaptation

Marginal fit of substructures was investigated by using the values of absolute marginal discrepancy (AMD) and marginal gap (MG). Figure 4 shows the optical micrograph of the representative gap at 50X magnification. The median and 25^{th}, 75^{th} percentile of AMD and MG of premolar and molar substructures made from IPS e.max® Press and Lava™ Zirconia are listed in Tables 2 to 5.

Median marginal gaps of IPS e.max® Press group ranged between 39 – 82 and 38 – 106 µm while Lava™ Zirconia group ranged between 35 – 96 and 51 – 101 µm for single crown (Cr) and three-unit fixed partial denture or bridge (Br), respectively. There was no significant difference of gap widths between Cr and Br groups of IPS e.max® Press, except the MG at mesial side of premolar substructure ($p < 0.05$) as shown in Table 2. On the contrary, Lava™ Zirconia showed differences between Cr and Br groups for AMD and MG at mesial and buccal side of premolar and mesial side of molar MG as shown in Table 3.

There was no significant difference in the molar crown substructure between IPS e.max® Press and Lava™ Zirconia; nevertheless, premolar crown presented differences in 5 points as shown in Table 4. For the three-unit fixed dental prostheses, the differences showed in both premolar and molar bridge at mesial side (AMD and MG) of the premolar bridge and palatal and mesial side (AMD and MG) of the molar bridge substructure as shown in the table 5.

2. Internal fitness

The internal gaps were measured as chamfer area (CA), axial wall (AX), cusp tip (CT) and, occlusal adaptation (OA). The median gap width and 25^{th}, 75^{th} percentile are listed in Tables 2 to 5.

The significant differences between Cr and Br substructures fabricated from IPS e.max® Press were found in 5 points for the premolar substructure and 3 points for the molar substructure as shown in the Table 2. However, Lava™ Zirconia presented differences only in the palatal and mesial side of AX of molar substructure (Table 3).

The significant differences between IPS

e.max® Press and Lava™ Zirconia crown were presented in 8 points for the premolar substructure and 5 points for the molar substructure as shown in Table 4. Regarding the premolar and molar bridge substructure, most of the measurement locations exhibited significant differences as shown in Table 5.

Discussion

These results demonstrated that the marginal gaps of IPS e.max® Press were significantly greater than those of Lava™ Zirconia in premolar substructures, both of crown and bridge groups. The results were similar to another study, which showed that mean marginal discrepancy values of lithium-disilicate (IPS e.max® Press) copings were greater than those CAD/CAM fabricated Lava™ zirconia copings. [15]

Table 2. Median and 25^{th}, 75^{th} percentile (μm) of marginal and internal gap width of IPS e.max® Press premolar and molar substructure compared between single crown and three-unit bridge

Location	Side	e.max® premolar substructure		*p*-value	e.max® molar substructure		*p*-value
		Crown (n=10)	Bridge (n=10)		Crown (n=10)	Bridge (n=10)	
AMD	B	78 (64,106)	76 (60,128)	0.941	69 (58,131)	86 (71,105)	0.406
	P	77 (58,94)	93 (65,119)	0.364	94 (76,118)	106 (55,113)	0.651
	M	91 (65,108)	116 (84,125)	0.071	89 (68,103)	65 (52,83)	0.141
	D	102 (63,120)	82 (59,105)	0.326	100 (67,125)	109 (93,133)	0.406
MG	B	69 (53,98)	67 (50,93)	0.762	57 (35,125)	67 (44,80)	0.651
	P	56 (34,88)	74 (37,91)	0.762	82 (65,110)	66 (37,92)	0.257
	M	39 (36,57)	106 (68,127)	0.001*	58 (45,68)	42 (36,46)	0.095
	D	70 (57,116)	75 (28,96)	0.651	69 (60,96)	91 (69,137)	0.174
CA	B	156 (103,193)	200 (156,238)	0.059	139 (97,185)	199 (147,208)	0.096
	P	180 (122,213)	152 (127,187)	0.597	157 (106,226)	138 (118,160)	0.496
	M	166 (103,184)	250 (201,205)	0.001*	147 (117,189)	175 (143,195)	0.226
	D	143 (124,196)	158 (108,212)	0.762	164 (137,197)	181 (127,205)	0.705
AX	B	68 (51,103)	85 (65,95)	0.651	57 (44,96)	99 (86,107)	0.016*
	P	46 (30,66)	108 (81,135)	0.001*	64 (47,105)	58 (47,75)	0.427
	M	70 (56,117)	173 (157,195)	0.001*	72 (46,96)	96 (58,123)	0.096
	D	89 (67,98)	92 (72,127)	0.451	54 (48,80)	147 (118,194)	0.001*
CT	B	87 (72,113)	80 (59,141)	0.705	76 (49,121)	119 (58,145)	0.326
	P	108 (96,138)	92 (76,153)	0.364	117 (72,158)	127 (46,195)	0.941
	M	74 (52,102)	163 (119,182)	0.004*	100 (59,197)	88 (55,146)	0.364
	D	65 (44,106)	101 (45,165)	0.326	81 (68,106)	149 (84,207)	0.049*
OA	B-P	142 (75,267)	119 (87,170)	0.705	182 (118,227)	168 (120,215)	0.881
	M-D	148 (63,242)	96 (87,178)	0.821	174 (115,225)	143 (79,259)	0.496

* Indicates significant difference by Mann Whitney U-test at significant level of 0.05.
AMD = Absolute marginal discrepancy, MG = Marginal gap, CA = Chamfer area, AX = Axial wall, CT = Cusp Tip, OA = Occlusal adaptation, B = Buccal, P = Palatal, M = Mesial, D = Distal

Table 3. Median and 25th, 75th percentile (μm) of marginal and internal gap width of Lava™ Zirconia premolar and molar substructure compared between single crown and three-unit bridge

Location	Side	Lava™ premolar substructure		*p*-value	Lava™ molar substructure		*p*-value
		Crown (n=10)	Bridge (n=10)		Crown (n=10)	Bridge (n=10)	
AMD	B	54 (33,62)	78 (66,111)	0.004*	66 (49,103)	74 (41,88)	0.999
	P	64 (57,84)	81 (59,97)	0.406	88 (50,163)	112 (92,151)	0.174
	M	45 (37,62)	79 (53,87)	0.016*	67 (42,103)	82 (76,97)	0.151
	D	58 (38,81)	79 (55,109)	0.112	104 (68,182)	107 (89,118)	0.941
MG	B	38 (27,53)	70 (42,81)	0.016*	50 (32,90)	54 (35,78)	0.762
	P	50 (39,61)	53 (48,79)	0.545	75 (32,126)	101 (79,130)	0.226
	M	37 (28,45)	51 (37,67)	0.049*	42 (31,75)	75 (51,83)	0.049*
	D	35 (26,54)	48 (38,83)	0.071	96 (54,142)	90 (67,109)	0.496
CA	B	76 (67,89)	79 (51,97)	0.821	106 (82,118)	108 (94,130)	0.65
	P	99 (83,109)	90 (74,131)	0.762	88 (61,143)	134 (92,154)	0.174
	M	65 (58,84)	86 (44,118)	0.496	90 (74,113)	106 (94,110)	0.29
	D	71 (62,76)	90 (56,119)	0.364	120 (106,166)	131 (97,147)	0.821
AX	B	69 (51,88)	68 (61,92)	0.597	61 (45,77)	64 (56,86)	0.406
	P	49 (45,83)	63 (31,75)	0.881	59 (35,69)	71 (57,96)	0.034*
	M	35 (29,52)	53 (36,65)	0.291	45 (27,53)	79 (45,95)	0.026*
	D	49 (30,58)	47 (30,59)	0.821	37 (30,47)	46 (30,66)	0.291
CT	B	160 (157,181)	172 (125,186)	0.881	178 (162,210)	211 (185,238)	0.071
	P	153 (141,171)	170 (126,193)	0.496	176 (148,230)	239 (218,250)	0.096
	M	123 (108,135)	163 (118,181)	0.174	184 (160,218)	232 (178,255)	0.131
	D	95 (74,120)	101 (45,164)	0.677	121 (98,143)	154 (75,206)	0.545
OA	B-P	197 (188,221)	192 (163,223)	0.597	200 (173,295)	247 (209,283)	0.451
	M-D	203 (176,212)	189 (168,211)	0.406	215 (160,273)	267 (219,286)	0.257

* indicates significant difference by Mann Whitney U-test at significant level of 0.05.
AMD = Absolute marginal discrepancy, MG = Marginal gap, CA = Chamfer area, AX = Axial wall,
CT = Cusp Tip, OA = Occlusal adaptation, B = Buccal, P = Palatal, M = Mesial, D = Distal

The imprecision of heat-press ceramic (IPS e.max® Press) substructures that affected the restoration adaptability could be influenced by many factors; for example, the thickness of die spacer, [16] the shrinkage of wax pattern upon cooling at room temperature, [17] and the thermal shrinkage after pressing.[18] This thermal shrinkage is generally compensated by setting and thermal expansion of an investment material. [17] The CAD/CAM fabrication process such as scanning, design, milling, and sintering could affect the premature contact at the surface of the substructure and internal gap discrepancy. [21] Moreover, several fabricated steps in milling and sintering also cause the internal inaccuracy; for example, mismatch of milling instrument to narrow area, worn cutting instrument form prolonged use, [19] and software inaccuracy to compensate the material shrinkage. [12] In addition, the anisotropic shrinkage after post-sintering of zirconia blank caused the larger shrinkage in the horizontal axis than the tooth long axis. [12] Regarding this

Table 4. Median and 25th, 75th percentile (μm) of marginal and internal gap width of premolar and molar crown substructure compared between e.max® Press and Lava™ Zirconia

Location	Side	Premolar crown substructure		*p*-value	Molar crown substructure		*p*-value
		e.max® (n=10)	Lava™ (n=10)		e.max® (n=10)	Lava™ (n=10)	
AMD	B	78 (64,106)	54 (33,62)	0.008*	69 (58,131)	66 (49,103)	0.545
	P	77 (58,94)	64 (57,84)	0.364	94 (76,118)	88 (50,163)	0.762
	M	91 (65,108)	45 (37,62)	0.004*	89 (68,103)	67 (42,103)	0.364
	D	102 (63,120)	58 (38,81)	0.028*	100 (67,125)	104 (68,182)	0.705
MG	B	69 (53,98)	38 (27,53)	0.003*	57 (35,125)	50 (32,90)	0.496
	P	56 (34,88)	50 (39,61)	0.881	82 (65,110)	75 (32,126)	0.597
	M	39 (36,57)	37 (28,45)	0.496	58 (45,68)	42 (31,75)	0.406
	D	70 (57,116)	35 (26,54)	0.005*	69 (60,96)	96 (54,142)	0.406
CA	B	156 (103,193)	76 (67,89)	0.001*	139 (97,185)	106 (82,118)	0.131
	P	180 (122,213)	99 (83,109)	0.001*	157 (106,226)	88 (61,143)	0.071
	M	166 (103,184)	65 (58,84)	0.001*	147 (117,189)	90 (74,113)	0.007*
	D	143 (124,196)	71 (62,76)	0.001*	164 (137,197)	120 (106,166)	0.131
AX	B	68 (51,103)	69 (51,88)	0.999	57 (44,96)	61 (45,77)	0.941
	P	46 (30,66)	49 (45,83)	0.226	64 (47,105)	71 (57,96)	0.496
	M	70 (56,117)	35 (29,52)	0.016*	72 (46,96)	79 (45,95)	0.881
	D	89 (67,98)	49 (30,58)	0.001*	54 (48,80)	46 (30,66)	0.257
CT	B	87 (72,113)	160 (157,181)	0.002*	76 (49,121)	178 (162,210)	0.001*
	P	108 (96,138)	153 (141,171)	0.059	117 (72,158)	176 (148,230)	0.028*
	M	74 (52,102)	123 (108,135)	0.019*	100 (59,197)	184 (160,218)	0.023*
	D	65 (44,106)	95 (74,120)	0.199	81 (68,106)	121 (98,143)	0.010*
OA	B-P	142 (75,267)	197 (188,221)	0.762	182 (118,227)	200 (173,295)	0.406
	M-D	148 (63,242)	203 (176,212)	0.545	174 (115,225)	215 (160,273)	0.186

* Indicates significant difference by Mann Whitney U-test at significant level of 0.05.
AMD = Absolute marginal discrepancy, MG = Marginal gap, CA = Chamfer area, AX = Axial wall,
CT = Cusp Tip, OA = Occlusal adaptation, B = Buccal, P = Palatal, M = Mesial, D = Distal

precision of prosthesis adaptation. [19] During the post-machining sintering, the distortion of the framework and shrinkage of the pontic might produce bending stress on the substructure and influence its adaptability. [12]

In this study, IPS e.max® Press had larger gaps than those of Lava™ Zirconia except for the cusp tip and occlusal adaptation. The CAD/CAM fabricated Lava zirconia, which uses the optical scanner with striated projection, might cause the overshoots [20] and rounded edges [19,21] phenomena. These phenomena create the internal gap discrepancies. The overshoots phenomenon is a physical phenomenon, which produces the virtual peak adjacent the edges over the true contour of the die geometry. In reality, there is no elevation and therefore this may increase the internal gap, [20] and the rounded edges phenomenon creates the round angle at the true sharp angle of the object, which results in

Table 5. Median and 25th, 75th percentile (μm) of marginal and internal gap width of premolar and molar bridge substructure compared between e.max® Press and Lava™ Zirconia

Location	Side	Premolar bridge substructure		*p*-value	Molar bridge substructure		*p*-value
		e.max® (n=10)	Lava™ (n=10)		e.max® (n=10)	Lava™ (n=10)	
AMD	B	76 (60,128)	78 (66,111)	0.881	86 (71,105)	74 (41,88)	0.131
	P	93 (65,119)	81 (59,97)	0.364	106 (55,113)	112 (92,151)	0.034*
	M	116 (84,125)	79 (53,87)	0.007*	65 (52,83)	82 (76,97)	0.013*
	D	82 (59,105)	79 (55,109)	0.999	109 (93,133)	107 (89,118)	0.651
MG	B	67 (50,93)	70 (42,81)	0.941	67 (44,80)	54 (35,78)	0.545
	P	74 (37,91)	53 (48,79)	0.597	66 (37,92)	101 (79,130)	0.013*
	M	106 (68,127)	51 (37,67)	0.001*	42 (36,46)	75 (51,83)	0.001*
	D	75 (28,96)	48 (38,83)	0.651	91 (69,137)	90 (67,109)	0.881
CA	B	200 (156,238)	79 (51,97)	0.001*	199 (147,208)	108 (94,130)	0.001*
	P	152 (127,187)	90 (74,131)	0.003*	138 (118,160)	134 (92,154)	0.364
	M	250 (201,205)	86 (44,118)	0.001*	175 (143,195)	106 (94,110)	0.001*
	D	158 (108,212)	90 (56,119)	0.007*	181 (127,205)	131 (97,147)	0.071
AX	B	85 (65,95)	68 (61,92)	0.545	99 (86,107)	64 (56,86)	0.006*
	P	108 (81,135)	63 (31,75)	0.001*	58 (47,75)	59 (35,69)	0.496
	M	173 (157,195)	53 (36,65)	0.001*	96 (58,123)	45 (27,53)	0.002*
	D	92 (72,127)	47 (30,59)	0.001*	147 (118,194)	37 (30,47)	0.001*
CT	B	80 (59,141)	172 (125,186)	0.016*	119 (58,145)	211 (185,238)	0.004*
	P	92 (76,153)	170 (126,193)	0.071	127 (46,195)	239 (218,250)	0.001*
	M	163 (119,182)	103 (81,135)	0.010*	88 (55,146)	232 (178,255)	0.001*
	D	101 (45,165)	91 (62,117)	0.597	149 (84,207)	154 (75,206)	0.821
OA	B-P	119 (87,170)	192 (163,223)	0.034*	168 (120,215)	247 (209,283)	0.019*
	M-D	96 (87,178)	189 (168,211)	0.034*	143 (79,259)	267 (219,286)	0.049*

* indicates significant difference by Mann Whitney U-test at significant level of 0.05.
AMD = Absolute marginal discrepancy, MG = Marginal gap, CA = Chamfer area, AX = Axial wall,
CT = Cusp Tip, OA = Occlusal adaptation, B = Buccal, P = Palatal, M = Mesial, D = Distal

shrinkage, the zirconia blanks need to be adjusted in the terms of anisotropic shrinkage for post-machining sintering, including the composition and homogeneity of the pre-sintered zirconia block for more accuracy in milling protcedures. [12, 22]

This study demonstrated that both all-ceramic systems revealed the larger marginal gap width in three-unit FDPs than those of single crowns. This finding is similar to other studies. [13,22] Nevertheless, there are many factors that affect the marginal and internal discrepancy of all-ceramic materials such as types of finish line preparation, luting cement, manufacturing process, the porcelain veneering, and effect of zirconia ageing. [4] All of these factors should be considered in clinical application for better marginal and internal adaptation and long-term success of all-ceramic dental prostheses.

In this study, median marginal gaps of all groups were in the range of clinical acceptability suggested by McLean and von Fraunhofer. [23] However, median internal gaps in this study ranged from 35 – 267 µm; the lowest gap width was found in the axial wall and the greatest gap width was found in the occlusal adaptation of Lava™ Zirconia, which were greater than the recommended internal space, between 50 – 100 µm. [24]

There are several methods that investigate the gap width of restorations. Micro-CT is a non-destructive and reproducible method that evaluates the marginal and internal gaps of restoration, but it is impossible to demonstrate an accurate analysis when deficient radiographic contrast exists. [25] The most commonly used techniques were direct-view, followed by cross-sectioning and replica technique (47.5%, 23.5%, and 20.2%, respectively). [25] Direct-view technique is less time-consuming because it can proceed without multiple or complex procedures. Moreover, it is low-cost and reproducible method. On the other hand, its disadvantage is that it can only be measured at the margin, not the internal surface. [25,26] Cross-section of the embedded specimen and silicone replica methods are the techniques for marginal and internal gap investigations. The embedded technique is precise as measurement points are repeatable and accurate, but restoration must be sacrificed for measurement, therefore, it is not possible to evaluate at different stages of all-ceramic manufacturing or if further investigation on the same specimen is necessary. [27,28] On the contrary, the replica technique used in this study is non-destructive, easy to carry out, less time-consuming, and inexpensive. Furthermore, the silicone layer, which simulates the gap width, can be sectioned and measured at many locations. For these advantages, many researchers used impression replica method, which is reliable and acceptable when compared with the embedded method. [29]

There was no significant difference between the silicone material and zinc phosphate cement to verify post-cementation space. [30] The thickness of low-viscosity light bodies silicone of replica technique did not demonstrate any significant difference from the Fuji I glass-ionomer cement thickness of embedded method. [29] The mean gap values of impression replica method and cross-sectioning technique were similar. Moreover, light bodies silicone is reliable and accurate for imitation of the existing space. [29]

Conclusion

The gap comparison between two all-ceramic systems with different span length of substructures was evaluated and can be summarized as follows:

1. Substructures from both all-ceramic systems demonstrated *in vitro* acceptable marginal discrepancy. However, there should be further study on the effect of veneering process on the fit of ceramic restorations.

2. Given the limitation of this study, most marginal and internal gaps of IPS e.max® Press were greater than those of Lava™ Zirconia. However, Lava™ Zirconia showed larger gap value in occlusal area both of premolar and molar bridge. The proper tooth preparation and case selection with available interocclusal distance should be concerned.

3. Three-unit fixed dental prostheses exhibited the larger gap value than those single crowns in both ceramic systems in this *in vitro* study, therefore, careful attention is required for more extensive or multiple-unit ceramic restorations.

Funding: None
Competing interests: None
Ethical approval: None

References

1. Venclikova Z, Benada O, Bartova J, Joska L, Mrklas L. Metallic pigmentation of human teeth and gingiva: morphological and immunological aspects. ***Dent Mater*** 2006; 26: 96-104.
2. Gökçen-Röhlig B, Saruhanoglu A, Cifter ED, Evlioglu G. Applicability of zirconia dental prostheses for metal allergy patients. ***Int J Prosthodont*** 2010; 23: 562-5.
3. Conrad HJ, Seong WJ, Pesun IJ. Current ceramic materials and systems with clinical recommendations: a systematic review. ***J Prosthet Dent*** 2007; 98: 389-404.
4. Abduo J, Lyons K, Swain M. Fit of zirconia fixed partial denture: a systematic review. ***J Oral Rehabil*** 2010; 37: 866-76.
5. Colpani JT, Borba M, Della Bona A. Evaluation of marginal and internal fit of ceramic crown copings. ***Dent Mater*** 2013; 29: 174-80.
6. Martins LM, Lorenzoni FC, Melo AO, et al. Internal fit of two all-ceramic systems and metal-ceramic crowns. ***J Appl Oral*** Sci 2012; 20: 235-40.
7. Tuntiprawon M, Wilson PR. The effect of cement thickness on the fracture strength of all-ceramic crowns. ***Aust Dent J*** 1995; 40: 17-21.
8. Adel F. Ibraheem, Sattar J.A. Hmedat. A comparison of vertical marginal fit of three different types of all ceramic crown restorations (An In vitro study). ***J. Genet. Environ. Resour. Conserv.*** 2015; 3: 84-92.
9. Asavapanumas C, Leevailoj C. The influence of finish line curvature on the marginal gap width of ceramic copings. ***J Prosthet Dent*** 2013; 109: 227-33.
10. Ural C, Burgaz Y, Sarac D. In vitro evaluation of marginal adaptation in five ceramic restoration fabricating techniques. ***Quintessence Int*** 2010; 41: 585-90.
11. Beuer F, Neumeier P, Naumann M. Marginal fit of 14-unit zirconia fixed dental prosthesis retainers. ***J Oral Rehabil*** 2009; 36: 2.
12. Kunii J, Hotta Y, Tamaki Y, et al. Effect of sintering on the marginal and internal fit of CAD/CAM-fabricated zirconia frameworks. ***Dent Mater J*** 2007; 26: 820-6.
13. Reich S, Kappe K, Teschner H, Schmitt J. Clinical fit of four- unit zirconia posterior fixed dental prostheses. ***Eur J Oral Sci*** 2008; 116: 579-84.
14. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. ***J Prosthet Dent*** 1989; 62: 405-8.
15. Yüksel Ece, Zaimoğlu Ali. Influence of marginal fit and cement types on microleakage of all-ceramic crown systems. ***Braz Oral Res*** 2011; 25: 261-6.
16. Richardson DW, Fletcher VA, Gardner LK, Allen JD. Film thickness of die coating agents. ***J Prosthet Dent*** 1991; 66: 431-4.
17. Ivoclar North America. IPS Empress All-Ceramic Crown Laboratory Manual. Amhert, New York: Ivoclar North America; 1992.
18. Dong JK, Luthy H, Wohlwend A, Schärer P. Heat-pressed ceramics: technology and strength. ***Int J Prosthodont*** 1992; 5: 9-16.
19. Bornemann G, Lemelson S, Luthardt R. Innovative method for the analysis of the internal 3D fitting accuracy of Cerec-3 crowns. ***Int J Comput Dent*** 2002; 5: 177-82.
20. Pfeiffer J. Dental CAD/CAM technologies: the optical impression (II). ***int J Comput Dent*** 1999; 2: 65-72.
21. Luthardt R, Weber A, Rudolph H, et al. Design and production of dental prosthetic restorations: basic research on dental CAD/CAM technology. ***Int J Comput Dent*** 2002; 5: 165-76.
22. Beuer F, Naumann M, Gernet W, Sorensen JA. Precision of fit: zirconia three-unit fixed dental prostheses. ***Clin Oral Investig*** 2009; 13: 343-9.
23. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. ***Br Dent J*** 1971; 131: 107-11.
24. Ishikiriama A, Oliveira Jde F, Vieira DF, Mondelli J. Influence of some factors on the fit of cemented crowns. ***J Prosthet Dent*** 1981; 45: 400-4.
25. 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.
26. Schmalz G, Federlin M, Reich E. Effect of dimension of luting space and luting composite on marginal adaptation of a class II ceramic inlay. ***J Prosthet Dent*** 1995; 73: 392-9.
27. Mitchell CA, Pintado MR, Douglas WH. Nondestructive, in vitro quantification of crown margins. ***J Prosthet Dent*** 2001; 85: 575-84.
28. Shearer B, Gough MB, Setchell DJ. Influence of marginal configuration and porcelain addition on the fit of In-Ceram crowns. ***Biomaterials*** 1996; 17: 1891-5.
29. Rahme HY, Tehini GE, Adib SM, Ardo AS, Rifai KT. In vitro evaluation of "replica technique" in the measurement of the fit of Procera crowns. ***J Contemp Dent Pract*** 2008; 9: 25-32.
30. Laurent M, Scheer P, Dejou J, Laborde G. Clinical evaluation of the marginal fit of cast crowns – validation of the silicone replica method. ***J Oral Rehabil*** 2008; 35: 116-22.