Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Effects of Preparation Design, Fabrication Technique, and Cementation on the Internal Fit and Marginal Adaptation of Porcelain Laminate Veneers: A Micro-CT Study

Meral ARSLAN MALKOÇ

meralarslanmalkoc@akdeniz.edu.tr

Akdeniz University

Feyza Telli Civitci

Research Article

Keywords: Internal fit, Marginal Adaptation, Laminate Veneers, Micro CT

Posted Date: November 19th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11353496/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

This study aimed to evaluate the effects of preparation design, fabrication technique, and cementation on the marginal adaptation and internal fit of porcelain laminate veneers (PLVs) using micro-computed tomography (micro-CT).

Methods

Sixty-four extracted human maxillary central incisors were randomly assigned to eight groups (n = 8) according to preparation design (overlap or bevel), fabrication technique (CAD/CAM or heat-pressing), and resin cement (Variolink Veneer or Clearfil Esthetic Cement EX). PLVs were fabricated using the CEREC CAD/CAM system or the IPS Empress Esthetic heat-pressing technique. Micro-CT (Sky Scan 1172, Bruker) scans were obtained before and after cementation. Marginal adaptation and internal fit were assessed at predefined measurement points in transverse and sagittal sections, yielding 95 measurements per specimen. Data were analyzed using nonparametric statistical tests, with statistical significance set at $p < 0.05$.

Results

CAD/CAM-fabricated PLVs generally exhibited lower marginal gap values than heat-pressed PLVs ($p < 0.05$). The bevel preparation design was generally associated with lower marginal gap values than the overlap design ($p < 0.05$), whereas differences in internal fit between preparation designs were less evident. Cementation did not significantly affect most marginal and internal fit measurements ($p > 005$). However, significant changes were observed at selected measurement locations in some groups. The effects of cementation were therefore location- and group-dependent.

Conclusions

Within the limitations of this in vitro study, fabrication technique and preparation design influenced the marginal adaptation of PLVs. CAD/CAM fabrication and bevel preparation may provide more favorable marginal adaptation. Cementation had limited effects on marginal adaptation and internal fit.

INTRODUCTION

Over the past four decades, porcelain laminate veneers (PLVs) have become an established option for the esthetic rehabilitation of anterior teeth. Their conservative approach, favorable esthetic characteristics, and satisfactory clinical performance have supported their widespread use in restorative dentistry [1, 2]. PLVs can be used to address a variety of esthetic conditions, including alterations in tooth morphology and alignment, diastema closure, replacement of discolored or unaesthetic restorations, incisal wear, erosive tooth surface loss, and intrinsic discoloration [3].

Despite their conservative nature, the clinical performance of PLVs may be affected by several factors related to tooth preparation, restorative material, fabrication procedure, and cementation. Both biological and mechanical complications have been reported, including ceramic fracture, debonding, periodontal complications, recurrent caries, and fracture of the supporting tooth structure [1, 4, 5]. The interaction between these factors may therefore play an important role in determining the clinical durability of PLVs. The adaptation of a PLV to the prepared tooth is an important consideration in this context. Inadequate marginal adaptation may facilitate plaque accumulation and microleakage, whereas excessive or uneven internal space may influence the thickness and distribution of the luting cement layer and consequently the mechanical behavior of the restoration [4, 6].

Marginal adaptation and internal fit are therefore relevant parameters for evaluating the quality of PLVs fabrication and cementation. However, the effects of preparation design, fabrication technique, and cementation protocol have not been sufficiently evaluated in combination, particularly with respect to changes in marginal adaptation and internal fit following cementation. Accordingly, this study aimed to evaluate the effects of preparation design, fabrication technique, and cementation on the marginal adaptation and internal fit of PLVs. The null hypotheses were that: (1) fabrication technique would not affect marginal adaptation or internal fit; (2) preparation design would not affect marginal adaptation or internal fit; and (3) cementation would not affect marginal adaptation or internal fit.

MATERIALS AND METHOD

The study was approved by the Clinical Research Ethics Committee of XXXXXXXXXXX University, XXXXXXXXXXX, XXXXXXXXXXXXXX (Approval No. 2013/108) conducted in accordance with the Declaration of Helsinki. A total of 64 caries-free, intact human maxillary central incisors, extracted for therapeutic reasons and with approximately similar dimensions, were included in the study. All teeth included in this study had been extracted for therapeutic reasons due to severe periodontal disease and were not extracted specifically for research purposes. This information was explicitly provided in the ethics committee application. Individual written informed consent from the patients for the use of their extracted teeth in this study was not obtained.

An initial sample size estimation was performed using G*Power 3.1.9.7 (Franz Faul, University of Kiel, Kiel, Germany) based on the expected effect size for marginal adaptation and internal fit measurements [7]. However, during the final statistical planning, the PLV was defined as the independent experimental unit because multiple measurements were obtained from each PLV. Therefore, measurements of marginal adaptation and internal fit were considered repeated observations within the same experimental unit rather than independent samples. Based on the final study design, eight PLVs per group were included in the analysis.

Study Groups and Design

The teeth were cleaned and disinfected and then randomly divided to eight groups, with eight specimens in each group. Overlap and Bevel incisal finish line design preparation designs for PLVs were evaluated. Two different fabrication methods were also evaluated: the CAD/CAM system (CEREC 3D Premium; Sirona, Germany) and heat-pressed porcelain (leucite-reinforced glass-ceramic material) were used for PLVs fabrication. And last; two different resin-based luting cements were used in the present study: Variolink Veneer (Ivoclar, Schaan, Liechtenstein) and Clearfil Esthetic Cement EX (Kuraray,Tokyo, Japan). The compositions and relevant details of the materials are presented in Table 1.

Table 1
Cements and PLVs manufacturing materials used in this study Y Bis-GMA indicates bisphenol A diglycidyl methacrylate; UDMA, urethane dimethacrylate; HEMA, 2-hydroxyethylmethacrylate; TEGDMA, triethylene glycol dimethacrylate; DMA, decamethylen-dimethacrylate.

Brand Name	Ingredients Y	Manufacturer and Lot. Number
Variolink Veneer	Ytterbium Trifluoride(%10–25), UDMA (%10–25), Aromatic Aliphatic UDMA(%2,5–10), Decandiol DMA (2,5–10), Dimethylbenzyl Hydroperoxide %2.5, Butylated Hydroxytoluene %2.5	Ivoclar Vivadent AG, Schaan, Liechtenstein K35423
Clearfil Esthetic Cement EX	Clearfil Esthetic Paste A: Bis-GMA, TEG-DMA, hydrophobic aromatic DMA monomers, barium glass filler, colloidal silica, accelerator Clearfil esthetic Paste B: Bis-GMA, TEG-DMA, hydrophobic aromatic DMA monomers, hydrophilic aliphatic DMA monomers, barium glass filler, silanated silica, colloidal silica, benzoyl peroxide, di-camphorquinone, pigments	Kuraray Medical Inc. Okayama, Japan 41298
IPS Empress Esthetic	SiO2 (57–80 wt%), Li2O (11–19 wt%), K2O (0–13 wt%), P2O5 (0–11 wt%), ZrO2 (0–8 wt%), ZnO (0–8 wt%), other oxides and ceramic pigments (0–10 wt%)	Ivoclar Vivadent AG, Schaan, Liechtenstein K35423
CEREC Bloks	SiO2 (% 56–64), Al2O3(% 20–23), Na2O(% 6–9), K2O (%6–8), CaO (% 0.3–0.8), TiO2 (% 0.0–0.1), Pigments(% < 0.1)	Sirona, VITA Zahnfabrik Bad Säckingen, Germany

In addition, The PLVs were classified into 8 groups based on the method of fabrication, preparation methods, and type of luting cement used (Table 2), and following abbreviations were used; COV: Cerec, Overlap, Variolink Veneer, COC: Cerec, Overlap, Clearfil Esthetic EX, CBV: Cerec, Bevel, Variolink Veneer, CBC: Cerec, Bevel, Clearfil Esthetic EX, EOV: IPS Empress Esthetic, Overlap, Variolink Veneer, EOC: IPS Empress Esthetic, Overlap, Clearfil Esthetic EX, EBV: IPS Empress Esthetic, Bevel, Variolink Veneer, EBC: IPS Empress Esthetic, Bevel, Clearfil Esthetic EX.

Table 2
Experimental Groups

Groups	Ceramic System	Preparation Design	Cements
COV	CEREC	Overlap	Variolink Veneer
COC	CEREC	Overlap	Clearfil Esthetic EX
CBV	CEREC	Bevel	Variolink Veneer
CBC	CEREC	Bevel	Clearfil Esthetic EX
EOV	IPS Empress Esthetic	Overlap	Variolink Veneer
EOC	IPS Empress Esthetic	Overlap	Clearfil Esthetic EX
EBV	IPS Empress Esthetic	Bevel	Variolink Veneer
EBC	IPS Empress Esthetic	Bevel	Clearfil Esthetic EX

Table 3

Marginal adaptation and internal fit (μ- micrometer) comparison of experimental groups and cementation procedure (median / minimum- maximu

GROUPS (n = 8)	MMD	MMG	MSG	IF	DSG	DMG	DMD	CMD	CMG	CSG	IMG	IM
	md (mn-mx)	md (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	m (m
A. Before Cementation- Between groups Mann Whitney U test with Bonferonni correction §												
COV	151 (91–294) ab	111(51–194)a	132 (84–265)	128(106–763)ab	152 (104–240)	82(56–168)ab	173 (130–208)a	170(154–250)a	115 (80–216)a	140 (93–249)	126 (88–150)ab	21 (1 25
COC	152 (112.6–212)ab	62(31–88)b	103 (55–168)	88(57–118)b	103 (63–142)	59 (34–90)b	140(84–172)ab	162 (120–232)a	78 (34–148)b	105 (55–210)	135 (60–218)ab	17 (1 24
CBV	113 (63–177) a	50(38–78)b	88 (58–117)	85(51–148)b	94 (35–352)	70(35–330)ab	125(86–220)b	135 (96–198)a	72(44–139)b	86 (37–135)	78 (26–101)b	12 17
CBC	122 (60–247) a	48(22–98)b	132 (75–266)	89(62–183)b	145 (96–218)	52 (32–135)b	142(84–224)ab	216 (120–322)ab	62 (46–137)b	103(60–189)	73 (58–125)b	16 (1 21
EOV	181(101–242) ab	91(51–148)ab	121(92–184)	125(45–162)ab	130 (40–172)	136 (40–172)a	182(114–362)a	270 (141–416)ab	170(81–275)a	145 (92–217)	154 (76–260)a	20 (1 39
EOC	274(192–495) b	112(62–151)a	156(122–229)	128(84–182)ab	148 (72–302)	142 (54–270)a	242(160–386)a	365 (254–460)b	183 (157–310)a	170 (104–256)	180 (65–288)a	34 (1 41
EBV	162 (123–504) ab	88(32–172)ab	153(79–387)	104(46–168)ab	142 (55–240)	105(42–194)ab	137(114–410)ab	148 (61–402)a	114 (41–256)a	121 (63–210)	82 (36–259)b	16 43
EBC	260 (80–372) b	78(48–114)ab	150(115–218)	156(121–167)a	112 (50–194)	112 (18–162)ab	209(145–358)a	285 (213–328)ab	70 (26–99)b	108 (45–139)	85 (46–180)b	21 (1 41
	0.009**	0.023*	0.211	0.037*	0.074	0.041	0,035	0,021	0,043	0.065	0,027	0,(
B. After Cementation -Between groups Mann Whitney U test with Bonferonni correction §												
COV	146 (90–305)ab	112 (87–216)	108 (95–220)	108 (83–870)	133 (98–259)	98 (60–163)	176(113–206)	150(67–198)ab	125(62–208)	118(82–165)	123(70–155)	16 26
COC	126 (110–175)a	98 (77–164)	120 (94–178)	115 (84–128)	110 (101–215)	95(82–233)	140(102–245)	145(96–204)a	103(56–158)	102(65–179)	118(73–158)	15 21
CBV	113 (96–146)a	90 (72–140)	115 (76–159)	93 (65–116)	105 (84–348)	112(96–334)	135(96–235)	121 (107–178)a	96(82–138)	97(82–159)	105(86–128)	11 19
CBC	158 (115–260)ab	105 (53–190)	148 (112–178)	129 (72–140)	156 (94–187)	108(65–150)	172(90–235)	168(95–290)ab	108(74–133)	124(92–204)	118(62–141)	17 24
EOV	192 (116–254)ab	94 (36–209)	125 (80–249)	105 (86–158)	136 (82–207)	130(86–218)	210(124–275)	233(146–375)b	142(80–272)	131(80–178)	144(80–182)	19 39
EOC	180 (133–338)ab	136 (100–168)	140 (70–245)	129 (56–157)	117(73–230)	113(78–233)	164(128–280)	235(184–368)b	165(126–229)	162(94–226)	156(96–235)	27 35
EBV	205 (184–462)ab	115 (85–186)	123 (80–282)	108 (60–168)	121(98–240)	120(52–198)	187(102–418)	216(138–417)bb	130(92–245)	118(72–218)	113(69–250)	15 43
EBC	258 (152–340)b	122 (68–190)	165 (118–220)	135 (122–169)	145(108–174)	104(76–185)	180(152–288)	262(165–353)b	139(96–147)	115(65–136)	115(62–169)	23 27
	0.039*	0.176	0.182	0.124	0.365	0.234	0,085	0,041	0,123	0.275	0,358	0,(
C.Comparison of A&B - Within groups Wilcoxon signed rank test ¥												
COV	0.57	0.40	0.14	0,20	0,06	0,16	0,67	0,03**	0,06	0,16	0,77	0,(
COC	0.16	0.02**	0.26	0,09	0,05	0,01**	0,67	0,09	0,09	0,57	0,88	0,2

GROUPS (n = 8)	MMD	MMG	MSG	IF	DSG	DMG	DMD	CMD	CMG	CSG	IMG	IM
	md (mn-mx)	md (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	med (mn-mx)	m (m
CBV	0.67	0.01**	0.32	0,26	0,57	0.16	0,77	0,48	0,48	0,07	0,01**	0,(
CBC	0.26	0.03**	0.40	0,08	0,07	0,03*	0,48	0,12	0,12	0,09	0,06	0,(
EOV	0.48	0.67	0.67	0,94	0,12	0,67	0,77	0,48	0,48	0,57	0,48	0,8
EOC	0.02 *	0.02	0.57	0,67	0,88	0,67	0,02*	0,02**	0,06	0,26	0,26	0,(
EBV	0.12	0.02	0.57	0,57	0,77	0,88	0,26	0,12	0,06	0,57	0,32	0,7
EBC	0.32	0.02	0.11	0,20	0,06	0,12	0,48	0,32	0,01**	0,57	0,26	0,8

MMD: mesial marginal distance, MMG: mesial marginal gap, MSG: mesial step gap, DMD: distal marginal distance, DMG: distal marginal gap, DSG: distal ste internal fit, CMD :cervical marginal distance,

CMG: cervical marginal gap, CSG: cervical step gap, IMD: incisal marginal distance, IMG: incisal marginal gap.

§ : Mann–Whitney U test with Bonferroni correction; medians sharing the same letter are not significantly different at α = 0.05

¥: Wilcoxon signed-rank test, *P < 0.05; **P < 0.01; ***P < 0.001

Two different preparation designs were performed in the study: overlap and bevel incisal finish line designs. A specially designed laminate veneer preparation kit (Komet 4151 Ceramic Veneer System, Germany) was used for the preparation of the laminate veneers. All tooth preparations were performed by a single, highly experienced operator (FT).

Overlap preparation design; Initially, depth-orientation burs were used to prepare horizontal depth grooves on the labial surface, dividing the tooth into three equal sections. A chamfer-type finish line was then prepared. The gingival margin was extended toward the interproximal areas, and the preparation margins were extended through the interproximal regions toward the incisal surface to establish the mesial and distal margins. The islands of tooth structure between the depth grooves on the labial surface were subsequently removed to the depth of the grooves, resulting in a preparation depth of 0.5 mm. Approximately 1 mm of incisal reduction was performed, and the preparation was terminated on the palatal surface with a chamfer-type finish line. All sharp edges were rounded and smoothed, and enamel irregularities were removed using a finishing bur.

Beveled preparation design; A horizontal depth groove was prepared on the labial surface to divide the tooth into three equal sections. Gingival extension and marginal preparation were performed. A chamfer-type finish line was prepared. The gingival margin was extended toward the interproximal areas, and the preparation margins were extended from the interproximal regions toward the incisal surface to establish the mesial and distal margins. The islands of tooth structure between the depth grooves on the labial surface were subsequently removed to the base of the grooves, resulting in a preparation depth of 0.5 mm. The incisal surfaces of the teeth were prepared at an angle of 30–40° toward the palatal surface, and the incisal edge was reduced by approximately 1 mm. Enamel irregularities were removed, and the prepared surfaces were smoothed by finishing bur.

Impressions of the 16 teeth prepared with the bevel and the 16 teeth prepared with the overlap design were obtained using a polyvinyl siloxane impression material (Zhermack, Italy). Dies were fabricated from the impressions (Alpha Die MF, Schültz-Dental, Germany). Two layers of die spacer (Aqua Fit, Renfert, Germany) were applied to the dies, leaving a 0.5-mm space from the preparation margin. Wax patterns were subsequently fabricated using Empress modeling wax (Ground Wax, Schuler Dental, Germany). A special IPS pressing system and investment material (IPS Press Vest, Ivoclar, Liechtenstein) were used according to the manufacturer's recommendations. The temperature of the preheating furnace was increased to 850°C and maintained at this temperature for 60 minutes. After removal of the casting cylinder from the preheating furnace, an ingot and an aluminum oxide plunger were placed into the space within the cylinder. The cylinder was then positioned in the center of the pressing furnace (EP 600 Kombi; Ivoclar Vivadent, Liechtenstein), and pressing was performed under vacuum at 915°C using the injection technique, according to the manufacturer's recommendations. The internal surfaces of the specimens were air-abraded with 30–50-μm Al_2O_3 particles at a pressure of 0.1–0.2 MPa for 2–3 seconds. The specimens were then placed in an ultrasonic cleaner (Whaledent Biosonic Jr; New York, NY, USA) for 2 minutes. Following this surface treatment, the IPS Empress Esthetic specimens were ready for cementation to the teeth.

The remaining 16 teeth prepared with the bevel design and the 16 teeth prepared with the overlap design were scanned using an intraoral scanner (CEREC Bluecam, Sirona, Germany) to design and mill the CAD/CAM laminate veneers (CEREC Blocks, Sirona, Germany). The resulting 3D optical scans were transferred to the CAD software (CEREC 4.2, Sirona, Germany), and the design phase was performed by a highly experienced CAD/CAM designer. The finish lines were then identified and adjusted on the digital models. The PLVs were designed with a spacer thickness of 30 μm. Subsequently, the CAD/CAM blocks were positioned in the milling chamber of the device (CEREC MC XL, Sirona, Germany) and securely stabilized, and the veneers were milled under wet conditions. Following this procedure, the IPS Empress Esthetic specimens were ready for cementation to the teeth.

Micro- CT Analysis

Marginal adaptation and internal fit were evaluated using a non-destructive, high-resolution Micro-CT system (SkyScan 1172; Bruker, Kontich, Belgium). Each specimen was scanned at 100 kV using a 1-mm aluminum filter and an 11-megapixel camera. Approximately 950–1000 cross-sectional images were obtained with a rotation step of 0.40° and a slice thickness of approximately 12 μm during a 360° rotation of the specimen. The resulting DICOM (Digital

Imaging and Communications in Medicine) compatible image data were subsequently converted to BMP (Bitmap) format for further analysis (Fig. 1). The area of evaluation was limited to the cervico- incisal direction of cross-section slides (CTAn 1.15.4.0, SkyScan; Kontich). Micro-CT measurements (mm) were performed on the transverse (Fig. 2) and sagittal (Fig. 3) sections using the distance measurement tool of CTAn software (SkyScan, Kontich, Belgium) and measurements converted micrometer (μm). A schematic representation of the predetermined measurement points in the transverse and sagittal sections is presented in Fig. 2, 3.

Five equidistant transverse sections were selected for the measurements. Marginal adaptation was evaluated on the transverse sections at 8 predetermined points: mesial marginal distance (MMD), mesial marginal gap (MMG), 2 mesial step gaps (MSGs), distal marginal distance (DMD), distal marginal gap (DMG), and 2 distal step gaps (DSGs). In addition, 5 internal fit (IF) measurements were obtained from the same transverse sections (Fig. 2). Thus, a total of 65 transverse measurements were obtained for each specimen. In the sagittal sections, a total of 6 measurements were performed at the cervical and incisal regions across 5 equidistant sections: cervical marginal distance (CMD), cervical marginal gap (CMG), 2 cervical step gaps (CSGs), incisal marginal distance (IMD), and incisal marginal gap (IMG). Thus, a total of 30 sagittal measurements were obtained for each specimen (Fig. 3). For each outcome variable, the measurements obtained from the predetermined measurement points were averaged to obtain a single representative value for each specimen.

Following the evaluation of the marginal adaptation and internal fit of the PLVs using Micro-CT, all 64 PLVs were cemented onto the incisors teeth by a single clinician (FT) using two different resin-based luting cements, Variolink Veneer and Clearfil Esthetic Cement EX, according to the manufacturers' instructions. After cementation, all specimens underwent a second Micro-CT scan (SkyScan 1172; Bruker, Kontich, Belgium) under the same scanning conditions as the initial scan (Fig. 4, 5). The same measurement protocol used for the initial scan was repeated, and the post-cementation Micro-CT data were obtained.

Statistical analysis

The data were presented as median (minimum–maximum) values. The normality of the data distribution was assessed using the Kolmogorov–Smirnov test. The Kruskal–Wallis H test was used for overall comparisons, followed by the Mann–Whitney U test with Bonferroni's correction for multiple comparisons. In addition, the Wilcoxon signed-rank test was used within groups at before and after cementation. The significance level (α) value was fixed at 0.05. All statistical analyses were performed using the Statistical Package for Social Sciences, Version 24.0 (SPSS, Inc., Chicago, IL, USA) and Microsoft Excel 2024 (Microsoft, Seattle, WA, USA).

RESULTS

When the MMD values were evaluated before cementation, the lowest values were observed in the CBV and CBC groups, whereas the highest values were observed in the EBC and EOC groups (P = 0.009). Following cementation, the lowest MMD values were observed in the CBV and COC groups, while the highest value was recorded in the EBC group (P = 0.039). When the MMD values before and after cementation were compared within each group, a statistically significant decrease in the MMD value was observed only in the EOC group (P = 0.02).

Before the cementation, the lowest MMG values were observed in the COC, CBV, and CBC groups, whereas the highest values were observed in the COV and EOC groups (p = 0.023). However, following cementation, no statistically significant differences in MMG values were observed among the groups (P = 0.176). Within-group comparisons revealed statistically significant increases in MMG values following cementation in the COC, CBV, and CBC groups (P = 0.02, 0.01, 0.03).

For MSG values, no statistically significant differences were observed among the groups either before cementation (P = 0.211) or after cementation (P = 0.182). Similarly, within-group comparisons revealed no statistically significant differences in MSG values between the pre- and post-cementation measurements (P > 0.05). The same pattern was observed for DSG values. No statistically significant differences were found among the groups before cementation (P = 0.074) or following cementation (P = 0.365). Likewise, within-group comparisons showed no statistically significant differences in DSG values between the pre- and post-cementation measurements (P > 0.05).

When the IF values were evaluated before cementation, the lowest values were observed in the COC, CBV, and CBC groups, whereas the highest value was observed in the EBC group (P = 0.037). However, following cementation, no statistically significant differences in IF values were observed among the groups (P = 0.124). Moreover, within-group comparisons revealed no statistically significant differences in IF values between the pre- and post-cementation measurements (P > 0.05).

Regarding DMG measurements, before cementation, the lowest values were observed in the COC and CBC groups, whereas the highest values were recorded in the EOV and EOC groups (P = 0.041). After cementation, no statistically significant differences were detected among the groups in terms of DMG values (P = 0.234). However, within-group comparisons of the pre- and post-cementation measurements revealed statistically significant increases in DMG values in the COC (P = 0.01) and CBC (P = 0.03) groups.

When the DMD measurements were evaluated, the lowest values before cementation were observed in the CBV, EBV, and COC groups, whereas the highest values were observed in the EOC and EBC groups (P = 0.035). However, no statistically significant difference in DMD values was found among the groups after cementation (P = 0.085). In the EOC group, DMD values decreased significantly after cementation (P = 0.020), whereas no significant difference was observed between pre- and post-cementation measurements in the other groups (P > 0.05).

Before cementation, the lowest CMD values were observed in the CBV and EBV groups, whereas the highest value was detected in the EOC group (P = 0.021). After cementation, the lowest CMD values were observed in the CBV and COC groups, whereas the highest value was found in the EBC group (P = 0.041). In the within-group comparisons, a statistically significant decrease in CMD values was observed only in the EOC group (P = 0.02).

Before cementation, the lowest CMG values were observed in the CBC, COC, CBV, and EBC groups, whereas the highest CMG values were detected in the EOV and EOC groups (P = 0.043). After cementation, no statistically significant difference in CMG values was observed among the groups (P > 0.05). Within-group comparisons revealed a statistically significant increase in CMG values after cementation only in the EBC group (P = 0.010). Regarding CSG values, no statistically significant difference was observed among the groups either before cementation (P = 0.065) or after cementation (P = 0.275). Furthermore, within-group comparisons revealed no statistically significant difference between pre- and post-cementation measurements.

The lowest IMG values before cementation were observed in the CBV and CBC groups, whereas the highest IMG values were observed in the EOV and EOC groups (P = 0.027). After cementation, no statistically significant difference in IMG values was observed among the groups (P = 0.358). Within-group comparisons revealed a statistically significant increase in IMG values after cementation only in the CBV group (P = 0.010).

Finally, for IMD values, the lowest value before cementation was observed in the CBV group, whereas the highest value was observed in the EOC group (P = 0.038). Similarly, after cementation, the lowest IMD value was observed in the CBV group, while the highest value was observed in the EOC group (P = 0.045). In the within-group comparisons between pre- and post-cementation measurements, statistically significant decreases in IMD values were observed in the COV (P = 0.040) and EOC (P = 0.030) groups.

DISCUSSION

In this study; PLVs were fabricated using either a chairside CAD/CAM system or a heat-pressed glass-ceramic technique and were placed on teeth prepared with either a bevel or overlap design. Additionally; two different resin cement were used for PLVs luting. The findings of this study led to the rejection of the first and second null hypotheses, indicating that fabrication technique and preparation design influenced the marginal adaptation and internal fit of PLVs. In contrast, the third null hypothesis was partly accepted, as cementation did not significantly affect either parameter.

This study was conducted in vitro, allowing experimental conditions to be standardized and potential confounding variables to be better controlled than would be possible in a clinical setting. Although micro-computed tomography (micro-CT) has been used to evaluate the marginal and internal fit of various types of restorations [8], studies specifically investigating both parameters in porcelain laminate veneers (PLVs) appear to be lacking. Accordingly, the present study addresses this gap in the literature by using micro-CT to assess the marginal adaptation and internal fit of PLVs.

Although dimensional standardization can be achieved using artificial teeth, these models cannot fully replicate the structural and physical properties of natural teeth [9]. Rosentritt et al. [10] comparatively evaluated the marginal adaptation and fracture resistance of all-ceramic restorations using metal dies, liquid crystal dies, and natural teeth. They reported that restorations evaluated on natural teeth exhibited marginal adaptation and fracture resistance values that were closer to clinical findings than those obtained using the artificial dies, suggesting that natural teeth may provide a more clinically representative testing substrate [10]. Furthermore, in Micro-CT analysis, metal-containing artificial dies may generate severe beam-hardening and related imaging artifacts, potentially compromising the accurate discrimination of tooth and restoration boundaries. Therefore, extracted natural teeth were used in the present study to provide a more clinically relevant substrate and to facilitate reliable micro-CT evaluation of marginal adaptation and internal fit.

Adequate marginal adaptation is essential for the long-term clinical success of restorations. Poor marginal adaptation may adversely affect the tooth and surrounding periodontal tissues and may also compromise the mechanical and physical performance of the restoration [2–6]. The marginal adaptation and internal fit of restorations can be evaluated using various methods, including cross-sectional analysis, digital microscopy, stereomicroscopy, the silicone replica technique, clinical examination, and scanning electron microscopy (SEM) [8]. Microscopic techniques generally provide 2D evaluations of marginal and internal gaps at the tooth - PLV interfaces or on selected cross-sectional surfaces, thereby limiting the number of measurement points and sections that can be examined in each specimen [8, 11]. In contrast, micro-CT enables 3D assessment of the PLV and its relationship with the underlying tooth, allowing a more comprehensive evaluation of marginal adaptation and internal fit while overcoming some of the limitations associated with conventional measurement techniques [8]. Micro-CT was therefore selected for the present study because previous investigations have reported that it provides accurate, reliable, and repeatable measurements [12, 13]. Despite these advantages, micro-CT has certain limitations, including high equipment costs and prolonged image acquisition and processing times. Nevertheless, its nondestructive nature allows high-resolution, micrometer-scale imaging and quantitative assessment of the tooth–restoration interface in two and three dimensions without sectioning or otherwise damaging the specimens [14]. As the micro-CT analysis did not require physical sectioning of the specimens, measurements were performed on five different cross-sections in each plane. In the transverse plane, marginal adaptation was measured at eight points and internal fit at five points on each cross-section, yielding a total of 65 measurements per specimen. In the sagittal plane, marginal adaptation was measured at three cervical and three incisal points across five different cross-sections, yielding a total of 30 measurements per specimen. Thus, a total of 95 quantitative measurements at the micrometer level were obtained from each specimen to improve the precision of the statistical analysis [15].

For fixed prosthetic restorations, the clinically acceptable marginal gap has been reported to range from 50 to 120 µm [16]. Regarding long-term prognosis, McLean [16] suggested a maximum clinically acceptable marginal gap of 120 µm, whereas Björn [17] proposed a threshold of 200 µm. Previous studies investigating CAD/CAM-milled ceramics have reported mean marginal gap values ranging from 56 to 315 µm and mean internal fit values ranging from 68 to 208 µm [8]. An exception was the study by Abushelib et al. [18], in which the mean marginal gap reached 545 µm. For heat-pressed ceramics, the reported mean marginal and internal gap values ranged from 22 to 295 µm and from 61 to 202 µm, respectively [8]. These findings are consistent with the results of the present study. Before cementation, the marginal adaptation values in the CB and CO groups ranged from approximately 48 to 112 µm at the mesial marginal gap, 52 to 82 µm at the distal marginal gap, 62 to 115 µm at the cervical marginal gap, and 73 to 126 µm at the incisal margin. These values were generally within the clinically acceptable range reported in the literature (8,16,17). Kim et al. [19] evaluated the fit of CEREC-fabricated partial crowns prepared using two different preparation designs by means of micro-CT, with the cement space set at 30 µm. The marginal gap values ranged from 82 to 306 µm in the group with a retentive preparation design and from 81 to 243 µm in the group with a non-retentive preparation design. The values obtained in the

present study were lower than those reported by Kim et al., which may be attributable to differences in preparation design. Among the CEREC-fabricated groups in our study, the highest marginal gap value was 126 μm, observed at the incisal margin in the CO group. Marginal gap values ranged from 48 to 78 μm in the bevel preparation group, whereas values in the overlap group ranged from 62to 135 μm.

Neves et al. [20] compared the marginal fit of IPS e.max Press and IPS e.max CAD/CAM crowns using a cement-space setting of 0 μm, reporting mean marginal gap values of 36.8 and 39.2 μm, respectively. In contrast, the present study revealed higher marginal gap values for IPS Empress Esthetic (78–183 μm) than for CEREC-fabricated veneers (48–126 μm). The multiple processing steps involved in heat-pressing, together with technician-dependent factors and material-related thermal changes, may contribute to variations in marginal adaptation. However, the findings should be interpreted cautiously because the cement-space settings differed between the studies. An insufficient cement space may restrict cement escape and generate hydraulic pressure, preventing complete seating of the restoration. Although a cement space of 50–120 μm has been reported as clinically acceptable, the appropriate range may vary according to the restoration and clinical conditions [16, 17, 21].

Baig et al. [22] used nano-CT to evaluate the marginal adaptation and internal fit of CAD/CAM-fabricated PLVs made from monolithic zirconia-reinforced lithium silicate (ZLS) and monolithic lithium disilicate (LDS; IPS e.max CAD), while also investigating the effects of two incisal preparation designs (butt-joint and chamfer). The marginal gap values for ZLS veneers were 65 μm and 100 μm in the butt-joint and chamfer groups, respectively, whereas those for LDS veneers were 100 μm and 104 μm, respectively. Internal fit values were comparable across all groups, ranging from 100 to 114 μm. In the present study, the absolute marginal gaps values in the CB and CO groups ranged from 48 to 136 μm at the mesial margin, 52 to 136 μm at the distal margin, 62 to 183 μm at the cervical margin, and 82 to 180 μm at the incisal margin. Although the values observed in the present study were generally higher, they were within a broadly comparable range to those reported by Baig et al. [22].

In the present study, the absolute marginal gap values were lower in the CEREC groups than in the heat-pressed groups. For the IPS Empress Esthetic groups, the measured values ranged from 78 to 136 μm at the mesial margin, 105 to 136 μm at the distal margin, 70 to 165 μm at the cervical margin, and 154 to 342 μm at the incisal margin. The lowest marginal gap value 48 μ was recorded at the mesial and distal margins of the CB groups, which featured a bevel preparation design, whereas the highest value 183 μm was observed at the cervical margin of the EO groups, which featured an overlap preparation design. Unlike conventional indirect techniques, the CEREC system does not require conventional impression taking or cast fabrication and is therefore not subject to dimensional changes associated with impression and model materials. Furthermore, because ceramic blocks are milled directly, heat-related shrinkage and deformation during ceramic processing may be avoided, potentially contributing to improved restoration fit [8, 19, 20]. The overlap preparation design may also contribute to increased marginal gap values because its more complex geometry may make scanning, digital design, and accurate adaptation more challenging than with a bevel preparation. Consistent with this observation, marginal gap values in the present study ranged from 48 to 72 μm in the CB group and from 62 to 126 μm in the CO group.

In a clinical study, Wolfart et al. [23] evaluated the marginal fit of lithium disilicate all-ceramic crowns and inlays before and after cementation by performing SEM measurements on silicone impressions obtained intraorally. Resin cement was used for luting, and the reported marginal gap values before and after cementation were 96 and 130 μm for crowns and 89 and 92 μm for inlays, respectively. Similarly, Gemalmaz et al. [24] assessed the marginal gaps of MOD inlays before and after cementation using silicone replica and sectioning techniques and found no significant differences between the two measurements. In the present study, no statistically significant differences were generally observed between pre- and post-cementation marginal adaptation and internal fit values, except for a significant increase in the MMG measurements. However, this increase may not be clinically relevant. Since both luting agents used in the present study were resin-based cements, their relatively low viscosity and adequate working time may have facilitated the seating of the restorations in a position similar to that achieved before cementation. Nevertheless, the clinical challenges associated with cementation should be considered carefully when comparing PLVs with full crowns, inlays, and onlays. In full-coverage restorations and intracoronal restorations, circumferential finish lines and occlusal contact points may provide additional references for positioning. In contrast, PLVs are bonded to a limited tooth surface and involve minimal tooth reduction, making accurate positioning during final cementation a particularly technique-sensitive procedure.

One limitation of this study is that the effects of cyclic masticatory loading on the marginal adaptation and internal fit of PLVs were not evaluated. Further studies incorporating simulated masticatory forces are therefore needed to investigate their potential effects on restoration fit under conditions that more closely resemble the oral environment. In addition, studies involving natural teeth and clinical evaluations are warranted to validate the present findings under actual clinical conditions.

CONCLUSION

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

1. CEREC fabricated PLVs exhibited lower marginal gap values than those fabricated using IPS e max Press.
2. Overall, the bevel preparation design was associated with lower marginal gap values than the overlap design, whereas no marked differences were observed in internal fit between the two preparation designs.
3. Cementation did not significantly affect the marginal adaptation or internal fit of PLVs.
4. Within the limitations of this in vitro study, CEREC fabrication and the bevel preparation design may be considered favorable options for achieving improved marginal adaptation in PLV restorations.

Abbreviations

- Porcelain laminate veneers
PLVs

- Micro-computed tomography
Micro-CT
- Computer-Aided Design / Computer-Aided Manufacturing
CAD/CAM
- COV
Cerec, Overlap, Variolink Veneer
- COC
Cerec, Overlap, Clearfil Esthetic EX
- CBV
Cerec, Bevel, Variolink Veneer
- CBC
Cerec, Bevel, Clearfil Esthetic EX
- EOV
IPS Empress Esthetic, Overlap, Variolink Veneer
- EOC
IPS Empress Esthetic, Overlap, Clearfil Esthetic EX
- EBV
IPS Empress Esthetic, Bevel, Variolink Veneer
- EBC
IPS Empress Esthetic, Bevel, Clearfil Esthetic EX
- µm
Mikrometer
- mm
Milimeter
- DICOM
Digital Imaging and Communications in Medicine
- MMD
Mesial marginal distance
- MMG
Mesial marginal gap
- MSG
Mesial step gaps
- DMD
Distal marginal distance
- DMG
Distal marginal gap
- DSG
Distal step gap
- IF
Internal fit
- CMD
Cervical marginal distance
- CMG
Cervical marginal gap
- CSG
Cervical step gaps
- IMD
Incisal marginal distance
- IMG
Incisal marginal gap
- SEM
Scanning electron microscopy
- ZLS
Zirconia-reinforced lithium silicate
- LDS
Lithium Disilicate
- MOD
Mesial-Occlusal-Distal

Declarations

Ethics approval and consent to participate

The study was approved by the Clinical Research Ethics Committee of İnönü University, Malatya, Türkiye (Approval No. 2013/108).

Consent for Publication

Not applicable

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING

DECLERATION

This study was funded by TUBITAK research grant and the project number 112S605.

Author Contribution

MAM: Conceptualization, Methodology, Micro-CT Analysis, Data Analysis, Statistical Analysis, Original Draft Writing , and prepared the figures , SupervisorFT: Micro-CT Analysis, Laboratory Procedure, Data Collection

Acknowledgement

MAM: Research planning, Micro CT Analysis, Data evaluation, Statistical Analysis, Manuscript writing and editingFT: Laboratory procedure, Data Collection, Data preparation for Micro CT analysis

Data availability

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

References

1. Cötert HS, Dündar M, Oztürk B. The effect of various preparation designs on the survival of porcelain laminate veneers. J Adhes Dent. 2009;11:405–11.
2. Beier US, Kapferer I, Burtscher D, Dumfahrt H. Clinical performance of porcelain laminate veneers for up to 20 years. Int J Prosthodont. 2012;25:79–85.
3. Friedman MJ. Commentary. Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: a literature review. J Esthet Restor Dent. 2012;24:266–7.
4. Alenezi A, Alsweed M, Alsidrani S, Chrcanovic BR. Long-Term Survival and Complication Rates of Porcelain Laminate Veneers in Clinical Studies: A Systematic Review. J Clin Med. 2021;10:1074.
5. Oztürk E, Bolay S. Survival of porcelain laminate veneers with different degrees of dentin exposure: 2-year clinical results. J Adhes Dent. 2014;16:481–9.
6. Karagözoğlu İ, Toksavul S, Toman M. 3D quantification of clinical marginal and internal gap of porcelain laminate veneers with minimal and without tooth preparation and 2-year clinical evaluation. Quintessence Int. 2016;47:461–71.
7. Demir N, Ozturk AN, Malkoc MA. Evaluation of the marginal fit of full ceramic crowns by the microcomputed tomography (micro-CT) technique. Eur J Dent. 2014;8:437–44.
8. Baig MR, Qasim SSB, Baskaradoss JK. Marginal and internal fit of porcelain laminate veneers: A systematic review and meta-analysis. J Prosthet Dent. 2024;131:13–24.
9. Vilaplana-Vivo J, Vilaplana-Vivo C, Miguel-Sanchez A, Garcia-Ballesta C, Camacho-Alonso F. In vitro fracture resistance of mandibular incisors restored with modified partial-coverage ceramic restorations. Dent Traumatol. 2014;30:356–61.
10. Rosentritt M, Plein T, Kolbeck C, Behr M, Handel G. In vitro fracture force and marginal adaptation of ceramic crowns fixed on natural and artificial teeth. Int J Prosthodont. 2000;13:378–91.
11. Alajaji NK, Bardwell D, Finkelman M, Ali A. Micro-CT Evaluation of Ceramic Inlays: Comparison of the Marginal and Internal Fit of Five and Three Axis CAM Systems with a Heat Press Technique. J Esthet Restor Dent. 2017;29:49–58.
12. Çelik Güler Ö, Malkoç S. Effects of orthodontic force on root surface damage caused by contact with temporary anchorage devices and on the repair process. Korean J Orthod. 2019;49:106–15.
13. Kucuk EB, Malkoc S, Demir A. Microcomputed tomography evaluation of white spot lesion remineralization with various procedures. Am J Orthod Dentofac Orthop. 2016;150:483–90.
14. Malkoç MA, Sevimay M, Tatar İ, Çelik HH. Micro-CT Detection and Characterization of Porosity in Luting Cements. J Prosthodont. 2015;24:553–61.

15. Nawafleh NA, Mack F, Evans J, et al. Accuracy and reliability of methods to measure marginal adaptation of crowns and FDPs: a literature review. J Prosthodont. 2013;22:419–28.
16. McLean JW, von Fraunhofer JA. The estimation of cement film thickness by an in vivo technique. Br Dent J. 1971;131:107–11.
17. Bjorn AL, Bjorn H, Grkovic B. Marginal fit of restorations and its relation to periodontal bone level. II Crowns Odontologisk Revy. 1970;21:337–46.
18. 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.
19. Kim JH, Cho BH, Lee JH, Kwon SJ, Yi YA, Shin Y. Influence of preparation design on fit and ceramic thickness of CEREC 3 partial ceramic crowns after cementation. Acta Odontol Scand. 2015;73:107–13.
20. Neves FD, Prado CJ, Prudente MS, Caneiro TA, Zancope K, Davi LR, Mendonca G, Cooper LF, Soares CJ. Micro-computed tomography evaluation of marginal fit of lithium disilicate crowns fabricated by using chairside CAD/CAM systems or the heat-pressing technique. J Prosthet Dent. 2014;112:1134–40.
21. Şen D. Simantasyon, 1. Baskı. İstanbul, Quintessence yayıncılık ltd şti. 2003: 4–13, 23–28.
22. Baig MR, Akbar AA, Sabti MY, Behbehani Z. Evaluation of Marginal and Internal Fit of a CAD/CAM Monolithic Zirconia-Reinforced Lithium Silicate Porcelain Laminate Veneer System. J Prosthodont. 2022;31:502–11.
23. Wolfart S, Wegner SM, Al-Halabi A, Kern M. Clinical evaluation of marginal fit of a new experimental all-ceramic system before and after cementation. Int J Prosthodont. 2003;16:587–92.
24. Gemalmaz D, Ozcan M, Yoruc AB, Alkumru HN. Marginal adaptation of a sintered ceramic inlay system before and after cementation. J Oral Rehabil. 1997;24:646–51.

Figures

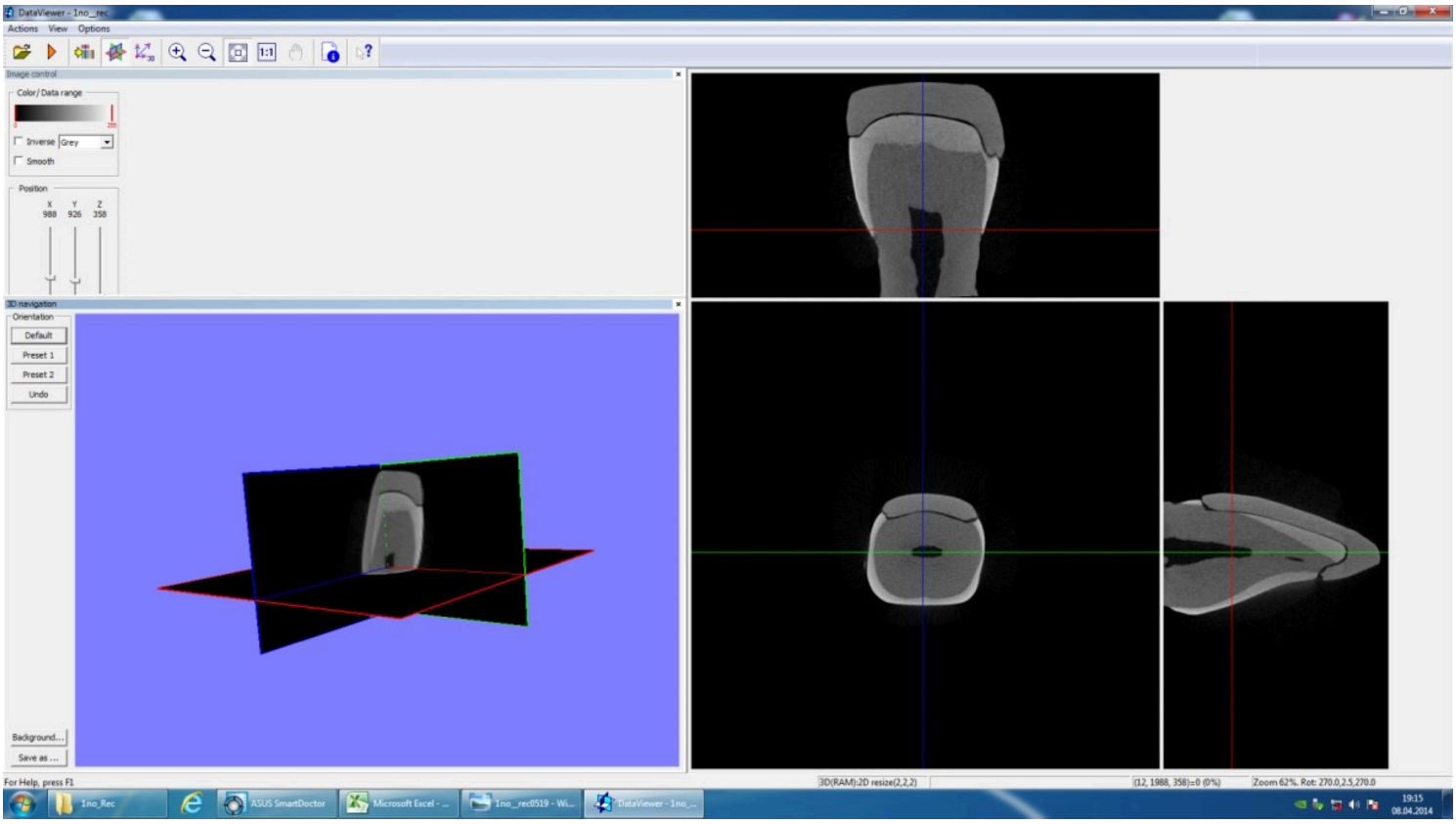


Figure 1

Micro CT analysis software program (CTAn) for sectioning of PLV samples on transversal, sagittal and vertical dimensions.

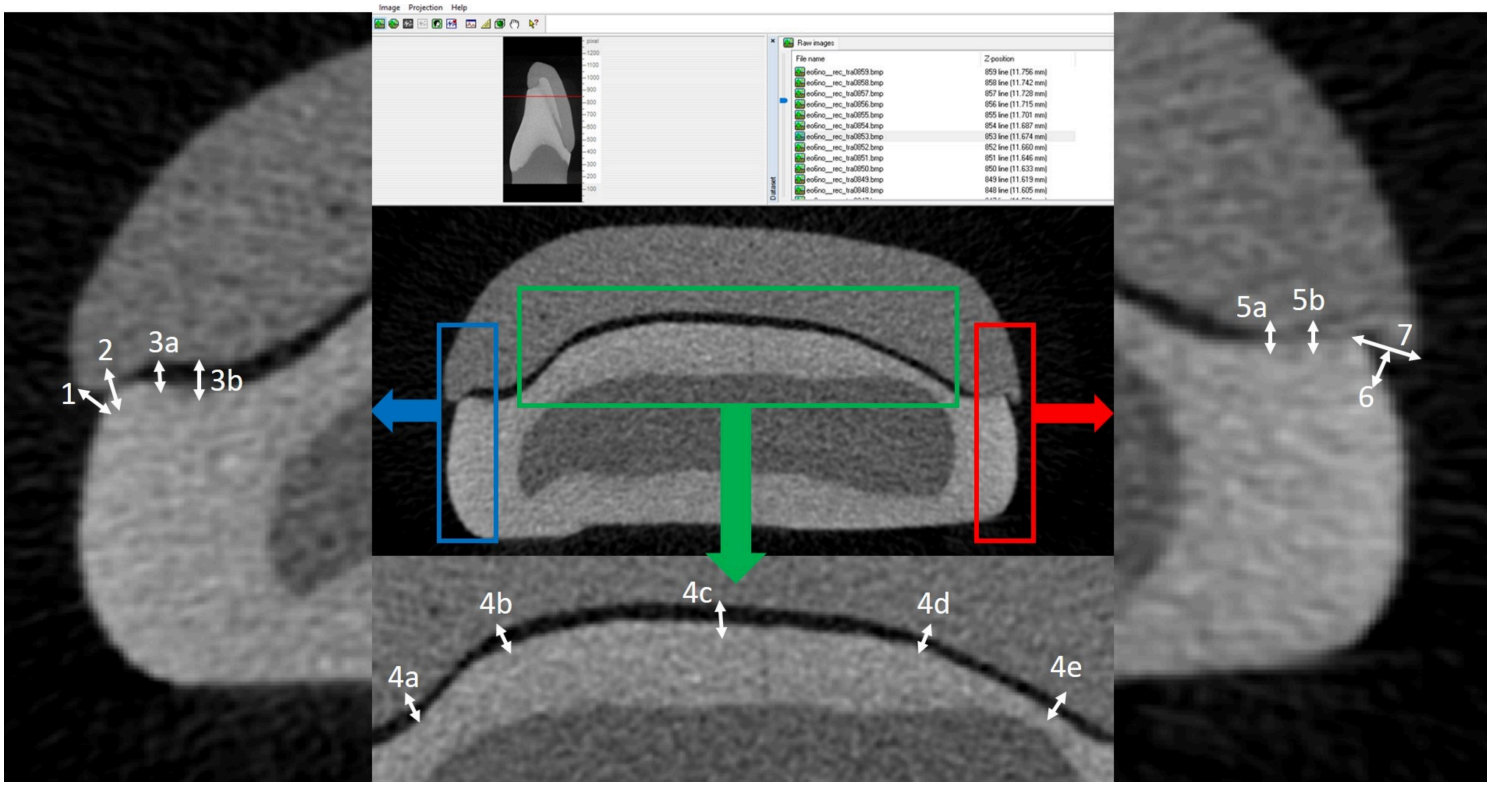


Figure 2

Marginal adaptation and internal fit measurements on transversal plane. 1, mesial marginal distance; 2, mesial marginal gap; 3, mesial step gap;4, internal fit; 5, distal step gap; 6, distal marginal gap; 7, distal marginal distance.

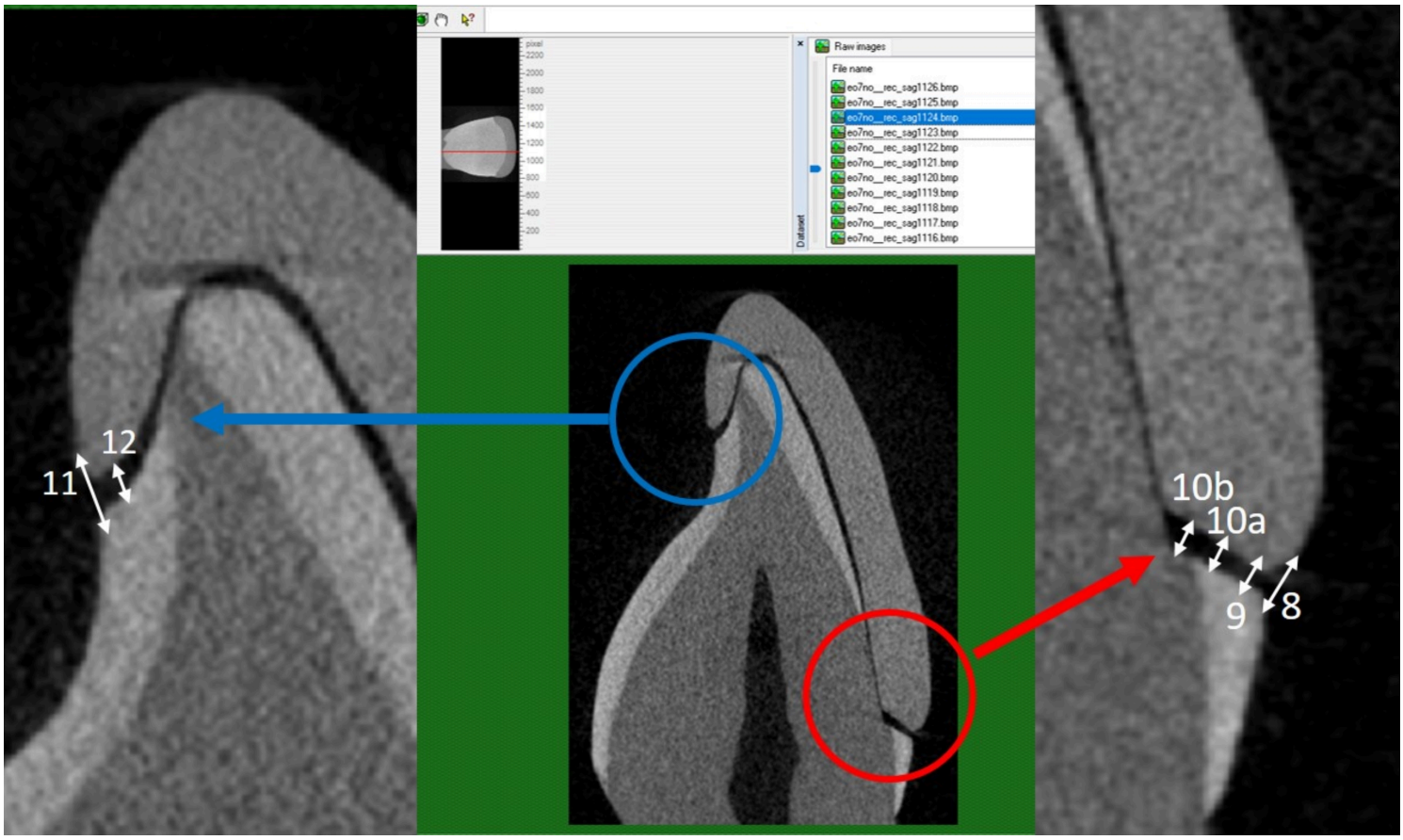


Figure 3

Marginal adaptation measurements on sagittal plane. 8, cervical marginal distance; 9, cervical marginal gap; 10, cervical step gap; 11, incisal marginal distance; 12, incisal marginal gap.

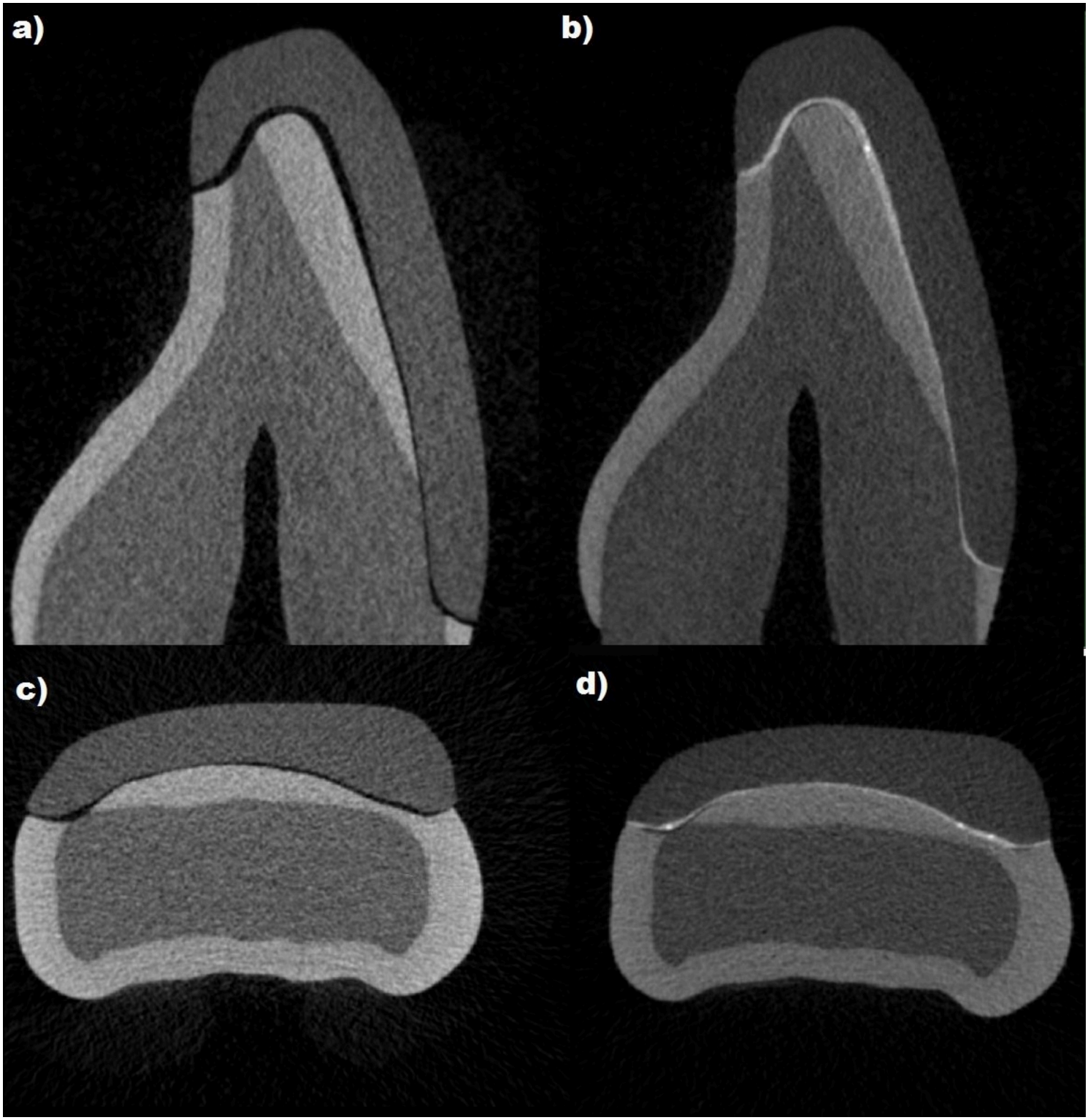


Figure 4

Overlap preparation design. a, sagittal section before cementation; b, sagittal section after cementation; c, transversal section before cementation; d, transversal section after cementation

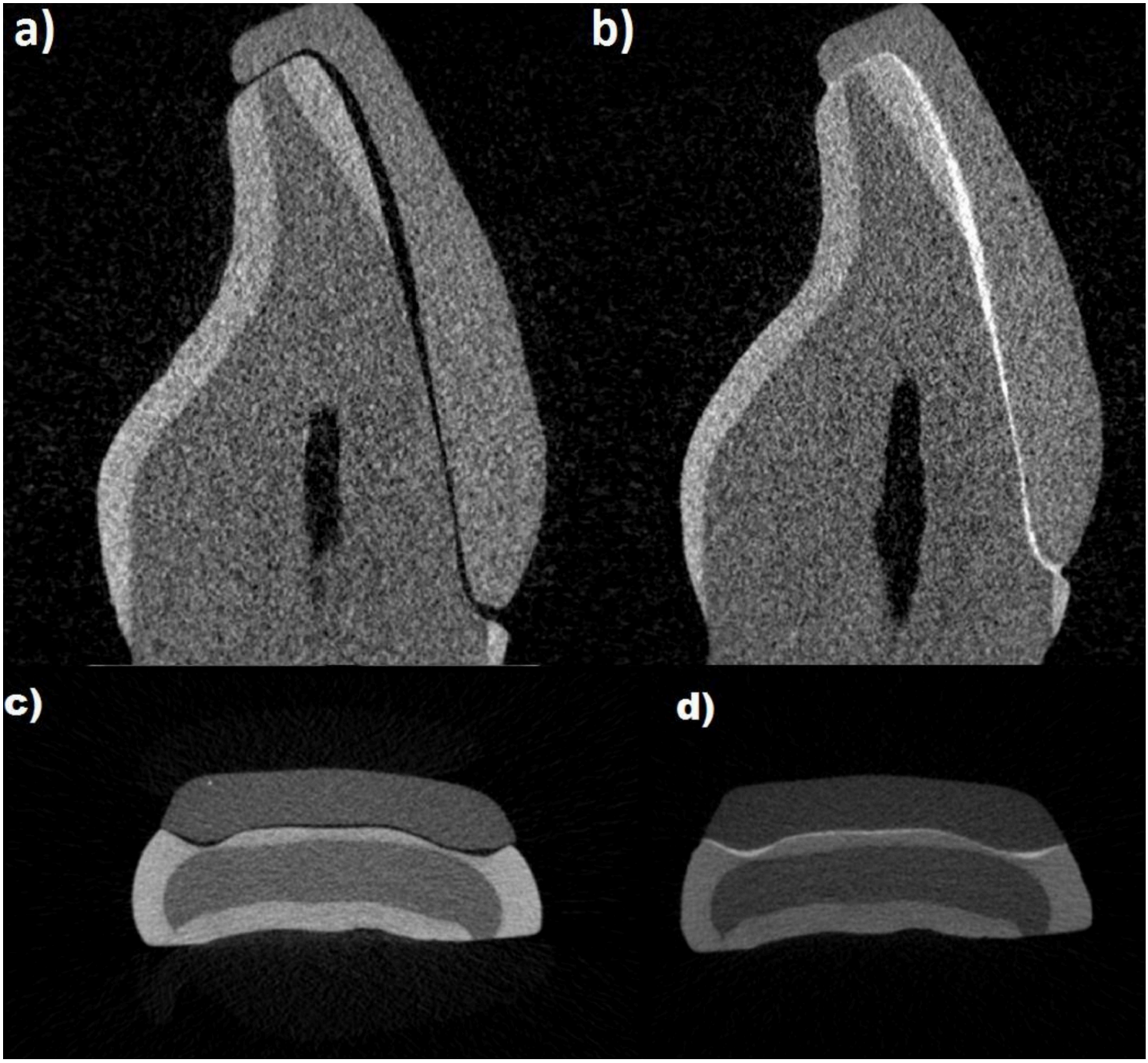


Figure 5

Bevel preparation design. a, sagittal section before cementation; b, sagittal section after cementation; c, transversal section before cementation; d, transversal section after cementation

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- coi.bmc.docx