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Original article

Marginal and internal fit of three-unit zirconia fixed dental prostheses: Effects of prosthesis design, cement space, and zirconia type

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ABSTRACT

Purpose: The purpose of this study was to compare the marginal and internal fit of three-unit fixed dental prostheses (FDPs) fabricated using CAD/CAM with two designs, two cement space (CS), and two zirconia types.

Methods: A master model with two zirconia abutments and a missing tooth was scanned with an intraoral scanner. FDPs were fabricated with two designs (Full contour: FC, Framework: FW), two zirconia types (multi-layer: L, single-layer: W), and two CS values (30 and 45 μm for L and 30 μm for W). There were six experimental groups. The fit of the FDPs was evaluated using the replica method. The space between an abutment and the FDPs in the marginal (MO), chamfer (CH), axial (AX), and occlusal (OC) areas was measured under an optical microscope and the data was statistically analyzed using three-way ANOVA and Bonferroni test ($p < 0.05$).

Results: FW-L-45 μm showed a significantly smaller space than those for the FC in MO ($p = 0.011$), CH ($p = 0.001$) and AXE ($p = 0.003$). FW-L-30 μm showed a significantly smaller space than that for the 45 µm in AXE ($p = 0.000$) and OC ($p = 0.016$). FW-W-30 µm showed a significantly smaller space than that for the L in MO ($p = 0.000$), CH ($p = 0.000$), AXE ($p = 0.000$), and OC ($p = 0.002$).

Conclusions: The design and CS of the FDPs affected the fit. FDPs with single-layer zirconia showed better fit than that obtained with multi-layer zirconia.

1. Introduction

Digital dentistry has become increasingly popular for enhancing the effectiveness of treatment procedures and outcomes. Along with that, materials with excellent properties have been developed for clinical applications. Zirconia has become increasingly popular in digital dentistry [1,2]. Zirconia has excellent strength, which is a shortcoming of conventional ceramic materials [3]. However, it is difficult to mimic the color and details of natural teeth with a single material.

Conventional zirconia is monochromatic and has low light transmittance, which limits its clinical application to the coping and framework in the aesthetic area [4]. Veneering porcelain has to be applied on the zirconia framework to obtain aesthetics similar to those of natural teeth. However, an inappropriate design of the supporting framework and a large discrepancy in the occlusal area [5] can cause delamination and fracture of the veneering porcelain. A highly translucent zirconia [6] and zirconia with a multi-layered structure [7] that may reproduce the various colors from the cervical area to the incisal edge of a natural tooth (multi-layer zirconia) have recently been developed. With these materials, it is now possible to fabricate an aesthetic monolithic zirconia without veneering porcelain [8,9], reduce the risk of fracture [10] and facilitating the laboratory process [7]. However, few studies have investigated the properties of highly translucent multi-layer zirconia, and the fit of fixed dental prostheses (FDPs) fabricated from this material has not been clarified.

The fit of FDPs fabricated using CAD/CAM has been previously reported. In past studies, there exists some reports that suggest the importance of marginal fit. [11,12]. Poor marginal fit of FDPs can increase plaque retention and change the distribution of the microflora, which might lead to the occurrence of microleakage, secondary caries, and root canal infection, and can induce the onset

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Fig. 1. Zirconia master model with two abutment teeth (mandibular left second premolar and second molar) with one missing tooth at the first molar area was prepared.

of periodontal diseases [13–15]. For most researchers, a marginal fit of below 120 µm in *in vivo* studies is clinically acceptable [16]. However, this is an old report, and there is no clear consensus regarding the appropriate marginal fit of FDPs on advanced dentistry. Until clear guidelines regarding acceptable misfit are available, clinicians should strive for the best FDPs fit possible to decrease potential complications [17].

There are two methods for manufacturing a zirconia FDPs: milling from a completely sintered zirconia disk (fully sintered zirconia) and milling from a semi-sintered zirconia disk (pre-sintered zirconia). Pre-sintered zirconia can be quickly manufactured because it has a relatively low flexural strength of 31 to 50 MPa [18]. However, since shrinkage of about 15 to 30% may occur during secondary firing, it is necessary to mill to a size that compensates for this shrinkage. This more complex production processes will affect the fitness of FDPs [19].

Morimoto et al. reported that the amount of dimensional change in zirconia strips depends on the thickness of the zirconia because the weight of the zirconia causes a morphological change during secondary firing [20]. However, there are no reports on the effect of the zirconia thickness in FDPs.

Many studies have attempted to compensate for the dimensional change to achieve a better fit of zirconia FDPs. One study adjusted the cement space (CS) before manufacturing. Kale et al. compared the marginal fit of single-crown zirconia with CS values of 30, 40, and 50 µm from the axial area to the occlusal area [21]. The results showed that the smallest marginal opening was obtained with a CS of 50 µm. However, there are no reports on the proper CS for multi-unit FDPs.

Here, we performed an in vitro study on the effects of FDPs designs, CS, and zirconia types on the fit of three-unit zirconia FDPs. The factors that contribute to a better fit of FDPs are identified. The null hypothesis were that the FDPs designs (full contour and framework), CS (30 and 45 μm), and zirconia types (single- and multi-layer zirconia) would not have effect on the marginal and internal fit of three-unit zirconia FDPs.

2. Materials and methods

2.1. Master model

In this study, a zirconia master model with two abutment teeth (mandibular left second premolar and second molar) with one missing tooth at the first molar area was prepared. Each abutment tooth had a 360° chamfer preparation for fabricating the three-unit all ceramic bridge (Fig. 1). The same operator obtained an optical impression of the master model 13 times with an intraoral scanner (Trios 3, 3SHAPE, Copenhagen, Denmark) to acquire 13 STL files.

2.2. FDPs designs

For each STL file, two types of FDPs, namely Full contour (FC group) and Framework (FW group), were designed using CAD software (S-WAVE Dental System Premium, Shofu, Kyoto, Japan). The

Table 1
The basic composition of the zirconia powder (Zpex smile®) that makes up the zirconia disk (SHOFU DISK ZR-SS LUCENT 5 L Lite and Pearl white) used in this study.

Y_2O_3 (wt%)	9.3
HfO2 (wt%)	<0.5
Al2O3 (wt%)	0.05
Na2O (wt%)	0.04
Si2O3 (wt%)	0.02
Fe2O3 (wt%)	0.01
Size (nm)	90
Crystallite Size (nm)	36

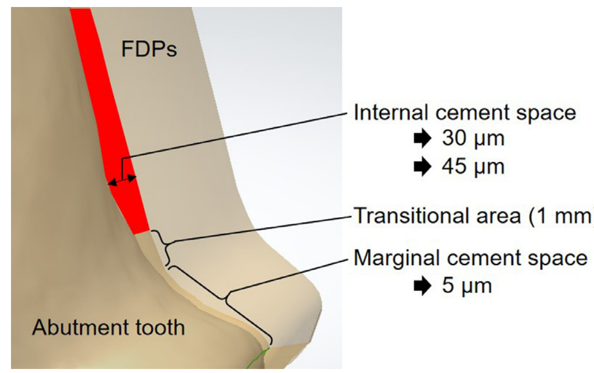

Fig. 2. Cement space used in each experimental group.

prosthesis fabricated for the FC was a fully anatomical zirconia bridge, whereas the design of the FW is a cutback for the fabrication of an all-ceramic bridge of the same design as the FC group.

2.3. Zirconia types

In the FDPs milling process with CAM software (GO2dental, Shofu), the FC and FW were further divided into subgroups according to zirconia type. The materials used for the fabrication of each design (FC and FW) were highly translucent zirconia (5 mol% partially-stabilized zirconia, 5Y-PSZ) with a single-layer structure (SHOFU DISK ZR-SS LUCENT Pearl white, Lot. DBU 146 D 191, Shofu; W group) and that with a multi-layer structure (SHOFU DISK ZR-SS LUCENT 5 L Lite, Lot. DBU 146 D261, Shofu; L group). These two zirconia disk have the same basic composition (Table 1) and crystal structure (tetragonal and cubic crystal). However, the amount of metal oxide particles as a colorant incorporated into each layer in the multi-layer zirconia desk is different.

The FDPs were placed so that both the FC and the FW had all the layers of the zirconia disk in L.

2.4. Cement space values

Setting the cement space was also performed in the CAD software. For the W, a CS of 30 μm was used for the axial and occlusal surfaces of the abutment. For the L, CS values of 30 and 45 μm were used. For all groups, the CS at the finish line was set to 5 μm (Fig. 2). Finally, each STL file was used to fabricated six types of FDPs, namely (i) FC-L-30 μm, (ii) FW-L-30 μm, (iii) FC-L-45 μm, (iv) FW-L-45 μm, (v) FC-W-30 μm, and (vi) FW-W-30 μm, for a total of 78 groups (n = 13/group).

2.5. Fabrication of FDPs

The semi-sintered FDPs were milled with a milling machine (DWX-51D Dental Milling Machine, Roland DGA) and then fired in

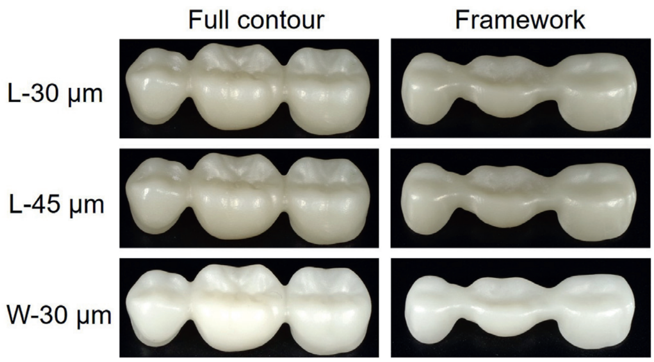

Fig. 3. FDPs fabricated in this study. Full contour (FC) and Framework (FW). Multi-layer structure (L) and Single-layer structure (W).

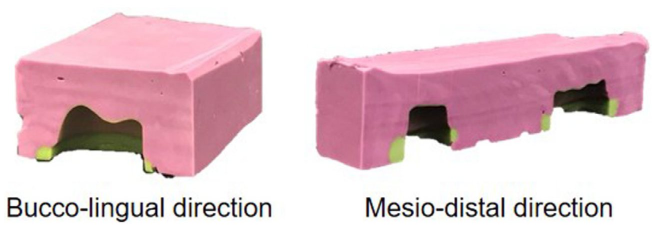

Fig. 4. Replicas segmented at the center of the second premolar and second molar in bucco-lingual and mesio-distal directions.

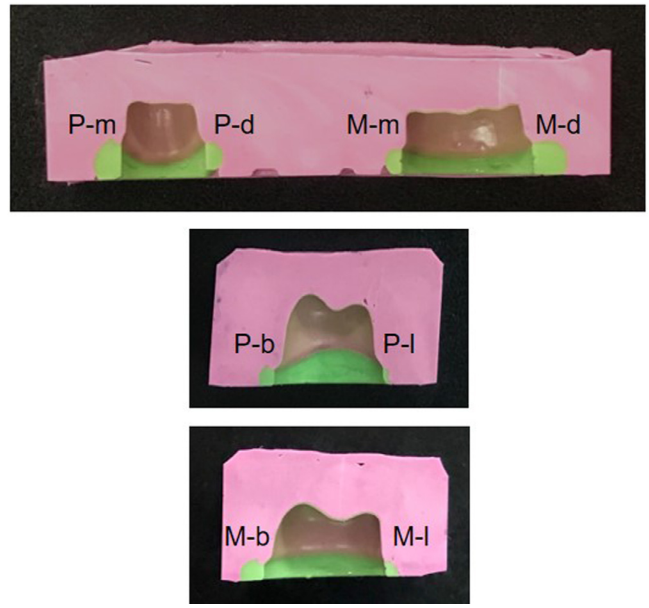

Fig. 5. Measurement points used in this study. (P-m: Premolar-mesial, P-d: Premolar-distal, P-b: Premolar-buccal, P-l: Premolar-lingual, M-m: Molar-mesial, M-d: Molar-distal, M-b: Molar-buccal, M-l: Molar-lingual).

a sintering furnace (Esthemat Sinta II, Shofu). The firing conditions were 1450 °C, a heating rate of 5 °C/min, and a heating time of 120 min. The FDPs were allowed to cool in the furnace. After firing, sand blasting was performed using 30 μm alumina particles for 10 to 20 s at 0.3 MPa to remove contaminants on the FDPs surfaces. The final FDPs are shown in Fig. 3.

2.6. Measurement of marginal and internal fit

The replica method [22] was applied to measure the marginal and internal fit. Each FDPs was filled with light-body silicone (Genie Light Body, Sultan Healthcare, York, PA, USA) and placed on the master model with finger pressure in accordance with the clinical procedure. After the light-body silicone was set, the FDPs were removed, with the thin silicone remaining on the master model. Subsequently, a heavy-body silicone (Genie Heavy Body, Sultan Healthcare) was put onto the thin silicon. After setting, the silicone replica was removed from the master model. A total of 156 replicas were made, two for each FDPs.

The replicas were segmented at the center of the second premolar and second molar in the bucco-lingual and mesio-distal directions, and thus four cross sections (bucco-lingual and mesio-distal sections of the second premolar, and bucco-lingual and mesio-distal sections of the second molar) were obtained for each FDPs (Fig. 4). The measurement points were the mesial (m), buccal (b), lingual (l), and distal (d) of the second premolar (P) and second molar (M) (Fig. 5).

The replicas were examined at 50 × magnification under an optical microscope (Axioscope 2, Zeiss, Oberkochen, Germany). An image of every cross-sectional specimen was taken with a digital camera (D90, Nikon, Tokyo, Japan) attached to the microscope. Several digital images were taken of each cross section and then merged using image processing software (Adobe Photoshop CS, Adobe Systems Inc., San Jose, CA, USA) to create a single image for each cross section (Fig. 6a). Then, the color image was converted into a grayscale image (Fig. 6b).

All images were transferred to an imaging data program (Optimas 6.5, Media Cybernetics, Silver Spring, MD, USA). A series of points was set manually on the outer boundary between the light- and heavy-body silicone and the inner boundary between the light-body silicone and master abutment (Fig. 6c). The computer program connected two points from one side, and a perpendicular line was dropped from a point on the opposite border (Fig. 6d). The length of the perpendicular line corresponded to the amount of space between the inner boundary of the master model and the FDPs. For each plane, about 6000 perpendicular lines were measured (Fig. 6e). The following four areas of each measurement point were measured (Fig. 7):

Marginal opening area (MO: finish line of the abutment tooth)

Chamfer area (CH: 1 mm from the finish line toward the axial wall of the abutment tooth)

Axial area (AX: the axial wall of the abutment tooth, except 1 mm of CH)

Occlusal area (OC: outer and inner inclinations of occlusal surface of the abutment tooth)

2.7. Statistical analysis

Mean value, standard deviation (SD) and median value were calculated from the obtained data. Statistical analysis (IBM SPSS Statistics, v21, IBM Corp) was performed using three-way analysis of variance (ANOVA) and Bonferroni's post-hoc test (Fig. 8). There were four factors (A) design, (B) CS, (C) zirconia type, and (D) measurement area, in this study. The factor (A)(B)(C) for comparison of FC and FW, 30 μm and 45 μm. The factor (B)(C)(D) for comparison of L and W.

3. Results

In this study, the effects of three factors, namely FDPs designs (FC and FW), CS (30 and 45 μm), and zirconia types (L and W), on prosthesis fit were evaluated. Table 2 shows the mean value, standard deviation (SD), and median value of the amount of space in the marginal opening area (MO) and the internal area (CH, AX, OC) between the abutment teeth and the FDPs. Table 3 shows the amount of space at each measurement point in the marginal open-

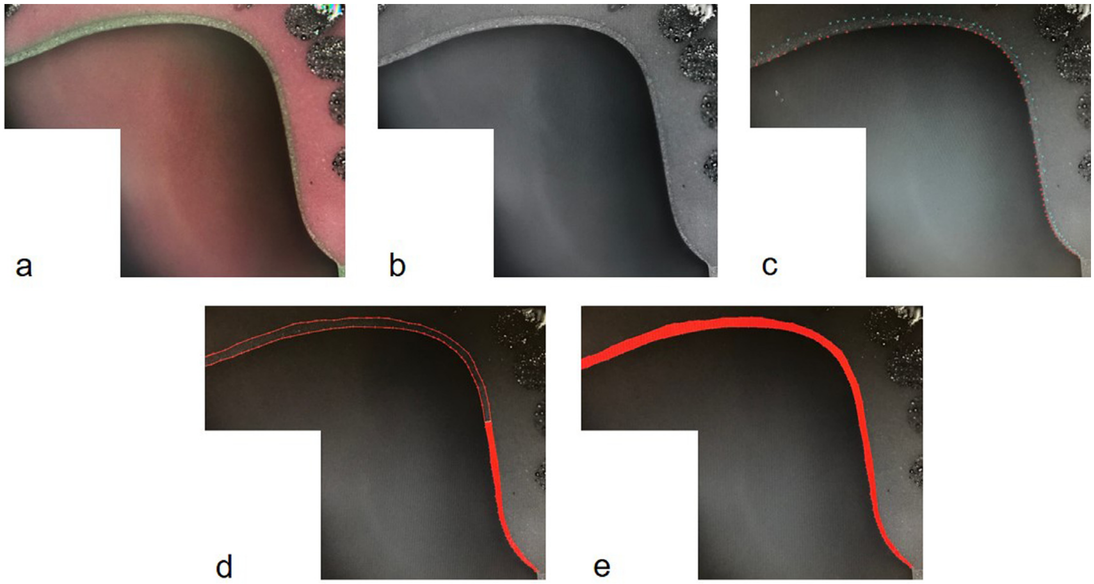

Fig. 6. (a): Digital images that were merged using image processing software. (b): Color image converted into a grayscale image. (c): Series of points was set manually on the outer boundary between light- and heavy-body silicone and the inner boundary between light-body silicone and abutment tooth. (d): About 6000 perpendicular lines were measured. (e): Perpendicular line length corresponds to the amount of space between the inner boundary of the abutment teeth and the FDPs.

Table 2
Mean value, standard deviation and median value of the amounts of space in the marginal opening area (MO) and the internal area (CH, AX, OC) between the abutment teeth and the FDPs.

Design	Cement space (|jm)	Material	Area	Mean (|jm)	SD	Median (|jm)
Full contour	30	Multi-layer	MO	41.52	16.33	36.27
			CH	42.65	12.53	37.91
			AX	46.19	4.77	45.62
			OC	82.20	23.07	76.19
Framework	30	Multi-layer	MO	43.76	7.81	43.06
			CH	41.44	4.81	41.14
			AX	43.64	5.11	45.76
			OC	85.97	142.03	84.57
Full contour	45	Multi-layer	MO	32.77	7.80	35.32
			CH	32.67	5.88	31.27
			AX	51.31	5.47	51.81
			OC	87.31	13.48	84.24
Framework	45	Multi-layer	MO	43.49	9.82	43.19
			CH	43.70	8.07	43.66
			AX	57.47	8.48	53.73
			OC	98.63	16.44	100.94
Full contour	30	Multi-layer	MO	34.23	10.48	31.71
			CH	34.39	10.00	34.34
			AX	27.95	4.49	27.19
			OC	78.43	17.50	76.07
Framework	30	Multi-layer	MO	26.28	6.99	23.44
			CH	27.41	6.08	25.04
			AX	30.98	4.60	31.21
			OC	64.02	14.78	6194

ing area. The amount of space for each group was shown as a graph in Fig. 9.

3.1. FDPs designs

The mean values of the space between the FDPs and abutment teeth, which represent the marginal and internal fit for the different designs (FC and FW), were shown in Fig. 9a. This graph showed the space in four areas (MO, CH, AX, and OC). Only multi-layer zirconia was used for this analysis because it had both 30 and 45 µm for CS.

When CS was set to 45 µm, the spaces in the marginal (MO), chamfer areas (CH) and axial area (AX) were significantly different. The fit in MO for FC and FW were 32.77 ± 7.80 and 43.49 ± 9.82 µm, respectively ($p = 0.011$). In CH, the spaces for the FC and FW were 32.67 ± 5.88 and 43.70 ± 8.07 µm, respectively ($p = 0.001$). In AX, the spaces for the FC and FW groups were 51.31 ± 5.47 and 57.47 ± 8.48 µm, respectively ($p = 0.003$).

3.2. Cement space

CS values of 30 and 45 µm were compared. The comparison was made using only the L group, since it had both CS values. The average values of the space for different CS values were shown in Fig. 9b.

The results showed that in the MO, the space for all groups were not significantly different. The 45 μm group showed significantly smaller values for CH (30 μm: 42.65 ± 12.53 μm, 45 μm: 32.67 ± 5.88 μm) ($p = 0.027$) for the FC. For the FW, The 30 μm showed a significantly smaller value in AX (30 μm:

Table 3
Mean value, standard deviation (SD), and median value of the amounts of space at each measurement point in the marginal opening area. (P-m: Premolar-mesial, P-d: Premolar-distal, P-b: Premolar-buccal, P-l: Premolar-lingual, M-m: Molar-mesial, M-d: Molar-distal, M-b: Molar-buccal, M-l: Molar-lingual).

Full contour		Cement space (μm)	P-m	P-b	P-l	P-d	M-m	M-b	M-l	M-d
Mean (μm)	Multi-layer	30	26.25	17.06	54.26	48.75	64.44	33.59	55.54	31.73
		45	26.15	20.53	32.22	33.14	50.08	22.71	39.97	19.00
	Single-layer	30	19.14	32.01	31.45	47.27	48.61	39.63	37.78	17.95
SD	Multi-layer	30	11.60	8.15	27.55	13.90	16.82	30.85	33.12	30.65
		45	5.86	9.34	8.66	7.64	17.13	9.12	19.59	9.37
	Single-layer	30	7.62	25.42	14.74	25.62	19.63	17.2	24.3	7.67
Median (μm)	Multi-layer	30	26.89	15.11	47.81	51.32	61.24	23.14	40.62	20.18
		45	25.84	20.58	30.35	35.17	49.23	19.01	37.52	17.88
	Single-layer	30	17.13	23.21	33.07	43.69	49.59	41.17	24.22	19.30
Framework		Cement space (μm)	P-m	P-b	P-l	P-d	M-m	M-b	M-l	M-d
Mean (μm)	Multi-layer	30	28.34	31.23	40.92	40.70	66.81	51.88	64.00	17.95
		45	33.31	27.61	37.31	41.31	73.64	48.15	64.48	22.07
	Single-layer	30	21.76	18.43	26.05	30.56	40.14	33.08	22.43	17.83
SD	Multi-layer	30	9.43	15.82	14.96	18.01	13.97	26.27	23.14	25.98
		45	10.53	11.61	11.15	14.08	27.08	13.91	23.61	10.70
	Single-layer	30	6.29	11.39	12.93	11.88	15.74	12.91	8.99	9.08
Median (μm)	Multi-layer	30	32.00	27.94	39.72	37.92	71.02	45.79	65.73	17.30
		45	29.51	27.64	34.05	42.50	76.42	76.42	57.78	17.16
	Single-layer	30	21.91	13.53	22.25	29.21	40.36	29.42	18.82	14.10

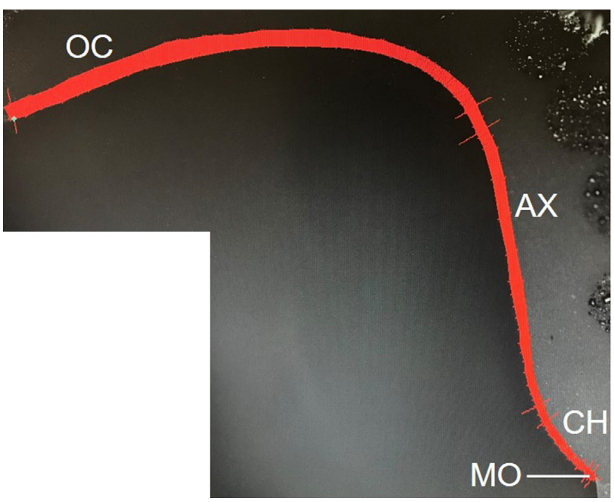

Fig. 7. Measurement area (MO: marginal opening area, CH: chamfer area, AX: axial area, OC: occlusal area).

43.64 ± 5.11 μm, 45 μm: 57. 47 ± 8.48 μm) (p = 0.000) and OC (30 μm: 85. 97 ± 14.20 μm, 45 μm: 98.63 ± 16.44 μm) (p = 0.016).

3.3. Zirconia types

To determine the effect of zirconia type on the fit of FDPs, the results were compared between L and W for a CS of 30 μm. The meanvalues of the space of all groups were shown in Fig. 9c.

The results showed that in all areas (MO, CH, AX, and OC), the space for L were significantly larger than those for W for the framework design (MO; W: 26.28 ± 6.99 μm, L: 43.76 ± 7.81 μm (p = 0.000), CH; W: 27.41 ± 6.08 μm, L: 41.44 ± 4.81 μm (p = 0.000), AX; W: 30.98 ± 4.60 μm, L: 43.64 ± 5.11 μm (p = 0.000), and OC; W: 64.02 ± 14.78 μm, L: 85.97 ± 14.20 μm (p = 0.002)). However, for the FC, a significant difference was found only in the AX (W: 27.95 ± 4.49 μm, L: 46.19 ± 4.77 μm) (p = 0.000).

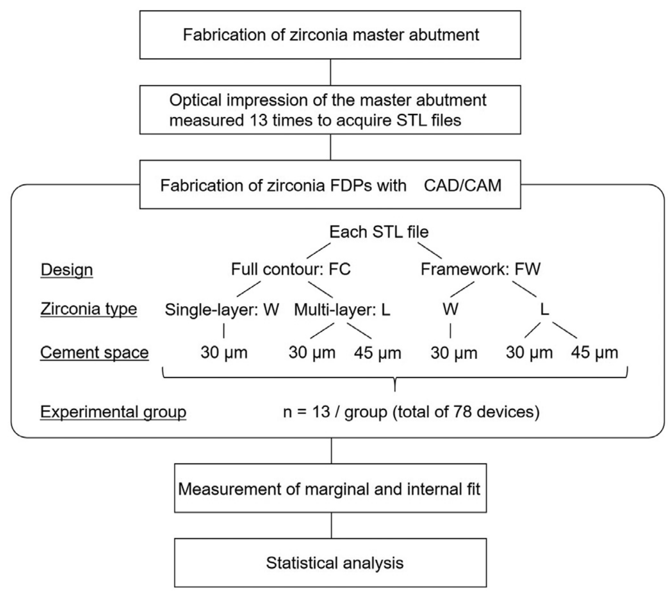

Fig. 8. Flowchart of experiment.

4. Discussion

In this study, the effect of FDPs design, CS provided between the FDPs and the abutment teeth, and zirconia type on the marginal and internal fit of three-unit zirconia FDPs were investigated. Based on the results, the null hypothesis that the FDPs design (full contour and framework), CS (30 and 45 μm), and zirconia type (single- and multi-layer zirconia) would not have effect on the marginal and internal fit was rejected.

4.1. Measurement method

The measurement method used to investigate the fit of FDPs should be highly accurate. To measure the marginal and internal fit of the FDPs, the replica method is commonly used. This method is considered to be effective for testing FDPs fit [23], and can be

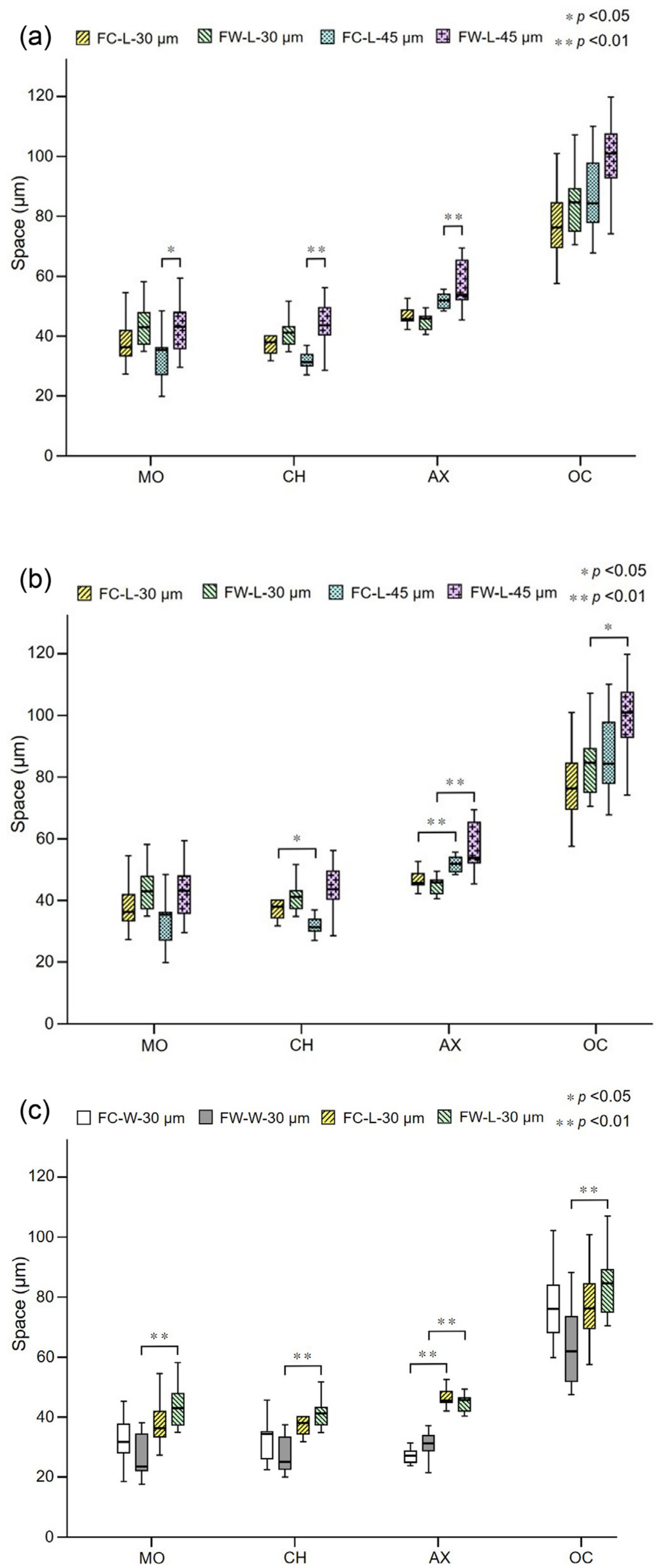

Fig. 9. (a) Amount of space in each group for two designs. (b): Amount of space in each group two cement space values. (c): Amount of space in each group for two zirconia types.

used for various types of FDPs [22,24–26]. The advantage of this method is that it can be applied both *in vitro* and *in vivo*, and it is not destructive to the master abutment and FDPs during repeated evaluations of the marginal and internal fit. In this study, FDPs were placed on the master abutment with finger pressure. This is a method that conforms to clinical practice, and this method has been used in several other studies [22,25,27]. Image analysis software was used to identify the amounts of space from the values obtained by drawing approximately 6000 perpendicular lines per cross section to obtain more reliable data [21]. And this software has been used in several other studies and has proven its reliability in evaluation of the fit [28,29].

4.2. Effect of FDPs design

A comparison at each measurement point in MO showed that for all groups, P-m had a smaller space compared with that of P-d. Further, M-d had a smaller space than that of M-m (Table 3). Kunii et al. compared the fit of the pontic and non-pontic sides of three- and four-unit zirconia FDPs [30]. They showed that the non-pontic side had a better marginal fit. The reason for this is that the volume of zirconia at the pontic area, which is larger than that of the retainer, affected the amount of shrinkage during secondary firing. The difference in the amount of shrinkage between the pontic area and the retainer caused a dimensional change in the FDPs. The results of our study are consistent with those reported by Kunii et al. It is considered that the shrinkage in the pontic area during secondary firing affects the fit of FDPs [30]. In the three-unit zirconia FDPs, it should be considered that the risk of causing marginal discrepancy is higher on the pontic side than on the non-pontic side.

In addition, the zirconia thicknesses for the two FDPs designs (full contour and framework) were different. It is thus possible that the difference in the thickness of zirconia affected the marginal area deformation, as mentioned by Morimoto et al. [20]. In this study, The FC-L-45 µm (32.77 ± 7.80 µm) had a significantly smaller space than that of the FW-L-45 µm (43.49 ± 9.82 µm) in MO ($p = 0.011$). Although there was no significant difference, the space for FC-L-30 µm was smaller than that for FW-L-30 µm. This cause could not be clarified in this study. Also, the clinical effect of this difference is not clear. It is considered that the thickness of zirconia in FDPs affected the fit of the zirconia FDPs, but the effect of the multi-layered structure of the zirconia disk is further added to make this problem more complicated.

4.3. Effect of cement space

Previous studies have reported that setting the CS between AX and OC of a three-unit zirconia FDPs to 30 or 50 μm achieves an acceptable marginal fit [25,30]. Accordingly, CS values of 30 and 45 μm were used to compare the marginal and internal fit of FDPs in our study.

Watanabe et al. reported that an insufficient CS causes interference between the inner surface of the retainer and the abutment tooth in AX [31]. From the results of our study, the amount of space in AX (43.64–57.47 μm) was larger than that in MO (32.77–43.76 μm) for the L group. These results show that CS was adequate in the L. And the amount of space in MO for the FDPs fabricated in this study was in the range of 18.89 to 58.49 μm, and is thus smaller than the 120 μm reported by Mclean et al. [16].

For OC, the FW-30 μm (85.97 ± 14.20 μm) showed a smaller space compared with that for the FW-45 μm (98.63 ± 16.44 μm). The study of Rezende et al. found that thicker occlusal space showed lower fracture load and higher stress concentration by finite element analysis. This suggests the possibility of better fracture resistance at CS 30 μm.

4.4. Effect of type of zirconia

A study reported that the development of highly translucent zirconia has made it possible to produce an all-ceramic crown that is aaesthetically superior to that made with conventional zirconia [25]. In that study, the fit of three-unit zirconia FDPs fabricated from highly translucent and conventional zirconia, respectively, was compared. The results showed that there is no significant difference between these two kinds of zirconia. However, there are no reports on the fit of three-unit zirconia FDPs fabricated using zirconia with a multi-layer structure. The effect of structure on fit is thus unclear.

This study showed that the FDPs design and CS affected the marginal and internal fit. We considered the possibility of a dimensional change caused by the multi-layer structure of zirconia and could thus investigate the effect of the multi-layer structure on the marginal and internal fit by adding FDPs fabricated using single-layer zirconia to the experimental group.

For OC, the FW-30 μm showed a smaller space compared with that for the FW-45 μm. Therefore, the CS of the experimental group with single-layer zirconia was set to 30 μm. In the comparison in this study, FW-W-30 µm showed significantly smaller space than FW-L-30 µm in all measurement area.

Due to the difference in the amount of metal oxide particles in each layer, the amount and timing of the shrinkage of each layer during secondary firing were different. This may have caused distortion among the layers. Since the company did not release any information about the coloring particles to the authors, there the influence of certain metal oxides and their amount on the fit cannot be revealed. In this study, it was not possible to clarify in what direction the distortion occurred. In addition, it is considered that the degree of this distortion is also affected by the method used to manufacture the multi-layer zirconia. Therefore, further research on this point is necessary.

From these results, it is considered that better fit can be obtained by using zirconia having a single-layer structure in the production of the zirconia framework. Further, in the full contour design, the FDPs manufactured using a zirconia disk having a multi-layer structure can obtain a marginal fit comparable to that using a single-layer structure zirconia disk.

This study investigated the factors that influence the fit of FDPs *in vitro*. Hence, there was no clear consensus on whether the differences in fit in each group as shown in the results of this study had a clinical impact. Therefore, it is thought that further research *in vivo* is necessary to see how each factor compared in this study affects clinically.

5. Conclusion

Based on the results of this study, the following conclusions can be drawn:

(1) The design of the three-unit zirconia FDPs affected the marginal and internal fit.
(2) The CS in the abutment of the three-unit zirconia FDPs affected the internal fit.
(3) Three-unit FDPs fabricated from single-layer zirconia showed better marginal and internal fit than that of FDPs fabricated from multi-layer zirconia.

Declaration of Competing Interest

The author have no conflicts of interest to declare with respect to this study.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jpor.2019.12.005.

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