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Evaluation of Different Obturation Techniques in Two Types of Vertucci Classification

SUMMARY

Objectives: *This study aimed to evaluate and compare the effectiveness of three different obturation techniques in 3D printed resin blocks with Vertucci Type V and Type VI canal morphology.* ***Methods***: *Three-dimensionally produced 66 resin blocks with Vertucci Type V and Vertucci Type VI canal morphology (n=33) were prepared.The blocks were divided into three subgroups; Group 1: Cold Lateral Condensation(CLC), Group 2: Continuous Wave Obturation(CWO), Group 3: Core Carrier Technique(CCT) and obturation techniques were applied (n=11). The total area and gaps were calculated as a percentage ratio on the periapical radiographs taken after obturation by using the Image J software.The groups were compared using Mann-Whiney U and Kruskal Wallis H tests (p< 0.05).* ***Results***: *When the ratio of the gap areas for Vertucci Type V blocks were analyzed, CLC has showed a significant difference at the coronal part of the deep split (p<0.017). Each groups showed a significant difference in paired comparisons at the apical part of the deep split (p<0.017). For Vertucci Type VI blocks, CLC showed a significant difference at the coronal part of the isthmus and isthmus(p<0.017).Each groups showed a significant difference in paired comparisons at the apical part of the isthmus (p<0.017).* ***Conclusions***: *Our study showed that none of the obturation techniques provided a complete filling.At the apical region, it can be stated that the CLC method is insufficient in complex anatomies such as Vertucci Type V and Type VI. Therefore the use of the CCT or CWO methods may be recommended for these type of anatomies.*

Keywords: Cold lateral condenstaion, core carrier technique, continuous wave obturation, vertucci, 3D resin blocks

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Introduction

The aim of root canal treatment is to remove pulpal tissue and necrotic residues with chemomechanical preparation, to disinfect the root canal system and to fill the canal without gaps. These stages should be applied completely for the success of endodontic treatment[1-5].

There are several factors that make the successful application of root canal treatment difficult. One of the most important factor is the anatomical variations of the root canal system. Especially the presence of extra canals, anatomical structures such as lateral and accessory canals or apical delta can make disinfection and filling of the canal system difficult[6,7]. It is known that highly variable canal variations are seen in premolar teeth particularly[8-10]. Although many classifications have been made over the years to understand the root canal configuration, the most widely used classification today is the classification made by Vertucci in 1984[11]. This classification helps clinicians to understand the diversity of root canal configurations, however it should be kept in mind that canal shape and anatomical differences can be challenging at every stage of endodontic treatment[12].

One of the critical stages of root canal treatment in teeth with anatomical differences is the hermetic filling of the root canal system[13]. Various methods have been proposed in the literature to provide a hermetic filling, each method has its own advantages and disadvantages[14]. For this reason, the clinician should choose the most appropriate filling technique in each case. For example, the cold lateral condensation technique, which is the most commonly used filling technique in clinical practice, has the advantage of ease of application; however, it is insufficient in completely filling irregularities within the canal and achieving a homogeneous filling[3,16-18]. On the other hand, warm filling techniques, which allow for a more homogeneous filling of canal irregularities, pose challenges in terms of dimensional stability[19-22]. The literature presents successful treatments performed using different filling techniques in teeth with various root canal configurations[23-25]. However, there is no gold standard or consensus on which filling technique is ideal for which configuration. Therefore, the aim of this study is to evaluate the filling efficiency of the cold lateral condensation technique, continuous heat condensation technique, and core-carrier obturation system in Vertucci Type V and Type VI canal morphologies. The first hypothesis of the study is that warm filling techniques evaluated in Vertucci Type V and Type VI canal morphologies will yield more successful results than the cold lateral condensation technique. The second hypothesis is that the evaluated filling techniques will provide higher-quality fillings in Vertucci Type VI group.

Material and Methods

In this study, three-dimensional standardized resin blocks with Vertucci Type V and Type VI canal morphologies, designed using the AutoCAD LT2024 program, were used (Edududent, Istanbul, Turkey). The sample size was determined based on the methodology of previous similar studies. The existing literature indicates that similar in vitro studies typically use 8 to 10 samples per group[26-28]. Accordingly, this study adopted a similar approach to ensure methodological consistency with previous research. The Vertucci Type V model was designed with a 1:2 canal morphology, where the canal bifurcates in the apical one-third, as described in the classification. The Vertucci Type VI model was designed with a 2:1:2 canal morphology, where the canals merge in the middle one-third (Figures 1,2). In the prepared samples, the apical diameter was set to 0.15 mm, and the canal length was adjusted to 16 mm.

Figure 1: Vertucci Type V Blocks

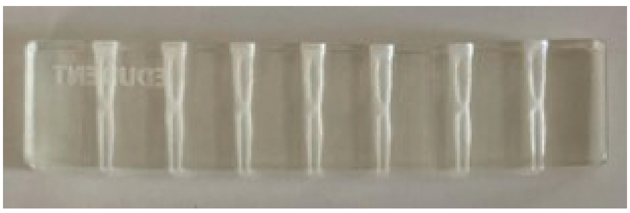

Figure 2: Vertucci Type VI Blocks

All experimental procedures were performed by a single experienced operator. All samples were shaped using the ProTaper Universal (Dentsply Maillefer, Germany) rotary file system at a setting of 250 rpm/2N. The final file, F3 (30.09), was applied at a setting of 300 rpm/3N. Irrigation with physiological saline was performed between each file. The canals were dried using ProTaper F3 (30.04) paper points (Dentsply, Germany). After completing root canal shaping, the samples with Vertucci Type V and Type VI morphologies were randomly divided into three subgroups, with 11 samples in each group (Table 1).

Table 1: Experimental Groups

Group 1: Vertucci Tip V (n=33)	Group 1a: Cold Lateral Condensation (CLC) (n=11)
	Group 1b: Continuous Wave Obturation (CWO) (n=11)
	Group 1c: Core Carrier Technique (CCT) (n=11)
Group 2: Vertucci Tip VI (n=33)	Group 2a: Cold Lateral Condensation (CLC) (n=11)
	Group 2b: Continuous Wave Obturation (CWO) (n=11)
	Group 2c: Core Carrier Technique (CCT) (n=11)

In the groups where cold lateral condensation was applied (Group 1a, Group 2a), a 0.02 taper master cone (Gutta-percha, Dentsply Maillefer, Ballaigues, Germany) appropriate for the apical constriction was placed into the canal, 0.5 mm short of the prepared working length, and checked for proper fit. After verification, the master cone was placed into the canal with Adseal root canal sealer (MetaBiomed, South Korea). Cold lateral condensation was performed by creating space in the canal using #20 and #25 hand spreaders, positioned 1 mm short of the working length. This process was repeated until the filling material reached the coronal 1 mm region.

In the groups where continuous heat obturation was applied (Group 1b, Group 2b), the master cone was placed into the canal 0.5 mm short of the prepared working length and checked for proper fit. After verification, the master cone was placed into the canal with Adseal root canal sealer. Subsequently, the gutta-percha cone was placed into the canal. The coronal portion of the gutta-percha was severed using the Fast Pack device (Eighteeth, China) and then condensed with a hand plugger. The remaining canal space coronal to the isthmus area was incrementally filled using thermoplasticized gutta-percha injection technique with the Fast Fill device (Eighteeth, China) until the gutta-percha was visible at the canal orifice. Vertical condensation was performed with a hand plugger every 3–4 mm to ensure proper compaction of the filling material.

In the groups where the core-carrier system was used for obturation (Group 1c, Group 2c), Adseal root canal sealer was applied to the canal using an appropriate master cone. Subsequently, the core-carrier-based GuttaCore ProTaper Next X3 (Dentsply, Germany) was heated in the ThermaPrep 2 Oven (Dentsply, Germany) according to the manufacturer's instructions and then inserted into the canal. The carrier was separated by bending it at the canal orifice level.

To ensure calibration in total area and void measurements, grooves were created at the beginning and end of the blocks using a 1 mm diameter fissure bur (SF40(107), Mani, Japan). These grooves were then filled with Glass Liner (WP Dental, Germany), a radiopaque material composed of resin-modified glass ionomer cement (Figure 3).

Subsequently, standardized periapical radiographs (60 kVp, 6.4 mA) were taken for each sample from the same angle and distance. The obtained images were transferred to the ImageJ software for measurement analysis. After calibrating the bur diameter in the images with the actual bur diameter, the total canal filling area and the void areas within the canal were calculated for each sample (Figure 4). Voids were regionally classified into two separate groups for Vertucci Type V as 'Coronal to the deep split' and 'Apical to the deep split.' For Vertucci Type VI, voids were categorized into three groups as 'Coronal to the isthmus,' 'Isthmus,' and 'Apical to the isthmus.' The comparative analysis of the data was performed by calculating percentage ratios, obtained by dividing the void area by the total area.

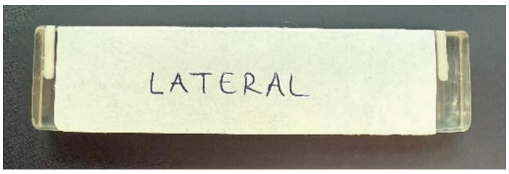

Figure 3: Radiopaque material composed of resin-modified glass ionomer cement.

Statistical Analysis

All analyses in this study were conducted using the SPSS IBM 30.0 statistical software package with a 95% confidence interval ($p=0.05$). Descriptive statistics, including median and interquartile range (IQR; Q3-Q1) values, were calculated. Normality testing was performed using the Shapiro-Wilk test ($n<50$) and graphical assessments. Since the data did not follow a normal distribution, pairwise group comparisons were performed using the nonparametric Mann-Whitney U test, while comparisons among three groups were conducted using the Kruskal-Wallis H test. Post-hoc analyses for three-group comparisons were carried out using the Bonferroni correction, whereas pairwise comparisons were performed using the Mann-Whitney U test. The Bonferroni-adjusted p-value ($p = 0.05/3$) was set at 0.017.

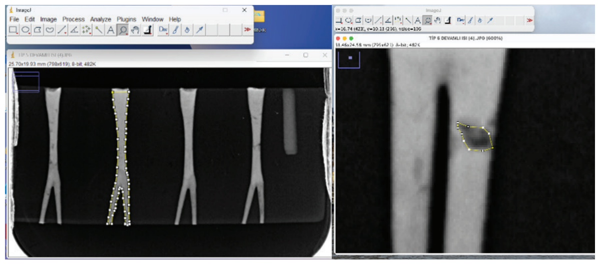

Figure 4: Calculation of total area and gaps on Image J program

Results

In this study, the filled area, void area, and total area of the root canal were calculated for each block. When analyzing the percentage of void areas in Vertucci Type V blocks (Group 1), pairwise comparisons in the coronal portion of the deep split revealed that CLC (Group 1a) differed significantly from both groups ($p<0.017$). However, no statistically significant difference was found between CWO (Group 1b) and CCT (Group 1c) ($p>0.017$). The median void percentages were 8%, 2%, and 1%, respectively (Table 2).

In pairwise comparisons conducted for the apical region of the deep split in Vertucci Type V blocks, a statistically significant difference was observed among the three groups (Group 1a, 1b, and 1c) ($p<0.017$). The median void percentages were 6%, 1%, and 0%, respectively. In pairwise comparisons of total void percentages, a statistically significant difference was found between CLC (1a) and CWO (1b), as well as between CLC (1a) and CCT (1c) ($p<0.017$). However, no statistically significant difference was observed between CWO (1b) and CCT (1c) ($p>0.017$). The median void percentages were 14.4%, 3.4%, and 1.9%, respectively (Table 2).

Table 2: The median void percentages of Vertucci Type V

Vertucci Type V

	CLC (n:11)	CWO(n:11)	CCT (n:11)	p	p1	p2	p3
Deep Split's Coronal	0,08(0,09)	0,01(0,02)	0,02(0,02)	p<0,001	p<0,001	p<0,001	0,743
Deep Split's Apical	0,06(0,04)	0,01(0,03)	0(0,01)	0,001	p<0,001	p<0,001	0,009
Ratio of the Gap Areas	0,144(0,073)	0,034(0,037)	0,019(0,03)	p<0,001	p<0,001	p<0,001	0,412

(p:Kruskal-Wallis H test, p1:CLC-CWO, p2:CLC-CCT, p3:CWO-CCT Mann-Whitney U Test with Bonferroni Correction p=0,05/3=0,017)

Cold Lateral Condensation(CLC), Continuous Wave Obturation(CWO), Core Carrier Technique(CCT)

When analyzing the void area percentages in Vertucci Type VI blocks (Group 2), pairwise comparisons for the coronal portion of the isthmus and the isthmus region revealed that CLC (2a) showed a statistically significant difference compared to the other two groups ($p<0.017$). However, no statistically significant difference was observed between CWO (2b) and CCT (2c) ($p>0.017$) (Table 3).

For Group 2, pairwise comparisons evaluating the apical filling efficiency of the obturation techniques revealed a statistically significant difference among the groups ($p<0.017$). In pairwise comparisons of total void percentages, a significant difference was found between CLC (2a) and CWO (2b), as well as between CLC (2a) and CCT (2c) ($p<0.017$). However, no significant difference was observed between CWO (2b) and CCT (2c) ($p>0.017$). The median void percentages were 10%, 1.8%, and 1.1%, respectively (Table 3).

As comparing Group 1 and Group 2, a statistically significant difference was observed between the groups for CLC (1a and 2a) ($p=0.028$). However, no statistically significant difference was found between the groups for CWO (1b and 2b) or CCT (1c and 2c) ($p>0.05$). Additionally, comparing the void area percentages, no statistically significant difference was observed ($p>0.05$) (Table 4,5).

Table 3: The median void percentages for Vertucci Type VI

Vertucci Type VI

	CLC (n:11)	CWO(n:11)	CCT (n:11)	p	p1	p2	p3
İsthmus's Coronal	0,04(0,03)	0,01(0,02)	0,01(0,02)	p<0,001	0,001	0,002	0,718
İsthmus	0,02(0,01)	0(0)	0(0,01)	p<0,001	p<0,001	0,004	0,968
İsthmus's Apical	0,05(0,04)	0,01(0,01)	0(0)	p<0,001	0,002	p<0,001	0,004
Ratio of the Gap Areas	0,1(0,062)	0,018(0,012)	0,011(0,03)	p<0,001	p<0,001	p<0,001	0,526

(p:Mann Whitney U Test)

Cold Lateral Condensation(CLC), Continuous Wave Obturation(CWO), Core Carrier Technique(CCT)

Table 4: Comparing the void area percentages of obturation techniques

Ratio of the Gap Areas

	Type V (n:11)	Type VI (n:11)	p
CLC	0,14(0,7)	0,10(0,06)	0,028
CWO	0,03(0,04)	0,02(0,01)	0,324
CCT	0,02(0,03)	0,01(0,03)	0,511

(p:Mann Whitney U Test)

Cold Lateral Condensation(CLC), Continuous Wave Obturation(CWO), Core Carrier Technique(CCT)

Median and IQR values (Values in the parentheses indicate the IQR)

Tablo 5: Comparing the void area percentages of Vertucci Types

	Type V (n:33)	Type VI (n:33)	p
Ratio of the Gap Areas	0,05(0,09)	0,03(0,07)	0,256

(p:Mann Whitney U Test) Median and IQR values

(Values in the parentheses indicate the IQR)

Discussion

In this study, which aimed to evaluate the success of different obturation techniques in various canal morphologies, none of the assessed techniques achieved a completely void-free filling. However, in both morphologies, warm obturation techniques demonstrated significantly higher filling quality compared to the cold lateral condensation technique. Notably, in the apical region, warm obturation techniques provided an almost void-free filling. Based on these findings, the first hypothesis of the study was accepted.

In the present study, three different obturation techniques were used. The first technique employed was the cold lateral condensation technique, which is the most commonly used and cost-effective method in clinical practice (29,30). The other selected techniques were warm obturation techniques, chosen for their superior ability to completely fill canal irregularities and achieve a more homogeneous obturation[31,32].

There are studies evaluating different obturation techniques in complex anatomies in the literature. These studies have frequently focused on inclined canals and C-shaped canal morphologies. Da Silva et al. (2002)

compared the lateral condensation technique with the core-carrier system in inclined canals using a digital radiography system. The voids in the core-carrier system group (Thermafil) were statistically significantly lower compared to the lateral condensation group. In the core-carrier system group (Thermafil), no voids were detected, whereas small voids were observed in some canals where the lateral condensation technique was applied[33]. However, in our study, a statistically significantly higher number of voids were detected in the lateral condensation group compared to the other groups. This discrepancy is thought to be due to the variability of anatomical variations assessed in different studies.

Similarly, in a study conducted by Alim et al., cold lateral condensation, single cone technique, core-carrier system, and continuous heat method were evaluated in severely curved canals using the Micro-CT technique at three different sections: 2 mm, 5 mm, and 8 mm[34]. According to the study results, contrary to our findings, the filling success was reported to be higher in the coronal region and lower in the apical region. Additionally, no statistically significant difference was found among the cold lateral condensation, core-carrier system, and continuous heat method in the apical 2 mm region. In our present study, in the group with Vertucci Type VI morphology where cold lateral condensation was applied, the coronal portion was found to be more successful than the apical portion.

In another study conducted by Karatekin et al., cold lateral condensation and the continuous heat method were compared in artificial blocks with C-shaped canal systems of different morphologies, produced using 3D printing technology[35]. This study generally observed that the continuous heat method provided a more effective filling compared to cold lateral condensation. However, in the apical 2 mm section of the C1 type, this result was reversed, with the cold lateral condensation technique found to be more successful. This finding is noteworthy as it highlights that even minor differences in canal anatomy can significantly impact filling efficiency.

On the other hand, Silva-Herzog et al. compared lateral condensation, GuttaCore, and continuous wave condensation techniques in terms of apical microleakage[36]. According to the results obtained, GuttaCore and continuous wave condensation methods demonstrated statistically lower microleakage values compared to the lateral condensation technique. However, no statistically significant difference was reported between GuttaCore and the continuous wave condensation technique. These findings suggest that, particularly in complex or multi-canal anatomies, thermoplastic-based systems or core-carrier techniques may be beneficial in reducing microleakage.

In summary, while studies addressing different obturation techniques in complex anatomies, such as inclined or C-shaped canals, are available in the literature, comprehensive research focusing on the types within the Vertucci classification remains limited. Existing data suggest that variations in canal anatomy have a significant impact on the success of the obturation technique. Therefore, a detailed analysis of morphology is crucial for determining the most appropriate obturation approach.

There are no studies in the literature specifically evaluating the Vertucci classification; instead, successful obturation techniques for such variable morphologies are typically presented through case reports. Therefore, a direct comparison of our findings with previous studies was not possible. Both canal morphologies examined in our study present unique anatomical challenges in achieving a void-free root canal filling. For Type V, the main challenge is adequately filling the apical region of the deep split, whereas for Type VI, it is effectively filling the isthmus region. When comparing Vertucci Type V and Type VI, no significant difference in filling quality was observed. Consequently, the second hypothesis of the study was rejected.

This study fills a significant gap in the literature as the first research to comprehensively evaluate the filling quality of different obturation techniques specifically within the context of Vertucci anatomy. While the findings of our study provide a new perspective to the field, certain limitations should be acknowledged.

The results obtained from blocks produced using 3D printing technology do not always correlate with those obtained under natural tooth conditions. For instance, a study by Aminsobhani et al. compared different obturation techniques (Modified Continuous Wave Compaction, Continuous Wave Compaction, Lateral Compaction, and Warm Vertical Compaction Techniques) applied to both natural teeth and acrylic blocks using digital radiography. While no significant differences were observed among obturation techniques in natural teeth, in acrylic blocks, the cold lateral condensation group demonstrated weaker adaptation of the filling material to the canal walls and a higher presence of voids compared to other groups[37]. The findings obtained from artificial teeth are consistent with our study. Although the use of natural teeth aims to better simulate clinical conditions, the variability in canal anatomy makes the interpretation and reproducibility of findings more challenging[38,39]. In contrast, the use of resin blocks allows for the control of these potential variations, ensuring adequate sample size and standardization.

Another limitation of our study is that the evaluations were conducted using two-dimensional images due to cost constraints. The use of three-dimensional imaging techniques would allow for a more in-depth analysis of anatomical details and consequently provide more comprehensive data. Therefore, further studies incorporating advanced imaging techniques are needed to evaluate different Vertucci classifications in greater detail.

Conclusion

Within the limitations of this study, it was determined that in teeth with complex anatomy, the apical filling quality was higher in continuous heat obturation and core-carrier systems. Cold lateral condensation was found to be the technique with the highest void percentage across all evaluated regions in both groups. Therefore, the use of warm obturation techniques may be recommended over cold lateral condensation for teeth with Vertucci Type V and Type VI morphologies. Further studies utilizing advanced imaging techniques are required to evaluate different Vertucci classifications in greater detail.

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