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Original article

CONE BEAM COMPUTERED TOMOGRAPHY EVALUATION OF THE ROOT CANAL OBTURATION OF PREMOLARS WITH ATYPICAL ANATOMY

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SUMMARY:

Purpose: The aim of the study is to evaluate, by cone beam computed tomography, the quality of obturation of the root canal system using the hydraulic condensation method and three preparation methods of printed 3D replicas of human premolars with Vertucci type III, IV and V configuration.

Materials and methods: The printed 3D replicas of human premolar teeth (n=45) are divided into three groups, depending on the morphology of their root-canal system and the method of preparation: Group 1: 15 specimens with Vertucci type III, IV, and V configuration (5 for each configuration), using a standard preparation technique with a .02 taper; group 2: 15 specimens with Vertucci type III, IV, and V configuration (5 for each configuration), Crown down preparation technique with .06 taper and group 3: 15 specimens with Vertucci type III, IV and V configuration (5 for each configuration), by hybrid preparation technique.

All root canals of all specimens were obturated using the hydraulic condensation method.

Cone beam computed tomography scans of the obturated endodontic spaces were compared using HOROS software.

Results: The quality of the root canal filling did not differ significantly in the three studied groups, with 3D obturation having the highest results in group 3 of the studied.

Conclusion: Obturation of premolars with atypical anatomy by the method of hydraulic condensation gives good results in three methods of preparation of the root canal system.

Keywords: cone beam computed tomography, root canal obturation, atypical anatomy,

INTRODUCTION

High success rates in endodontic treatment rely heavily on a precise understanding of the anatomy and morphology of the root canal system of teeth. This knowledge is crucial for the accurate identification, cleaning, shaping, and sealing of root canals. Particular attention must be paid to premolars, which often exhibit significant variations in their root canal system anatomy [1, 2].

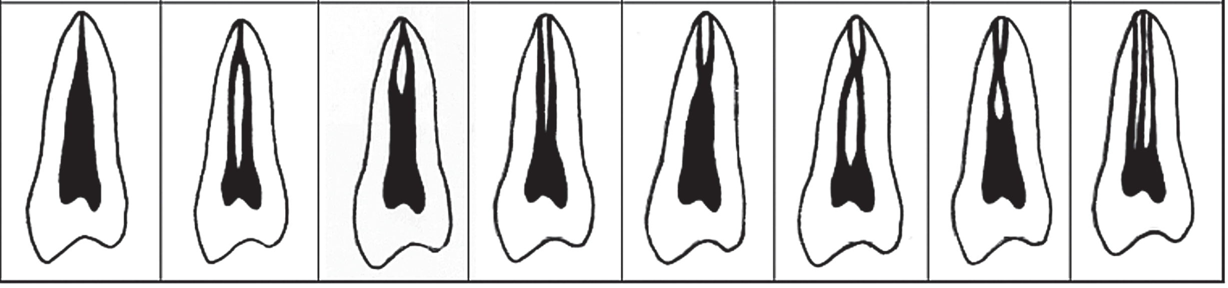
Maxillary premolars typically possess two root canals; however, some studies have shown the presence of three roots in a small percentage of cases [3, 4]. Mandibular premolars, on the other hand, usually have one root and one canal but may also present atypical anatomical variations [5, 6]. Vertucci et al. classified these anatomical variations into eight distinct types, facilitating diagnosis and treatment [7].

Anatomical variations in premolars create numerous challenges in endodontic treatment, including the potential to miss additional canals, difficulties in preparation and obturation, and an increased risk of instrument fracture. The use of cone-beam computed tomography (CBCT) greatly facilitates the diagnosis of these variations [8, 9]. Techniques such as Crown-Down and Step-Back are recommended for preparation [10, 11], alongside modern methods like thermoplasticized gutta-percha for achieving three-dimensional canal system sealing [12].

To study and refine protocols for treating root canals with atypical anatomy, creating working models replicating existing teeth with data derived from CBCT images is advantageous. These prototypes are made possible through 3D printing [13] and offer advantages over extracted teeth by ensuring ideal access, instrumentation, and obturation of the endodontium.

The objective of this study is to evaluate, via cone beam computed tomography, the quality of root canal obturation in 3D-printed replicas of human premolars with Vertucci configurations Types III, IV, and V, utilizing a bioceramic sealer and the hydraulic condensation technique. These methods were selected to enhance the effectiveness of obturation in complex anatomical configurations commonly found in premolars.

Fig. 1. Vertucci's Classification of Anatomical Variations in the Root Canal System of Premolars [7].

	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII
Root canals leaving the pulp chamber	1	2	1	2	1	2	1	3
Root canals along the dental root	1	2	2	2	1	1	2 into 1	3
Root canals with separate apical foramina	1	1	1	2	2	2	2	3
Illustration								

MATERIALS AND METHODS

Printed 3D replicas of human premolar teeth (n=45) were divided into three groups based on the morphology of their root canal systems:

Group 1: 15 samples with Vertucci Type III configuration

Group 2: 15 samples with Vertucci Type IV configuration

Group 3: 15 samples with Vertucci Type V configuration

Each group was subdivided into 3 subgroups:

Subgroup *a* (n=15) – 5 samples from each Vertucci configuration were prepared with the Standard preparation technique, .02 taper: The root canal preparation began with manual stainless steel K-files (#08 and #10) to establish patency and determine the working length. The canals were then sequentially enlarged using standard K-files from size #15 to #30 at the established working length, ensuring a consistent .02 taper. After each file, recapitulation was performed with a #10 K-file to maintain patency. The irrigation protocol included:

1.Initial irrigation with 2 mL of 2.5% sodium hypochlorite after each instrument change.

2.Final irrigation with 2 mL of 17% EDTA solution for 1 minute to remove the smear layer, followed by final rinse with 2 mL of 2.5% sodium hypochlorite and 2 mL of distilled water to remove residual irrigants.

3.Canal drying using sterile paper points.

Subgroup *b* (n=15) – 5 samples from each Vertucci configuration were prepared with the Crown-down preparation technique, .06 taper: The preparation was performed using ProTaper Gold rotary instruments (Dentsply Sirona, Switzerland). Initial canal patency and working length determination were carried out with manual K-files (#08 and #10). Preparation involved sequential rotary files (SX, S1, S2, F1, F2, F3) used in a crown-down manner to an apical size of 0.30 mm with a .06 taper. Recapitulation was performed consistently using a #10 K-file. The irrigation protocol was identical to subgroup *a*.

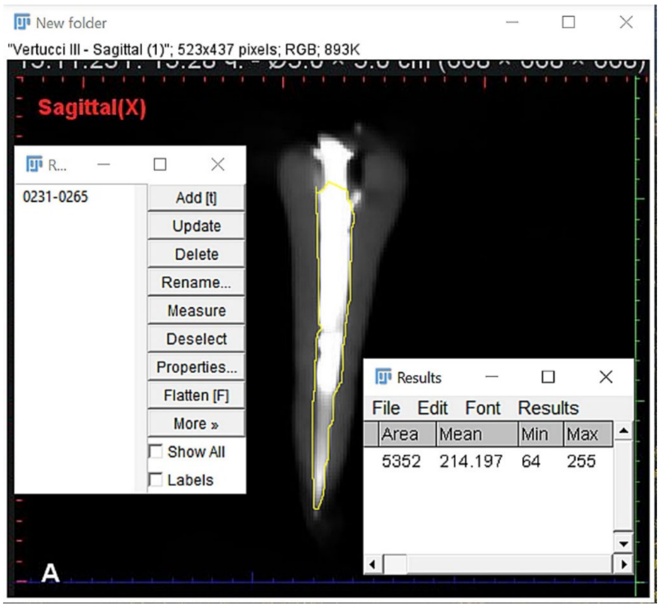
Subgroup *c* (n=15) – 5 samples from each Vertucci configuration were prepared with the Hybrid preparation technique: Canal patency and working length were initially determined with manual K-files (#08 and #10). Following manual enlargement (K-file #15), rotary ProTaper Gold instruments (S1 and S2) were used to further shape the coronal and middle thirds of the canal, stopping 1 mm short of the established manual working length. The apical third was then prepared using the manual step-back technique with stainless steel K-files (#20 to #30). Recapitulation with a #10 K-file was performed after each file to ensure patency. The irrigation protocol was as described in subgroups *a* and *b*

All samples (n=45) were dried with paper posts, and obturated using bioceramic sealer (Bioroot, Septodont) and master gutta percha cone as follows: *subgroup a* - #30, .02; *subgroup b and c* - #30, .06. The filled samples were scanned using 3D cone-beam computed tomography (CBCT), and the images were analyzed using the iRys Viewer software (MyRay®).

The volume of obturation material in the root canal space was evaluated using the ImageJ software's ROI (Region of Interest) manager function. This function manually outlines areas of gutta-percha and sealer for calculation.

These values were statistically analyzed using SPSS v26 [14].

Fig. 2. Manual outlining of the region of interest (ROI) in the ImageJ program, which automatically calculates the area.



RESULTS

The results of the average volume of root canal obturation for the three groups of samples are presented in Tables 1, 2, and 3:

Table 1. Group 1: Average Volume of Canal Filling Material (mm³)

GROUP 1	Average volume (mm³)
Subgroup 1-a	7.765 mm³
Subgroup 1-b	11.823 mm³
Subgroup 1-c	11.952 mm³
Average volume for group 1	10.513 mm³

Table 2. Group 2: Average Volume of Canal Filling Material (mm³)

GROUP 2	Average volume (mm³)
Subgroup 2-a	8.641 mm³
Subgroup 2-b	10.711 mm³
Subgroup 2-c	11.076 mm³
Average volume for group 2	10.142mm³

Table 3. Group 3: Average Volume of Canal Filling Material (mm³)

GROUP 3	Average volume (mm³)
Subgroup 3-a	7.485 mm³
Subgroup 3-b	11.189 mm³
Subgroup 3-c	12.284 mm³
Average volume for group 3	10.319 mm³

The control subgroups (1-a, 2-a, and 3-a) showed the lowest volume of filling material, while the highest volumes were observed in subgroups 1-c, 2-c, and 3-c, where the hybrid preparation technique was employed. This difference is statistically significant ($p<0.05$). No statistically significant differences were observed when comparing the average volumes across groups ($p>0.05$) or between groups prepared with the hybrid and entirely mechanical techniques ($p>0.05$).

Fig. 3. Comparison of the volume of canal filling material in sagittal sections from Group 1, subgroups a, b, and c.

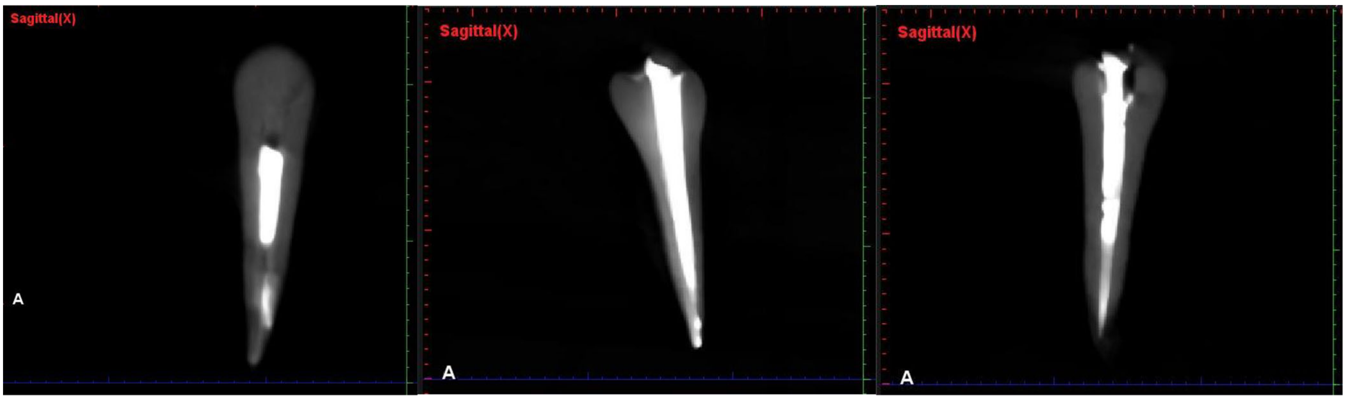


Fig. 4. Comparison of canal filling volume in axial sections from Group 2, subgroups a, b, and c.

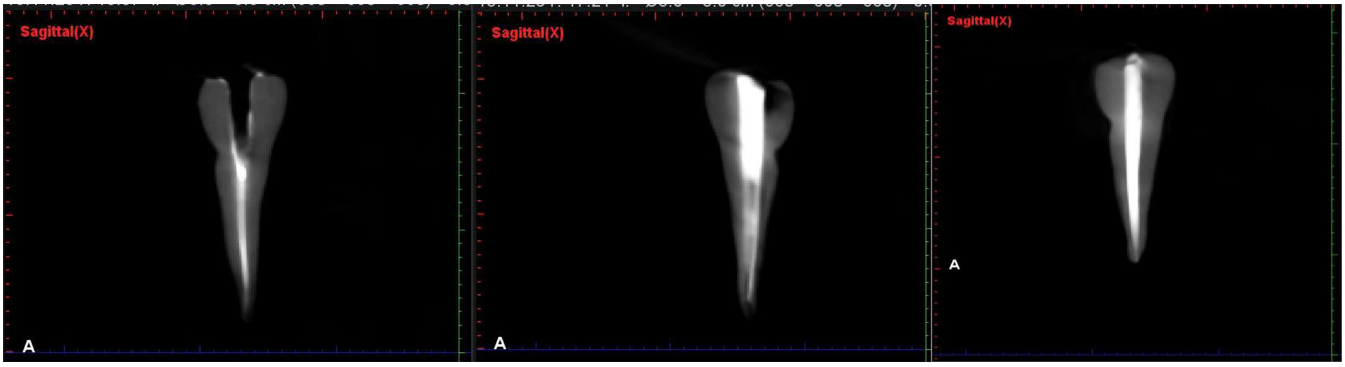
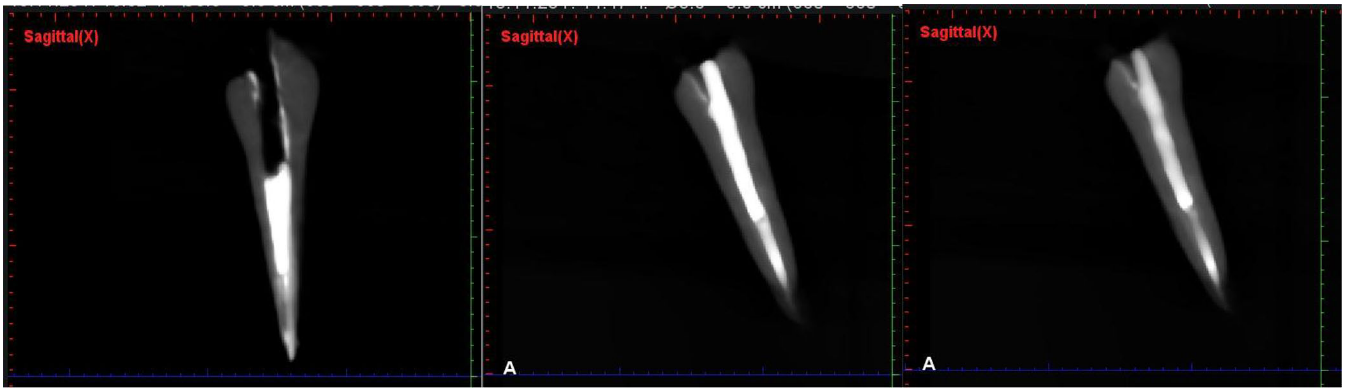


Fig. 5. Comparison of canal filling volume in axial sections from Group 3, subgroups a, b, and c.



DISCUSSION

The results of this study show that the hybrid technique for root canal preparation leads to a larger volume of root canal filling compared to the standard manual technique and the machine-assisted technique. This can be explained by the fact that the hybrid approach combines the advantages of different techniques, allowing for better shaping of the root canals, including their hard-to-reach areas. The technique includes pre-enlargement of the coronal and middle third with nickel-titanium instruments. This allows for deeper penetration of the irrigants **throughout the entire canal system, and better control over** the preparation of the apical zone while preserving the original anatomy. In this study, Type III, IV, and V canal configurations were selected. In Types III and V, there is a deep split located in the middle or apical part of the canal. Hybrid approach allows better visual(if an operating microscope is used) and tactile control, particularly at the level of the split, which makes it very helpful when dealing with these types if anatomical variations. The increased amount of canal filling material is crucial for ensuring effective obturation and reducing the risk of bacterial reinfection.

Interestingly, the difference between the hybrid technique and the machine-assisted technique is not statistically significant, which suggests that machine-assisted preparation also provides good quality obturation. This confirms previous studies showing that machine-assisted techniques improve both the precision of preparation and the quality of the final root canal obturation [15, 16]. The machine-assisted technique allows for better control over the shape of the canal and reduces the time needed for preparation, making it a preferred method for many endodontists [17]. The only disadvantage that we observed during this study was that in Types III, and V configurations, sometimes it can be difficult to pass rotary instruments in both canals after the level of the split. In these cases, for the second, more abruptly curved canal, the hybrid approach can be beneficial, as it allows for precurving of the hand instruments. With the development of the latest generations of nickel-titanium alloys with heat-treated technology, precurving of the instrument and inserting it into highly curved canals and splits is also possible.

It is also noteworthy that all three canal configurations show significantly lower filling volumes in the samples with the manual preparation technique. This result can be explained by the limitations of manual techniques. Using only stainless steel, rigid instruments predisposes the canal to blockages, ledges and transportations, especially in cases with more complex root canal morphology, which is often seen in Vertucci type III, IV, and V configurations. Trying to negotiate and prepare at the beginning the apical, most challenging part of the canal system, which is inherent disadvantage of this method, often leads to blockages and inability to clean and obturate. Such cases require more precise preparation, which can be difficult to achieve with manual techniques due to the limited maneuverability of standard instruments in root canals with complex anatomy [10].

Another important aspect of this study is the use of 3D-printed replicas to evaluate the quality of obturation. This methodology allows for an accurate reproduction of anatomical variations and offers an efficient way for training and simulating complex cases in endodontic practice. In the future, the development of 3D printing could offer new opportunities for even more precise simulations, leading to better clinician preparation and improved treatment quality.

CONCLUSION

Based on the results of this study, we can conclude that the hybrid technique for root canal preparation provides the highest volume of canal filling material, which is a key factor for the success of endodontic treatment. However, the machine-assisted technique also shows similar results, making it a suitable alternative in practice. The manual technique, although still used, is less effective in complex anatomical cases and requires further improvements or combinations with other methods to achieve optimal results.

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