MEANDROS MEDICAL AND DENTAL JOURNAL
March 2025 (1):108-116

Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1596545

Research Article

THE EFFECT OF DIFFERENT FIT-INDICATING MATERIALS AND PREPARATION DESIGNS ON THE MARGINAL AND INTERNAL FIT OF 3D-PRINTED PERMANENT ENDOCROWNS

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Received: *05 December 2024*
Revised: *03 February 2025*
Accepted: *05 February 2025*
Published: *20 March 2025*

Abstract

Objective: This study aimed to evaluate the effect of different fit-indicating materials and preparation designs on the marginal and internal fit of 3D-printed permanent endocrowns.

Materials and Methods: Maxillary right first molar typodont teeth were prepared with two designs and divided into two groups (N=80): Group 1-butt joint margin and a 4 mm pulp chamber depth, and Group 2-shoulder margin design and a 4 mm pulp chamber depth. The groups were scanned with a digital intraoral scanner, and 3D-printed master dies and permanent endocrowns were fabricated. Endocrowns were seated using vinyl polyether silicone (VPES) and polyvinyl siloxane (PVS) fit-indicating materials. Superimposition of prepared and fit-indicating material-applied master die scans was performed using 3D-analysis software. Multi-point measurements at standard points determined marginal, internal, pulp chamber and overall gap values, which were compared between the groups. Statistical analysis included Two-Way ANOVA for normally distributed data and Spearman's rho for non-normally distributed data (α=0.05). Pairwise comparisons were conducted with post hoc Tukey tests.

Results: VPES exhibited lower marginal and internal gap values than PVS ($p<0.001$). PVS usage in the butt-joint design showed the highest marginal gap, while the lowest internal gap was observed with VPES usage in the shoulder design ($p<0.001$).

Conclusion: Using different fit-indicating materials with different preparation designs affects the fit of endocrowns. VPES provides a more accurate determination of the internal fit of a 3D-printed endocrown in the shoulder margin design and the marginal fit of the endocrown with butt-joint margin design.

Keywords: Printing, Three-Dimensional, Dental Restoration, Permanent, Fit-Checker, Dental Marginal Adaptation

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INTRODUCTION

Endocrowns are popular monoblock restorations for endodontically treated teeth with substantial coronal structure loss, combining the crown and core into a single unit that covers all cusps, typically with a circular butt margin and shoulder or chamfer margin design extending to the pulpal floor (1,2). The macromechanical retention of endocrowns is achieved by anchoring them within the pulp chamber and adapting them to cavity margins, with varying depths and configurations of the chamber and the margin design, which plays a critical role in their mechanical performance (3).

The marginal and internal adaptation of a restoration is key in determining its longterm clinical performance (4). Marginal and internal adaptation of restoration was commonly evaluated using two-dimensional (2D) methods, which limit the number of cross-sections and measurement points used to describe overall adaptation (5). In contrast, digital techniques—especially three-dimensional (3D) analysis combined with intraoral scanners—offer a more comprehensive assessment, allowing unlimited measurements of the gap between the restoration and abutment tooth and enabling evaluation of both adaptation and cement gap volume (4). This 3D analysis digitally aligns the scans of the tooth preparation and fit-indicating material over the preparation and allows the gap measurement.

Fit-indicating materials are elastomeric materials used in the fit assessment of restorations and clearly reveal gaps between the restoration and abutment tooth, facilitating precise adjustments (6,7). The light-body consistency form of polyvinylsiloxane (PVS) is a commonly used fit-indicating material in studies (8,9). Vinyl polyether silicone (VPES), marketed as Fit Checker, is an alternative impression material specifically designed to evaluate the marginal and internal fit of restorations (6,7). During the silicone disclosing procedure, they contact the restoration's internal surface and the prepared tooth (10,11).

Innovations in 3D-printing technology have provided alternative material options by offering several advantages, such as high accuracy and reduced material waste (12). Recently, 3D-printed ceramic-filled hybrid materials have emerged with application areas of single-tooth restorations, inlays, onlays, tabletops, veneers, and three-unit bridges in posterior areas. The manufacturer claims this material has high dimensional stability, flexural strength, and modulus and can be used as a permanent restorative material (Bego; VarseoSmile Triniq technical product information data sheet. n.d.).

To the best of the authors' knowledge, there are studies in the literature evaluating the marginal and internal fit of endocrowns with different preparation designs using different fit-indicating materials. However, no study has evaluated the fit of 3D-printed ceramic-filled permanent endocrowns with different preparation designs by comparing them with different fit-indicating materials through 3D analysis. Therefore, the present study aims to evaluate the effect of different fit-indicating materials and preparation designs on the marginal and internal fit of 3D-printed permanent endocrowns. The null hypotheses for this study were as follows; there would be no effect of different fit-indicating materials on the marginal and internal fit of endocrowns, there would be no effect of different preparation designs on the marginal and internal fit of endocrowns

MATERIALS AND METHODS

The sample size calculation was performed using a statistical software program (G*Power v3.1.9.2) using data from another study by Seo et al. (13) the minimum sample size of 20 specimens for each group achieved 95% power to detect differences, with a significance level of 0.05, to test the null hypotheses.

A pilot study was performed with four samples for each group before the present study. During the pilot study, one operator experienced performing the final preparations after multiple preparation trials under a dental operation microscope and scanning them with a digital intraoral scanner. Master dies were designed and fabricated as single and in sets of four. An attempt was made to produce all prepared samples as single master dies. Because it provided ease of measurement. The endocrowns were adhered to the master dies using different fit-indicating materials and were applied with a standard 50 N force on each master die three times. When attempting to apply this force using finger pressure, gradual increases and decreases in pressure were observed. Therefore, it was decided to use an electric motor-driven machine to ensure the application of a constant force. To enable easy separation of the endocrowns from the master die, water, petroleum jelly (Vaseline), and hand lotion (Geistlich Pharma AG, Bahnhofstrasse, Wolhusen) were tested. The best and most controlled results were achieved with Vaseline. Multiple

3D analysis attempts were made by another operator. Based on these findings, the main study proceeded as outlined below.

Tooth preparations were performed by one operator according to different preparation designs on typodont maxillary first molars (AG-3 ZE, Frasaco GmbH, Tettnang, Germany) using a dental operation microscope (Zumax OMS 2000, Zumax, China) at x18.4 magnification. The groups were as follows:

- Group 1: Butt-joint margin and a 4 mm pulp chamber depth
- Group 2: Shoulder (1 mm) margin and a 4 mm pulp chamber depth

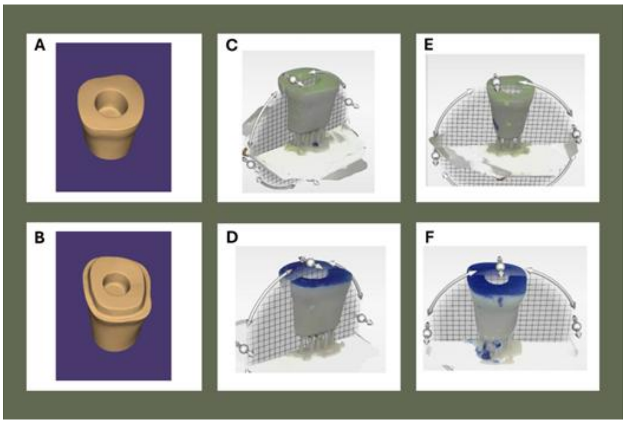

Figure 1.(A) The preparation scan of Group 1, (B) The preparation scan of Group 2, (C&D) Buccolingual section images taken via STL data superimposition in Oracheck 3D analysis software, (E&F) Mesiodistal section images taken via STL data superimposition in Orach

A 2 mm occlusal reduction was performed on each group using a green belt occlusal-reduction diamond bur (Frank Dental GmbH D.828.017.G.FGA, Gmund, Germany) as the first step in the preparation process. In Group 1, a 2 mm wide circumferential butt-joint margin is prepared using a green belt wheel diamond bur (Meisinger 909G-031-FG Coarse 5/Pk, Neuss, Germany). The pulp chamber is subsequently prepared using a red belt conical diamond bur (Frank Dental GmbH D.845KR.016.G.FGA, Gmund, Germany) with an internal taper of 8° axial walls (14). Additionally, the internal line angle was rounded down, irregularities were eliminated, and a flat, polished surface was created using a red belt medium round-end tapered diamond bur (Frank Dental GmbH D.850.016.FG, Gmund, Germany). The preparation design of Group 1 is shown in **Fig.1A**. The identical burs used in Group 1 were utilized throughout the whole preparation process in Group 2. The primary difference was that in contrast to Group 1, a red belt modified shoulder fine W diamond bur (Meisinger 848WF-018-FG, Gmund, Germany) was used to prepare the 1 mm shoulder margin following occlusal reduction with an occlusal-reduction diamond bur and pulp chamber preparation with a conical diamond bur. The preparation design of Group 2 is shown in **Fig.1B**. Following the preparations, a periodontal probe and a digital calliper (Digimatic, Mitutoyo Corporation, Japan) were utilized to confirm the measurements of pulp chamber depths, margin widths, and occlusal reductions.

A digital intraoral scanner (CEREC AC, Primescan, Dentsply Sirona, York, PA, USA) was used to scan the prepared teeth for each group, and Sirona InEos X5 software (InEos X5, Dentsply-Sirona, York, PA) to process the external CAD data. Then, Shapr 3D (Shapr 3D, Budapest, Hungary), a CAD program for generating and creating ready models, was used to import standard tessellation language (STL) files. Drawing bases beneath the prepared teeth STLs for various groups allowed for the design of the single master dies. Forty single master dies of each group were then printed with a layer thickness of 50 µm using a 3D printer (Asiga Ultra (50), ASIGA, Sydney, Australia) and 3D-printed model resin (VarseoWax Model, Bego, Bremer, Germany). Following printing, the dies were cleaned with 99% isopropanol alcohol for 3 minutes (Form Wash, Formlabs®, Somerville, USA) and post-cured twice for 20 minutes at 60° (Form Cure, Formlabs®, Somerville, USA).

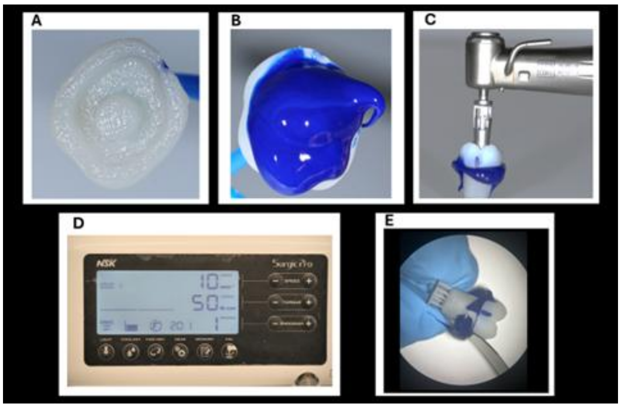

Figure 2. (A) Vaseline application to the inner surface of endocrown (B) Loading of endocrown using VPES fit-indicating (C&D) Application of 50 N force over endocrown until the setting of fit-indicating material is completed (E) Removal of excess fit-indicating material using a surgical blade under the dental microscope.

Typodont maxillary molar teeth were scanned before and after preparation for the endocrown design. The exocad DentalCAD program (exocad GmbH, Darmstadt, Germany) was utilized to process these STL data. Endocrown designs were created on the prepared tooth STLs, to reflect the tooth's initial morphology. In the

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March 2025 (1):108-116

Meandros Medical and Dental Journal
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chairside CAD design, the cement space was specified at 80 µm. The endocrowns were subsequently printed with a 50 µm layer thickness using a 3D printer and 3D-printed ceramic-filled hybrid material (VarseoSmile Triniq, Bego, Bremer, Germany). Following the manufacturer's instructions, the 3D-printed endocrowns were rinsed with 99% isopropanol alcohol for a total of 5 minutes (Form Wash, Formlabs®, Somerville, USA), and post-cured twice for 20 minutes at 60° (Form Cure, Formlabs®, Somerville, USA).

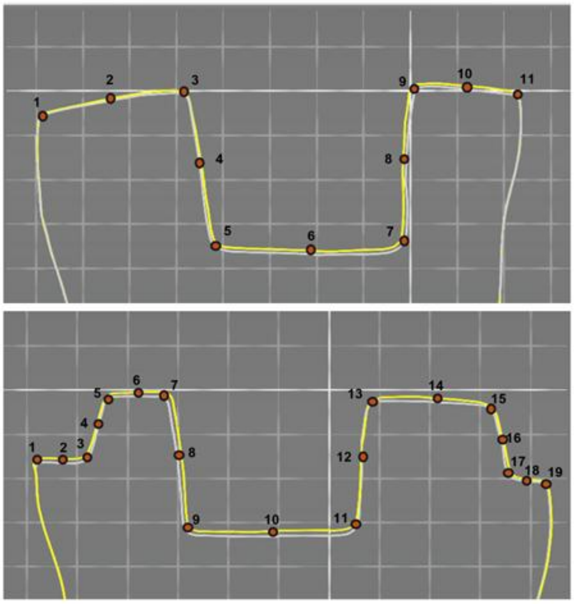

Figure 3. (A) Marginal and internal fit analysis of Group 1 from 11 points in the image taken via STL data superimposition in Oracheck 3D analysis software. (B) Marginal and internal fit analysis of Group 2 from 19 points in the image taken via STL data superimposition in Oracheck 3D analysis software. *Images represent mesiodistal (MD) sections, and each square is 1 mm².

A proprietary software (OraCheck, Cyfex AG, Zurich, Switzerland) program specifically designed for the CEREC system was used for the 3D analysis of the fit of endocrowns. Using the digital intraoral scanner, the endocrown preparation dies were initially scanned and saved as the preparation's master digital file.

The inner surface of each endocrown was gently wiped with Vaseline as a lubricant **(Fig. 2A)**. Each group was divided into two subgroups according to the fit-indicating material (n=20). The VPES (Fit Checker; GC Europe, Leuven, Belgium) and PVS fit-indicating materials (Elite HD+ light-body; Zhermack SpA, Badia Polesine (RO), Italy) were used to load endocrowns before seating on master dies **(Fig.2B)**. The force was standardized by applying 50 N while seating (15). For each group, after the endocrowns were seated on the master dies, 50 N was applied with an electric motor-driven machine (Surgic Pro, NSK, IL, USA) to mimic a 5 kg weight until the setting times of the fit-indicating materials were completed **(Fig.2C&D)**. The setting time was 2 min and 4 min for VPES and PVS fit-indicating material, respectively. Under the dental microscope, excess fit-indicating material was gently removed from the margins using a surgical blade (no. 12; Feather Safety Razor Co., Ltd., Osaka, Japan) **(Fig. 2E)**.

The digital intraoral scanner was utilized to perform a second scan with the fit-indicating material covering the preparation die after the endocrown was removed from the preparation. For every tested group, the two recorded scans were digitally superimposed in STL files using the 3D analysis software. The distances between each surface point in the first data set and the surface points in the second data set were calculated for the subtractive analysis. Approximately 20,000 points were chosen for each surface matching by the software's best-fit algorithm (9). To assess the means of the marginal gap (MG), internal gap (IG), pulp chamber gap (PCG), and overall gaps (OG) of Group 1 and Group 2 in all three dimensions over the superimposition views, vertical sections were chosen from the core region of each superimposition in the buccolingual **(Fig.1C&D)** and mesiodistal directions **(Fig.1E&F)**. The mean values for Group 1 were determined by making the MG measurement at points 1 and 11, the IG measurement at points 2 to 10, the PCG measurement at points 3 to 9, and the OG measurement at points 1 to 11 **(Fig.3A)**. The means of the MG measurement points 1 and 19, the IG measurement points 2 to 18, the PCG measurement points 7 to 13, and the OG measurement points 1 to 19 were computed for Group 2 **(Fig.3B)**. The PCG assessment was also included in the IG evaluation. Furthermore, both IG and MG evaluation areas are included in the OG measurements.

The data were analyzed with IBM SPSS V23 (IBM Statistics, Armonk, NY). The normality of distribution was examined with the Shapiro-Wilk and Kolmogorov-Smirnov Test. Spearman's rho Correlation Coefficient was used to examine the relationship between the parameters that were not normally distributed. A Two-Way ANOVA was used to compare the parameters that were normally distributed according to the fit-indicating material and preparation design. For pairwise comparisons, the post hoc Tukey test was applied. The results were presented as mean ± standard deviation. The significance level was set as $p<0.05$.

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RESULTS

MG, IG, PCG, and OG measurements were compared according to the main effects of different fit-indicating materials, different preparation designs and the interaction between the two, as shown in **Table 1**. The only statistically non-significant difference was observed in the main effect of preparation design on the IG values (p=0.317) **(Table 1)**.

Table 1. Comparison of marginal, internal, pulp chamber and overall gap values according to fit-indicating material and preparation designs

Marginal Gap Measurements (MG)			
	F	**p**	**PES**
Fit-indicating material	46.89	<0.001	0.382
Preparation design	29.43	<0.001	0.279
Fit-indicating material*Preparation design	42.66	<0.001	0.359
Internal Gap Measurements (IG)			
	F	**p**	**PES**
Fit-indicating material	57.54	<0.001	0.431
Preparation design	1.01	0.317	0.013
Fit-indicating material*Preparation design	5.31	0.024	0.065
Pulp Chamber Gap Measurements (PCG)			
	F	**p**	**PES**
Fit-indicating material	166.17	<0.001	0.686
Preparation design	50.64	<0.001	0.400
Fit-indicating material*Preparation design	59.76	<0.001	0.440
Overall Gap Measurements (OG)			
	F	**p**	**PES**
Fit-indicating material	69.42	<0.001	0.477
Preparation design	23.85	<0.001	0.239
Fit-indicating material*Preparation design	17.23	<0.001	0.185

F: Two-Way ANOVA Test Statistic; PES: Partial Eta Square. Statistically significant at p<0.05.

When comparing the mean values of gap measurements using different fit-indicating materials, VPES showed lower results than PVS in all groups (p<0.001). Lower gap values were obtained in Group 1 than in Group 2 among MG, PCG, and OG measurements in different preparation design evaluations (p<0.001). Regarding the interaction between different fit-indicating materials and preparation designs, VPES used in Group 1 resulted in lower MG values (0.0184 ± 0.0053 mm) than PVS and Group 1 (0.0501 ± 0.0134 mm). VPES and Group 2 showed lower values (0.0736 ± 0.0055 mm) compared to PVS and Group 2 (0.1078 ± 0.0081 mm) in IG measurements. PCG measurements revealed a higher value in PVS and Group 2 (0.1503 ± 0.0124 mm) than VPES and Group 2 (0.0759 ± 0.0069 mm). Additionally, while PVS and Group 2 (0.1014 ± 0.0082 mm) showed a higher OG, VPES and Group 1 showed a lower value (0.0673 ± 0.0065 mm) (Table 2). The mean differences between groups are shown in Figure 4.

Table 3. Correlation analysis between parameters based on average marginal, internal, pulp chamber, and overall gap measurements

		1	**2**	**3**	
Marginal Gap (MG) Measurements (1)	r	1			
	p	---			
Internal Gap (IG) Measurements (2)	r	0,372	1		
	p	**0.001**	---		
Pulp Chamber Gap (PCG) Measurements (3)	r	0,337	0,925	1	
	p	**0,002**	**<0,001**	---	
Overall Gap (OG) Measurements (4)	r	0,487	0,937	0,913	
	p	**<0,001**	**<0,001**	**<0,001**	-

r: Spearman's rho correlation coefficient

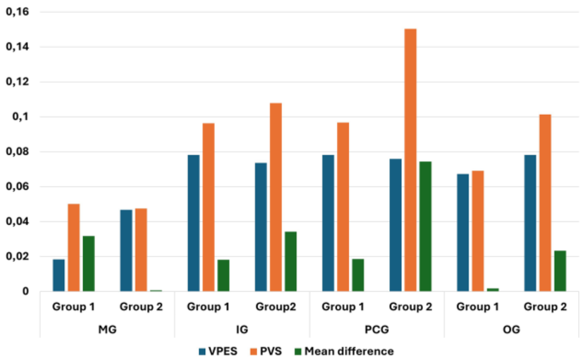

Figure 4 The column chart of mean differences of the marginal, internal, pulp chamber and overall gap values of different preparation designs using different fit-indicating materials. (VPES; Vinyl polyether silicone, PVS; Polyvinyl siloxane, Group 1; Butt joint design and 4 mm pulp chamber depth, Group 2; Shoulder design and 4 mm pulp chamber depth, MG; Marginal gap, IG; Internal gap, PCG; Pulp chamber gap, OG; Overall gap)

The results of the Spearman correlation coefficient test are presented in Table 3. A significant weak positive correlation was found between MG and IG measurements (r=0.372, p=0.001) as well as between MG and PCG measurements (r=0.337, p=0.002).

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doi: 10.69601/meandrosmdj.1596545

Table 2. The marginal, internal, pulp chamber and overall gap values (mm) of different groups

Gap Measurements	Preparation design	Fit-indicating material		Mean ± SD	p Values
		Vinylpolyether silicone (VPES)	Polyvinyl siloxane (PVS)		
Marginal Gap (MG)	Group 1	0.0184 ± 0.0053[B]	0.0501 ± 0.0134[A]	0.0343 ± 0.0189	< 0.001
	Group 2	0.0468 ± 0.0057[A]	0.0475 ± 0.0145[A]	0.0471 ± 0.0109	
	Mean ± SD	0.0326 ± 0.0154	0.0488 ± 0.0138	0.0407 ± 0.0167	
Internal Gap (IG)	Group 1	0.0781 ± 0.0074[B]	0.0963 ± 0.0283[A]	0.0872 ± 0.0224	0.024
	Group 2	0.0736 ± 0.0055[B]	0.1078 ± 0.0081[A]	0.0907 ± 0.0186	
	Mean ± SD	0.0759 ± 0.0068	0.1020 ± 0.0214	0.089 ± 0.0205	
Pulp Chamber Gap (PCG)	Group 1	0.0781 ± 0.0077[C]	0.0967 ± 0.0279[B]	0.0874 ± 0.0223	
	Group 2	0.0759 ± 0.0069[C]	0.1503 ± 0.0124[A]	0.1131 ± 0.0389	< 0.001
	Mean ± SD	0.0770 ± 0.0073	0.1235 ± 0.0345	0.1002 ± 0.0341	
Overall Gap (OG)	Group 1	0.0673 ± 0.0065[C]	0.0781 ± 0.0200[B]	0.0727 ± 0.0157	< 0.001
	Group 2	0.0691 ± 0.0049[BC]	0.1014 ± 0.0082[A]	0.0853 ± 0.0177	
	Mean ± SD	0.0682 ± 0.0058	0.0897 ± 0.0192	0.0790 ± 0.0178	

Mean ± Standard Deviation (SD); No difference between values with the same letter in all directions between rows and columns of each gap measurement. Statistically significant at p<0.05. Group 1; Butt joint design and a 4 mm pulp chamber depth, Group 2; Shoulder design and a 4 mm pulp chamber dep

In contrast, a moderate positive correlation was observed between MG and OG measurements (r=0.487, p<0.001). Additionally, a very strong positive correlation was found between IG measurements and both PCG (r=0.925, p<0.001) and OG measurements (r=0.937, p<0.001). Similarly, PCG and OG measurements exhibited a very strong positive correlation (r=0.913, p < 0.001)

DISCUSSION

Marginal and internal fit are essential factors for the long-term success of restorations (2). While the poor marginal fit raises the likelihood of plaque accumulation, gingival inflammation, secondary caries, and cement dissolution (16), the internal fit has a major impact on the mechanical characteristics of the restoration, including retention (17). The present study evaluated the effect of different fit-indicating materials and preparation designs on the marginal and internal fit of 3D-printed permanent endocrowns. The results of this study showed that using different fit-indicating materials and preparation designs affected the determination of marginal and internal fit of 3D-printed permanent endocrowns. Thus, the null hypotheses were rejected.

The 3D analysis technique used in this study requires the use of a fit-indicating material since it involves superimposing the endocrown preparation surface with that of fit-indicating material. The properties of the fit-indicating material used may cause differences in the marginal and internal gap values of the restoration. The weight and density of the fit-indicating material, finger pressure, material flow and the base/catalyst ratio are critical factors influencing the accuracy of marginal and internal gap measurements (18). Thus, we aimed to clarify this by comparing the VPES and PVS fit-indicating materials to evaluate the marginal and internal fit of endocrowns. In the present study, the VPES material showed lower values than the PVS material in the gap measurements of endocrowns by standardizing the applied force. Habib et al. (19) stated in their study that VPES showed lower film thickness in the fit-indication performed before cementation of restorations compared to PVS material, similar to this study. The reason for this might be that the film thickness of VPES material is lower, and its fluidity is higher. Considering that the main purpose of using the material is to check the fit of restorations, this is an expected result.

The preparation design of endocrown is another influential factor in its adaptation (20). Farghal et al. (21) reported that a butt-joint design reduces marginal and internal gaps in endocrown restorations, while the 1- and

2-mm ferrule (shoulder) design offers greater retention. According to Seo et al. (13), the marginal fit is improved in endocrowns with a 1 mm shoulder margin design due to the higher surface area available for bonding. Additionally, PVS was used as fit-indicating material in both studies mentioned. In this study, consistent with the findings of Farghal et al. (21), the butt-joint margin design demonstrated a better marginal gap than the shoulder design. This difference may result from the easier removal of fit-indicating material from the two axial wall configuration of the butt-joint design compared to the four walls in the shoulder margin design. However, while the PVS and butt-joint preparation design resulted in the highest marginal gap, the VPES and butt-joint design provided the lowest gap values. This underscores the significant impact of the chosen fit-indicating material on the determination of the fit of endocrown. The flow characteristics of the VPES may have caused this result.

The internal fit plays a crucial role in the ability of restoration to provide adequate retention (17). Considering that there are studies stating that the shoulder margin design offers a larger bonding area and greater retention than the butt-joint (13,14,21), it is reasonable to expect the shoulder design to demonstrate superior fit. However, in the present study, no significant difference was found between butt-joint and shoulder margin designs regarding internal fit. Notably, the best internal fit was determined with VPES and shoulder margin designs, while the highest internal gaps were observed with PVS and shoulder design, highlighting the critical influence of fit-indicating materials on outcomes.

In the present study, pulp chamber gap measurements are incorporated into the internal gap assessment to provide a more comprehensive evaluation of the fit within the pulp chamber. Furthermore, the pulp chamber gap results in this study are similar to the internal gap results. In a study by Hajimahmoudi et al. (22), a PVS impression material was used as a fit indicator, and it was reported that the pulpal floor had the greatest gap in endocrowns with butt-joint preparation design, regardless of the ceramic materials used. However, in the present study, the shoulder design showed a higher pulp chamber gap than the butt-joint. This may be due to the technical limitations of digital intraoral scanners during scanning. In addition, the lowest pulp chamber gap values observed with the VPES and the highest gap values observed with PVS material in the fit evaluation are both seen in the shoulder margin design, which may also be influenced by the fit-indicating materials. Although there are studies that used VPES to assess the fit of crowns (23,24), there is no study using it to assess the marginal and internal fit of endocrowns. During this study, observations showed that while the PVS material exhibited separation and tearing from the die, VPES remained stable on the surface. The setting time and flow of VPES likely contributed to better results. Given the 4 mm pulp chamber depths in the preparation designs, it is crucial to remove the fit-indicating material without tearing, especially in pulp chamber gap measurements, as this may have influenced the results.

The fit of restorations is commonly evaluated using 2D, such as the silicone replica method, which measures gaps at specific points through sectional image analysis (25). However, 2D evaluations are limited in precision and cannot easily be compared across studies as the measurements were made from artificially set reference points. This study employs 3D analysis software for more accurate assessments without data loss, allowing unlimited measurements at multiple points across all dimensions (9,10). The 3D analysis method involves scanning both the prepared tooth and fit-indicating material surface, then superimposing the scans for comprehensive marginal and internal gap evaluation. Thus, fit evaluation was conducted with better reproducibility, allowing for a greater number of measurements to be performed easily in this study.

To strengthen the validity of this study, the methodology of this study is based on the results obtained from a pilot study conducted beforehand. Despite using natural human teeth, typodont maxillary first molar teeth were chosen to standardize the measurements. All preparations were performed by one experienced operator. PVS and VPES fit-indicating materials were applied with a standard 5 kg force on each master die three times. The single master dies have been fabricated to apply fit-indicating materials within their working times. 3D analysis of the gaps was performed from two different sections after multiple trials under blinded conditions and by another operator.

The limitations of this in vitro study were that the restorations were not cemented, which may have contributed to the increase in the overall gap, the difference in setting times of fit-indicating materials, and the possibility of Vaseline remaining on the surface. Furthermore, different results can be obtained with different intraoral scanners, 3D printers, and materials. To add new insights to the literature, various materials and equipment would be beneficial to incorporate. Addressing these limitations in future in vitro research is recommended, particularly studies comparing PVS and VPES fit-indicating materials to evaluate the fit of endocrowns on natural human teeth. Additionally, in vivo studies are essential to evaluate the findings of this study under clinical conditions.

CONCLUSION

Using different fit-indicating materials and preparation designs affects the fit values of endocrowns. Vinyl polyether silicone provides a more accurate evaluation of the fit of 3D-printed permanent endocrown restorations compared to polyvinyl siloxane. Specifically, vinyl polyether silicone enhances accuracy in assessing the internal fit of 3D-printed endocrowns with a shoulder margin and a 4 mm pulp chamber depth, yielding results comparable to the butt-joint design while also offering greater precision in evaluating the marginal fit in the latter.

Acknowledgments
The authors declare that there are no acknowledgements for this study.

Authorship contributions
Concept: BA Design: BA Data collection and processing: İTK, SÖ Analysis or interpretation: İTK Literature search: İTK, SÖ Writing: İTK

Data availibility statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of competing interest
There is no conflict of interest in this study.

Ethics
Since resources obtained from humans or animals were not used in this study, ethics committee approval was not obtained.

Funding
No financial support was received from any institution or organisation for this study.

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Meandros Medical and Dental Journal
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