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Original research

The trueness of CAD-CAM custom-milled post-and-cores: a comparison of three materials and two milling systems

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Purpose

The purpose of this *in-vitro* study was to evaluate the 3D digital trueness of CAD/CAM custom milled post-and-cores fabricated from three contemporary materials using two different 5-axis milling machines.

Materials and Methods

A standardized virtual post-and-core CAD design, augmented with landmarks for the standardization of milling, scanning, and 3D analysis protocols, was imported into the CAM software of two different 5-axis milling machines: the CORiTEC 350i and the InLab MC X5. Custom post-and-cores were fabricated from three distinct materials: zirconia, fiber-glass composite, and polyetheretherketone (PEEK). For each material, 10 post-and-cores were milled on each machine, resulting in a total of 60 custom samples. After milling, these post-and-cores were scanned using a standardized method. The resulting scan meshes were superimposed onto the reference CAD design mesh to evaluate 3D surface deviations. A two-way analysis of variance (ANOVA) was employed to determine the effects of material and milling machine on the trueness of the milled post-and-cores.

Results

No significant interaction between material and milling machine was found (p=0.813). PEEK showed significantly lower deviations (mean of 37.2 µm) compared to zirconia (57.2 µm, p<0.001) and glass-fiber composite (48.8 µm, p=0.017). The 350i produced PEEK post-and-cores with mean deviations of 12.7 µm less than the MC X5 (p=0.03), with no significant differences for other material-machine combinations.

Conclusion

Both milling machines demonstrated high trueness in milling post-and-cores. PEEK outperformed zirconia in trueness. When milled with the CORiTEC 350i, PEEK showed a small improvement in trueness over glass-fiber; however, no significant difference was observed with the InLab MC X5. The CORiTEC 350i excelled in milling PEEK, achieving the least 3D deviation, highlighting the influence of both material and machine on the trueness of milled post-and-cores.

Keywords: *3D Analysis, CAD/CAM, custom post-and-core, fiber-glass composite, PEEK, trueness, zirconia*

Introduction

Custom post-and-cores represent one of the treatment modalities for structurally compromised endodontically treated teeth. They offer numerous advantages over prefabricated post systems. Notably, they are customized to fit the unique morphology of the existing root canal, necessitating minimal preparation of the radicular dentin. Secondly, because custom post-and-cores are fabricated as a single piece, the integrity of the post-core interface is inherently stronger (1-4). These benefits render custom post-and-cores particularly suitable for restoring teeth with structural weaknesses, such as those with flared, noncircular cross-section ca-

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nals, or very small canals. They are also preferable when a modification in the emergence profile is needed for aesthetic reasons (1,5,6).

With the advent and widespread adoption of computer-aided design/computer-assisted manufacturing (CAD/CAM) technology in dental practices and laboratories, custom post-and-cores can now be manufactured not only from conventional cast alloys but also from a variety of modern dental materials such as zirconia, Nano-ceramic resin composite, fiber-reinforced composite, and high-performance polymers (7-13).

The accurate fit of a custom post-and-core is crucial, whether fabricated by conventional laboratory techniques or through a digital workflow (14,15). Good adaptation not only enhances retention but also optimizes force distribution within the radicular post space. Studies have recognized that maximum adaptation of post-and-cores to the residual tooth structure and to the prepared post space in root canals is a key factor in increasing fracture resistance and the survival of endodontically treated teeth (16,17). Furthermore, an accurate fit reduces the necessity for manual adjustments to the post's surface prior to insertion (9,18), which in turn reduces chairside time. Additionally, in the context of indirect restorations, a poor internal fit may lead to increased cement thickness, impede the proper seating of the restoration, compromise retention, adversely affect final restoration adaptation, and ultimately reduce the fracture resistance of both the restored tooth and the restoration itself (18-19).

The digital workflow for fabricating custom post-and-cores can be either a partially digital or a fully digital process (20,21). Studies have shown that both methods produce clinically acceptable results, with accuracy in terms of fit (both marginal and internal) that is comparable to, or even surpasses, conventionally fabricated post-and-cores (14,22,23).

The overall accuracy of CAD/CAM custom-milled post-and-cores is determined by the sum of potential errors at each stage of the fabrication process; therefore, accuracy in each step is crucial for an accurately fitting restoration. Milling, a critical step in both digital workflows, requires exactness to ensure proper fit and functionality of the fabricated restoration (24). Current research assesses the trueness of the milling process by the degree of conformity between the milled restorations and the reference virtual design or dataset provided to the milling machine. Accurate evaluations of trueness require 3D analysis, which has proven both valid and reliable for detecting deviations across all dimensions, thus ensuring data integrity (25,26). Studies employing 3D analytical methods have demonstrated that variations in milling machine construction and machining strategies significantly affect milling trueness. Furthermore, the material selected for milling notably impacts the accuracy and trueness of the fabricated restoration (24,26,27).

To date, there have been sparse studies examining the impact of variability in milling machines and the range of CAD/CAM materials used for fabricating custom-milled post-and-cores on their dimensional trueness. Studies have not specifically focused on the trueness of the milling process for custom cast post-and-cores with respect to these variables. Consequently, this study aimed to fill that gap by investigating how different milling machines influence the trueness of milled custom post-and-cores made from various CAD/CAM materials. The null hypothesis of this study posits that neither the type of CAD/CAM material nor the choice of milling machine significantly affects the geometric trueness of milled custom post-and-cores.

Materials and Methods

Sample size estimation

The sample size was deemed appropriate based on a power analysis for a two-way ANOVA conducted using G*Power software (version 3.1.9.6, Heinrich Heine University Düsseldorf). The analysis was set with a significance level of 0.05 and a power of 0.85. The variance estimates for between- and within-group differences were taken from the study by Kirsch *et al*. (24) The analysis indicated that ten specimens per group (n=10) would be sufficient to achieve the desired statistical power.

3D design process

A Virtual Post-and-Core design for an upper canine was utilized in this study (Figure 1). The stereolithography (STL) file of the design was imported into open-source 3D modeling software (Meshmixer v. 3.5, Autodesk). Within Meshmixer, three boxes were appended to the cingulum, mid-buccal, and incisal aspects of the core to act as standardized points for attaching the sprues and the scanner platform. Additionally, four small half spheres were placed on the mesial, distal, inciso-buccal aspects of the core, and on the apical third of the post to facilitate tripodization and provide reference points for initial alignment in the 3D deviation analysis (Figure 2).

The modified STL file was then imported into machine-specific CAM software programs, specifically iCAM v.4.6 (Imes Icore, Dental & Medical Solutions, Eiterfeld, Germany) and InLab CAM SW v.16.1 (Dentsply Sirona Inc.; York, PA, USA). Instrument geometry and milling strategies were set according to the specifications of the milling machines. The nesting of the post-and-cores within the blanks was oriented vertically on the CAD/CAM discs to standardize milling angles relative to the z-axis of the milling spindle. The post-and-cores were connected with two sprues, each 1.1 mm in diameter, attached to the buccal and cingulum boxes as required by both milling software systems (Figure 3).

Milling process

Post-and-cores were milled from three different materials: 3 yttrium-stabilized tetragonal zirconia polycrystals (3Y-TZP), polyetheretherketone (PEEK), and unidirectional fiber-glass composite (Table 1). Each material was provided in blank discs with a diameter of 98.5 mm. The discs for PEEK and the fiber-glass composite were 20 mm in height, while those for 3Y-TZP were 25 mm in thickness. To ensure standardization in the milling process, post-and-cores were produced from the same batch of three discs for each material type. Initially, ten post-and-cores were milled from each disc using one milling machine, and then the disc was transferred to a second milling machine to produce an additional ten post-and-cores for each material. A total of 60 post-and-cores were milled.

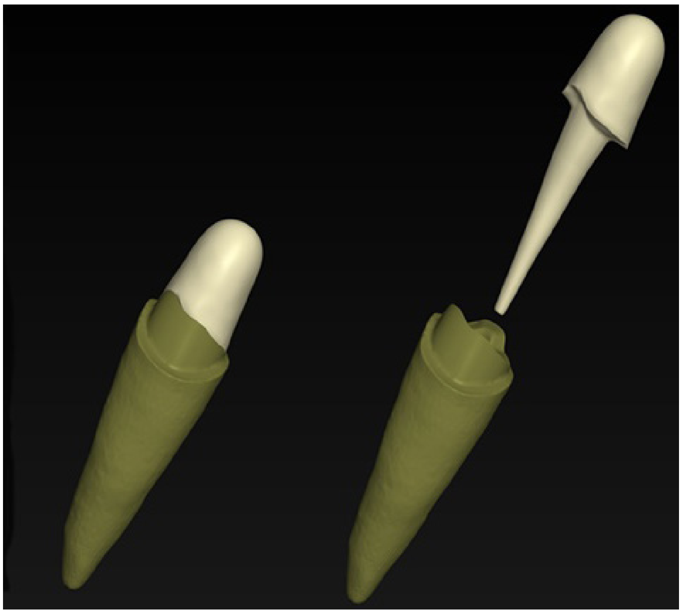

Figure 1. *Custom post-and-core design for upper canine used in the study.*

Figure 2. *Custom post-and-core with appended standardization boxes and tripodization points.*

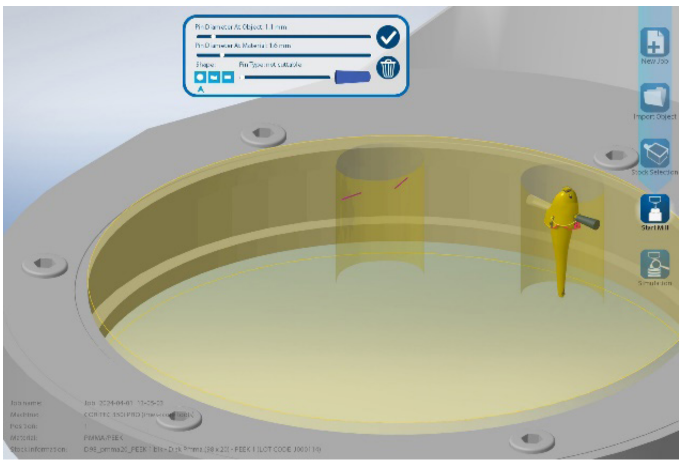

Figure 3. *Screenshot of virtual nesting process for custom post-and-core designs with dual sprues in CAD/CAM disc via software program.*

All post-and-core materials were milled on two five-axis milling devices, the CORiTEC 350i Loader Pro (Imes-Icore, Eiterfeld, Germany), using a dry milling process with new rotary instruments of sizes 2.5, 1, and 0.6 mm. The manufacturer provided bur coding numbers to indicate the appropriate instrument for each material. For the InLab MC X5 (Dentsply Sirona Inc.; York, PA, USA), wet milling was conducted for the glass-fiber and PEEK post-and-cores, while dry milling was applied to the 3Y-TZP post-and-cores. This machine also used new rotary instruments with sizes of 2.5, 1, and 0.5 mm, which were color-coded by the manufacturer for material identification. The PEEK and fiber-glass post-and-cores were milled to their final dimensions at a 1:1 ratio. In contrast, for the 3Y-TZP, a scaling factor of 1.2153 was used as recommended by the manufacturer, adhering to the conventional workflow for soft milling zirconia.

Scanning protocols

After milling, the post-and-cores were cleaned, dried, and then mounted on a custom-made scanning platform. They were attached vertically using a box-shaped extension that was part of the initial design, ensuring standardized positioning for all samples during scanning process (Figure 4). The post-and-cores underwent high-precision scanning with the Vinyl Open Air (Smart optics Sensortechnik GmbH, Bochum, Germany) laboratory scanner, utilizing dental Scan software v. 3.11.4 (Smart optics Sensortechnik GmbH, Bochum, Germany). Multiple angles were captured to ensure a complete surface representation of each post-and-core, and the data were exported as STL files.

For the zirconia post-and-cores, which were milled with a magnification factor to account for sintering shrinkage, the scanning process was performed before sintering. Scanning in the soft, partially sintered state ensures greater accuracy than scanning in the reflective, fully sintered state, and it also helps to avoid any size discrepancies that could result from the sintering process. (26, 28) Before proceeding to 3D analysis, these zirconia post-and-cores were resized in the software using the same scaling factor that was applied during the milling stage.

Comparing the scan data

The original virtual STL design file of the post-and-core, provided to the CAM software, was imported into CloudCompare. This STL file served as the "reference mesh." Subsequently, the virtual STL scan files of the milled post-and-cores, produced from three distinct materials using two separate milling devices, were also imported into CloudCompare for comparison against the reference mesh. All 3D analyses were conducted by a single operator who performed the evaluations blindly and randomly to ensure unbiased results. To align each milled mesh with the reference, a rough initial alignment was performed. After this coarse adjustment, the overlapping meshes were edited to retain only the post-and-core structures.

Following the cropping, a precise alignment of each mesh with the reference mesh was executed using the Iterative Closest Point (ICP) algorithm. After the fine registration, the Root Mean Square (RMS) error for each milled post-and-core

Table 1. *Overview of the characteristics of the investigated post-and-core materials.*

Brand	**Type**	**Composition (wt%)***	**Manufacturer**	**Lot #**
IPS e.max ZirCAD LT	Pre-shaded zirconium Oxide (3Y-TZP) 3Y-TZP (0% c)	ZrO_2=87-95% HfO_2=1-5% Y_2O_3 =4-6% Al_2O_3= 0.1-1%	Ivocalr Vivadent AG.; Schaan, Liechtenstein	Z051MF
Ceramill PEEK	High-Performance Polymer	100% polyetheretherketone (PEEK)	Juvora Ltd., Lancashire, UK	J000114
Numerys GF	Glass-Fiber Composite	80% unidirectional radiopaque glass fibres embedded in 20% epoxy-resin	iTena Clinical, Villepinte, France	56299

*Y-TZP , Yttria-tetragonal zirconia polycrystal; c, Cubic phase; PEEK, Polyetheretherketone; * According to manufacturer's data.*

mesh, in comparison to the reference mesh, was calculated. This was done using the "Compute Cloud/Mesh Distances" plugin within CloudCompare (Fig. 5). The RMS error, expressed in micrometers, represents the average three-dimensional deviation of all vertices on the test meshes from the reference mesh. The absolute RMS values were then recorded for each milled post-and-core for further statistical analysis.

Statistical analysis

The statistical analysis was performed using IBM SPSS Statistics 20 software (Statistical Package for Social Sciences, Armonk, NY, USA). A two-way Analysis of Variance (ANOVA) was performed to evaluate the effects of the milling machine and the post-and-core material, on the RMS 3D surface deviation score. Residual analysis was performed to test the assumptions of the two-way ANOVA. Outliers were assessed through boxplot inspection, normality was confirmed using Shapiro-Wilk's test for each cell of the design, and homogeneity of variances was established using Levene's test. The results showed no outliers, normally distributed residuals, and homogeneity of variances. Following the two-way ANOVA, post-hoc analyses were conducted using the General Linear Model (GLM) Univariate procedure. Estimated marginal means were compared using the EMMEANS command with Bonferroni adjustment for multiple comparisons. To examine the main effects of post-and-core material type and milling machine on RMS deviation, pairwise comparisons were performed using Tukey's HSD test. The confidence level was set to 95% and p values less than 0.05 were considered significant.

Results

Descriptive statistics are presented as the mean ± standard deviation in Table 2. The interaction effect between the milling machine type and the material on RMS deviation values was not statistically significant, as indicated by an F-statistic of $F(2, 54) = 0.208$, $p=0.813$, with a partial eta squared (η^2) of 0.008 (Table 3). However, there was a statistically significant main effect of the material on RMS deviation, with $F(2, 54) = 12.248$, $p<0.001$, and a partial η^2 of 0.348. There was also a statistically significant main effect of the milling machine on RMS deviation, with $F(1, 54) = 8.915$, $p=0.004$, and a partial η^2 of 0.142.

Custom-made post-and-cores milled from PEEK showed higher trueness to the reference model with a lower average deviation of 37.2 µm, compared to the RMS values for zirconia and glass-fiber custom-made post-and-cores, which averaged 57.2 µm and 48.8 µm, respectively. Regarding the milling machines, custom-made post-and-cores milled by CORiTEC 350i demonstrated lower deviation (higher trueness) with an average RMS value of 42.8 µm compared to those milled by InLab MC X5, which had an average of 52.6 µm (Figure 6).

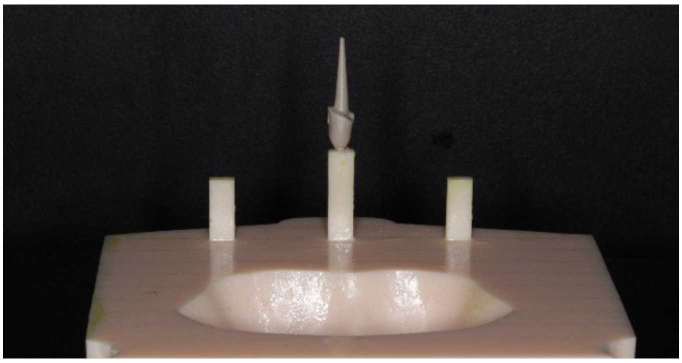

Figure 4. *Milled custom post-and-core mounted with incisal box attachment on custom 3D-printed scanning platform.*

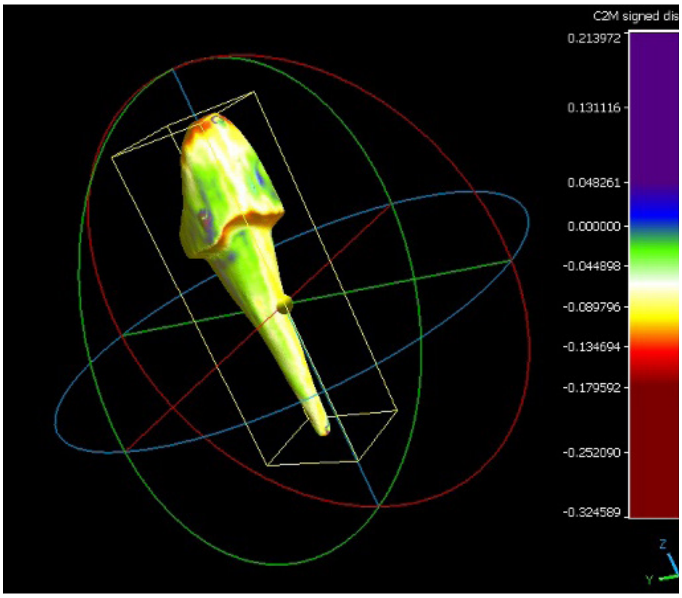

Figure 5. *3D colored map illustrating root mean square deviations between virtually scanned milled custom post-and-core mesh and reference mesh.*

The data presented in Table 4 and Table 5 revealed that there was no significant difference between zirconia custom-made post-and-cores milled using the CORiTEC 350i and those milled with the InLab MC X5, and similarly for glass-fiber custom-made post-and-cores, with p-values of 0.115 and 0.185, respectively. However, PEEK custom-made post-and-cores milled with the CORiTEC 350i were superior in terms of trueness (lower RMS deviation) compared to those milled with the InLab MC X5 ($p = 0.003$). This was evidenced by some PEEK samples milled on the InLab MC X5 showing striations that aligned with areas of over-milling or increased RMS values (Figure 7). Furthermore, PEEK custom-made post-and-cores milled using the CORiTEC 350i exhibited lower deviation than those made of zirconia and glass-fiber materials, with significant differences ($p = 0.001$ and $p = 0.049$, respectively). For PEEK custom-made post-and-cores milled with the InLab MC X5, there was a significant difference in comparison with zirconia-milled post-and-cores ($p = 0.007$), but no significant differences among other group comparisons.

Further examination of the main effects for post-and-core material and milling machine revealed significant differences. According to pairwise comparisons with Tukey's HSD test, the material factor showed that PEEK had significantly lower RMS deviation compared to both zirconia (Mean Difference = 19.9 µm, $p < 0.001$) and glass-fiber materials (Mean Difference = 11.5 µm, $p = 0.016$), while no significant difference was found between zirconia and glass-fiber materials ($p = 0.101$). For the milling machine factor, a significant difference was observed between the two machines (Mean Difference = 9.8 µm, $p = 0.004$), with the InLab MC X5 producing higher RMS values compared to the CORiTEC 350i.

Table 2. *Descriptive statistics of 3D root mean square deviation values (µm).*

Milling Machine	Material	Mean (±SD)
CORiTEC 350i	Zirconia	52.6 (11.5)
	Glass-fiber	44.9 (10.5)
	PEEK	30.9 (13.0)
	Total	42.8 (14.5)
InLab MC X5	Zirconia	61.7 (12.3)
	Glass-fiber	52.6 (13.4)
	PEEK	43.6 (15.0)
	Total	52.6 (15.2)
Total	Zirconia	57.2 (12.5)
	Glass-fiber	48.8 (12.4)
	PEEK	37.2 (15.1)
	Total	47.7 (15.5)

PEEK: Polyetheretherketone, SD: standard deviation.

Discussion

The results of this study led to a partial acceptance of the null hypothesis. This was based on the non-significant two-way interaction between these variables on the 3D RMS deviation. However, the analysis did reveal statistically significant main effects, with both the milling machine type and the material independently affecting the 3D surface deviations.

Several previous studies (25–27,29) have demonstrated that the 3D analysis method employed in this study is a validated approach for assessing the trueness of the milling process across different machines and materials. These studies typically use 3D analysis software to compare scanned data of manufactured or fabricated restorations with their corresponding CAD models. One commonly used software is the open-source program CloudCompare, which has been utilized in this approach by other researchers (30–32). This non-destructive technique provides comprehensive surface evaluation, generating color maps and quantitative data on point-to-point differences. Compared to traditional tech-

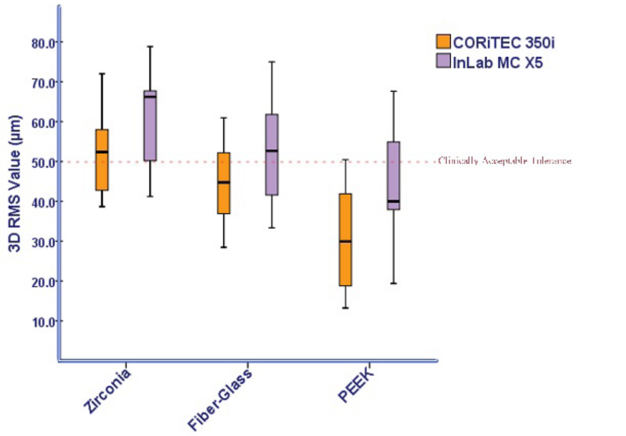

Figure 6. *Boxplot showing root mean square deviations among different post-and-core material types for both milling machines. PEEK, Polyetheretherketone.*

Table 3. *Two-way analysis of variance results for 3D root mean square deviation values (µm) related to effect of post-and-core material and milling machine (df, degrees of freedom; a. R Squared = 0.388, Adjusted R Squared = 0.331).*

Source	Type III Sum of Squares	df	Mean Square	F	p^b	Partial Eta Squared
Corrected Model	5508.379a	5	1101.676	6.837	< 0.001	0.388
Intercept	136595.639	1	136595.639	847.758	< 0.001	0.940
Milling Machine	1436.487	1	1436.487	8.915	0.004	0.142
Material	4004.956	2	2002.478	12.428	< 0.001	0.315
Milling Machine * Material	66.936	2	33.468	0.208	0.813	0.008
Error	8700.795	54	161.126			
Total	150804.813	60				
Corrected Total	14209.174	59				

Table 4. *Pairwise comparison of mean 3D root mean square deviation values (µm) among three Post-and-Core material types.*

Milling Machine	(I) Material	(J) Material	Mean Difference (I-J)	Std. Error	p^b	95% CI	
						Lower Bound	Upper Bound
CORiTEC	Zirconia	Glass-fiber	7.658	5.677	0.549	-6.368	21.684
		PEEK	21.710*	5.677	0.001	7.684	35.736
	Glass-fiber	Zirconia	-7.658	5.677	0.549	-21.684	6.368
		PEEK	14.052*	5.677	0.049	.026	28.078
	PEEK	Zirconia	-21.710*	5.677	0.001	-35.736	-7.684
		Glass-fiber	-14.052*	5.677	0.049	-28.078	-.026
InLab X5	Zirconia	Glass-fiber	9.130	5.677	0.341	-4.896	23.156
		PEEK	18.150*	5.677	0.007	4.124	32.176
	Glass-fiber	Zirconia	-9.130	5.677	0.341	-23.156	4.896
		PEEK	9.020	5.677	0.354	-5.006	23.046
	PEEK	Zirconia	-18.150*	5.677	0.007	-32.176	-4.124
		Glass-fiber	-9.020	5.677	0.354	-23.046	5.006

Std. Err, Standard Error; CI, Confidence Interval; PEEK. Polyetheretherketone; Based on estimated marginal means. The mean difference is significant at the 0.05 level. b. Adjustment for multiple comparisons: Bonferroni.*

Table 5. *Pairwise comparison of mean 3D root mean square deviation values (µm) across two milling machines .*

Material	(I) Milling Machine	(J) Milling Machine	Mean Difference (I-J)	Std. Error	p^b	95% CI Lower Bound	95% CI Upper Bound
Zirconia	CORiTEC	InLab X5	-9.090	5.677	0.115	-20.471	2.291
Glass-fiber	CORiTEC	InLab X5	-7.618	5.677	0.185	-18.999	3.763
PEEK	CORiTEC	InLab X5	-12.650*	5.677	0.030	-24.031	-1.269

Std. Err, Standard Error; CI, Confidence Interval; PEEK. Polyetheretherketone; Based on estimated marginal means. The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.*

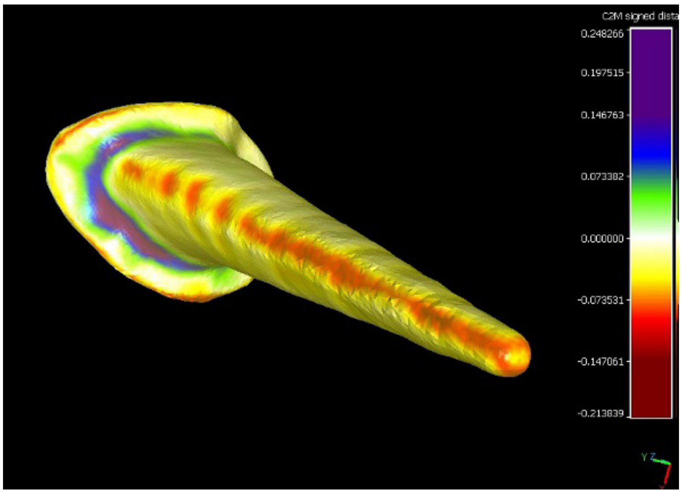

Figure 7. *3D colored map of custom post-and-core from PEEK group milled by MC X5, illustrating horizontal striations corresponding to areas of over-milling or increased negative RMS values (in red), alongside areas of under-milling at internal line angles at post-and-core interface with increased positive RMS values (in blue and violet).*

niques like silicone replica methods, microcomputed tomography (µCT), or die sectioning, this method offers advantages by allowing a detailed 3D assessment of milling trueness across different machines and materials without the need for multiple physical specimens or destructive testing.

This study appears to be the first to specifically assess the trueness of custom post-and-cores using 3D RMS deviation values. Previous research has applied 3D-digital assessment techniques to evaluate how milling machines and material choices affect the accuracy of milled restorations overall, but these did not focus on custom post-and-cores (24-27). Other studies that have concentrated on custom post-and-cores assessed restoration accuracy using digital volume, internal, and marginal fit analyses, or evaluated the accuracy of optical digital impressions. However, the diversity in their methodologies and scopes yields predominantly indirect insights (22,23,33,34). They contribute useful background knowledge but are not directly comparable to the results of this study.

Both milling machines exhibited high and comparable levels of trueness in the fabrication of post-and-cores, with RMS values around 50µm, which falls within the reference clinically acceptable tolerance as suggested in previously articles (25,28) This level of trueness is comparable to the results obtained by Kirsch *et al.* (24) for milling onlays from glass ceramic, a material that is typically harder to mill due to its greater hardness. These findings reinforce the concept that five-axis milling machines can achieve high trueness, benefiting from their ability to machine from various angles, thereby enhancing the final result. Despite using a larger minimum bur diameter of 0.6 mm compared to the 0.5 mm bur of the MC X5, the CORiTEC 350i machine exhibited marginally superior trueness, which may be explained by the differences in machine movement flexibility, chord error minimization, and the utilization of a finer discretization step pattern. These factors could justify the slight differences in trueness between the two machines (24,35).

PEEK showed the highest trueness in milling custom post-and-cores in this study, surpassing zirconia and glass-fiber composites. This is consistent with Nagi *et al*. (36) who reported better fit for PEEK than lithium disilicate, likely due to PEEK's softer nature. Negm *et al*.'s (37) findings of high accuracy in PEEK frameworks suggest that variations in accuracy may stem from differences in milling equipment and design complexity. Fiber-glass composite post-and-cores achieved high trueness, contrary to El Ghoul *et al*.'s (38) results where fiber composites showed poor milling accuracy. This discrepancy could be due to different fiber orientations, manufacturing methods, and restoration geometries.

Regarding zirconia, the post-and-cores in the current study were generally over-milled, aligning with Hamad *et al*.'s (26) findings for soft-milled zirconia crowns compared to hard-ground glass ceramics. Both studies used 3D analysis to assess trueness. Notably, the latter scanned sintered zirconia restorations using an intraoral scanner, more closely simulating clinical scenarios. In contrast, zirconia in the present study was scanned before sintering using a benchtop scanner for two reasons: to avoid applying scanning aids (powder- or liquid-based) on reflective surfaces and to focus specifically on milling trueness. This approach was chosen because both scan aid application and sintering protocols can lead to a lack of standardization and potential geometrical discrepancies, as evident in previous studies (39–41). Despite these methodological differences in scanning timing and equipment, both studies observed consistent over-milling of zirconia restorations, suggesting this tendency persists regardless of scanning stage, device, and restoration type.

Overall, while PEEK appears superior in this study, it's important to note that milling accuracy is affected by various factors including restoration design, complexity, analysis methods, and milling technology (35,42). These factors may contribute to the variations observed across different studies and materials.

The study, while focused on the overall trueness of custom post-and-cores, revealed through 3D assessments that internal angles at the post-core interface exhibited greater discrepancies, as illustrated in Figure 6. Such an observation is in line with research on various restorations, which identified internal angles as particularly prone to reduced accuracy due to milling challenges, corroborating the findings of previous researchers (26,27,36).

Acknowledging the limitations of this study, it is important to note that the focus on a single post-and-core design does not account for the potential variability in outcomes with more complex designs. Additionally, the exclusive use of two advanced 5-axis milling machines may not reflect the capabilities of widely used 4-axis chairside machines. The evaluation did not identify specific areas of inaccuracy within the overall 3D discrepancy, which is vital for enhancing milling precision and the subsequent fit and longevity of restorations. Therefore, future research should aim to conduct a detailed analysis of these inaccuracies to refine the milling processes in digital dentistry.

Conclusion

Within the limitations of this study, it can be concluded that both 5-axis milling machines demonstrated high trueness in milling post-and-cores. PEEK material exhibited better trueness compared to zirconia in both machines. When milled with the CORiTEC 350i, PEEK outperformed glass-fiber, showing a small improvement in trueness that was marginally significant. In contrast, no significant difference was observed between PEEK and glass-fiber when milled with the InLab MC X5. Additionally, the CORiTEC 350i outperformed the InLab MC X5 in milling PEEK post-and-cores, achieving the least 3D deviation.

Türkçe öz: *CAD-CAM yöntemiyle frezelenmiş post-core restorasyonlarının doğruluğu: üç malzeme ve iki frezeleme sisteminin karşılaştırılması. Amaç: Bu in-vitro çalışmanın amacı, üç farklı modern malzemeden CAD/CAM yöntemiyle üretilen post-core restorasyonlarının, iki farklı 5 eksenli frezeleme makinesinden elde edilen üç boyutlu dijital doğruluğunu değerlendirmektir. Gereç ve Yöntem: Frezeleme, tarama ve 3D analiz protokollerinin standartlaştırılması amacıyla belirteçlerle desteklenen standart bir sanal post-core CAD tasarımı, iki farklı 5 eksenli frezeleme makinesinin CAM yazılımına aktarıldı: CORiTEC 350i ve InLab MC X5. Üç farklı malzemeden (zirkonya, fiber-cam kompozit ve poliétereterketon [PEEK]) özel post-core restorasyonları üretildi. Her bir malzeme için her makinede 10 adet post-core frezelenerek toplamda 60 adet numune hazırlandı. Frezeleme işleminin ardından, post-core restorasyonları standart bir yöntemle tarandı. Tarama verileri, referans CAD tasarımıyla üst üste getirilerek 3D yüzey sapmaları değerlendirildi. Frezelenen post-core restorasyonların doğruluğu üzerindeki malzeme ve frezeleme makinesi etkileri, iki yönlü varyans analizi (ANOVA) ile analiz edildi. Bulgular: Malzeme ve frezeleme makinesi arasında anlamlı bir etkileşim bulunmadı (p = 0.813). PEEK, zirkonyaya (ortalama sapma: 57.2 µm, p < 0.001) ve cam-fiber kompozite (ortalama sapma: 48.8 µm, p = 0.017) kıyasla önemli ölçüde daha düşük sapmalar gösterdi (ortalama sapma: 37.2 µm). CORiTEC 350i, PEEK post-core restorasyonlarını InLab MC X5'e göre ortalama 12.7 µm daha düşük sapma ile üretti (p = 0.03). Ancak diğer malzeme-makine kombinasyonlarında anlamlı bir fark gözlemlenmedi. Sonuç: Her iki frezeleme makinesi de post-core restorasyonlarının üretiminde yüksek doğruluk sergiledi. PEEK, doğruluk açısından zirkonyadan daha üstün performans gösterdi. CORiTEC 350i ile frezelenen PEEK, cam-fiber kompozite kıyasla küçük bir doğruluk artışı sağladı; ancak InLab MC X5 ile frezelenen restorasyonlarda anlamlı bir fark bulunmadı. CORiTEC 350i, PEEK malzeme ile en düşük 3D sapmayı elde ederek frezeleme doğruluğu üzerinde hem malzemenin hem de makinenin etkisini vurgulamaktadır. Anahtar Kelimeler: 3D Analiz; CAD/CAM; özel post-core; cam-fiber kompozit; PEEK; doğruluk; zirkonya*

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