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ORIGINAL RESEARCH

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Comparison of the gutta-percha amounts used by two root canal obturation techniques in simulated root canals shaped with four different NiTi file systems.

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Abstract

Introduction: The three-dimensional and hermetic obturation of the root canal is considered a fundamental element for successful root canal treatment. **Aim of the study:** This study aimed to compare the effects of different NiTi file systems and canal obturation techniques on the amount of root canal filling. **Material and Methods:** A total of 80 standardized transparent acrylic blocks (TABs) with canals of 17 mm length, a constant taper of 2%, and a curvature of 30 degrees were used. The canals were shaped using 4 different NiTi file systems [ProTaper Next (PTN), ProTaper Ultimate (PTU), VDW Rotate (VR), and XP-Endo Shaper (XPS)], with 20 samples per system. After shaping, TABs were weighed 3 times using a precision scale, and the averages were recorded. They were then randomly divided into 2 subgroups [Single Cone (SC) and Continuous Wave Compaction (CWC)], and canal obturation procedures were performed. After obturation, TABs were again weighed 3 times on a precision scale, averages were recorded, and weight differences were calculated. Statistical analyses included the Shapiro-Wilk test, one-way ANOVA, and Tukey HSD post-hoc tests. **Results:** Statistically significant differences were found among all groups ($P < 0.05$). The PTU-CWC group exhibited the highest filling amount (0.0248 ± 0.0032), while the lowest filling amount was observed in the XPS-SC group (0.0083 ± 0.0027). Among SC groups, VR-SC showed the highest filling amount and XPS-SC the lowest. Within CWC groups, the PTU-CWC group had significantly higher filling amounts compared to the other groups, while no significant differences were found among the PTN, VR, and XPS groups. **Conclusions:** The findings of this study indicate that the amount of root canal filling significantly varies depending on the NiTi file system and obturation technique used. Thermoplastic techniques generally produced similar results; however, the PTU system provided significantly greater filling amounts. In SC techniques, the VR system exhibited the highest, and the XPS system showed the lowest filling effectiveness.

Keywords: Root canal treatment, endodontic files, root canal obturation, gutta-percha, NiTi rotary systems.

Introduction

Successful root canal treatment (RCT) requires appropriate technical procedures, including proper access cavity preparation, careful detection of the canal orifices, adequate chemico-mechanical instrumentation, and obturation of the root canals [1]. This optimal treatment approach cannot be achieved without a sound understanding and knowledge of the anatomy of the roots and canals [1].

There are several phases of the RCT, each with different objectives. The primary goal of the first stage is the elimination of tissue, debridement, bacteria, and their byproducts, achieved through mechanical instrumentation and chemical irrigation of the root canals. The next step is to obturate the root canal system to prevent potential bacterial invasion. This creates a three-dimensional (3D), hermetic seal that can prevent recontamination and prevent periapical fluids from feeding microorganisms that have made it through the cleaning and shaping process. The 3D obturation of the root canal system is widely accepted as a key factor for successful RCT [2,3].

Endodontic technique has advanced with the use of nickel-titanium (NiTi) rotary systems for root canal instrumentation, and studies [4-9] have demonstrated their efficacy. With a NiTi endodontic file system, root canal preparation is faster, results in less canal deviation, and minimizes loss of working length and apical extrusion of debris. To reduce errors, these systems have undergone constant innovation, and many new NiTi files have been created over time, with differences in design elements and techniques [4]. The ProTaper Next system (PTN) (Dentsply Maillefer, Ballaigues, Switzerland) owns an innovative asymmetric characteristic which permits only 2 cutting edges touch the canal wall under a continuous rotation [5,7]. It is made from NiTi M-Wire technology, which improves cyclic fatigue resistance by reducing internal stresses, combined with a progressive taper geometry that enhances cutting efficiency. Used technology features a distinctive off-centered rectangular cross-section that imparts a snake-like, swaggering motion to the files [6,7]. The ProTaper Ultimate (PTU) system (Dentsply Maillefer) is the most recent member of the ProTaper family. It shows a partially off-centered parallelogram cross-section with varied sharp angles. It differs from other files in that PTU integrates M-Wire, Gold, and Blue thermal treatments, achieving a balance of flexibility, fracture resistance, and superior clinical performance, along with a specific taper design that preserves the structural integrity of the root canal during instrumentation [7,8]. Another file system known as XP-Endo Shaper (XPS) (FKG Dentaire, LaChaux-de-Fonds, Switzerland) is fabricated with MaxWire alloy (martensite-austenite electropolishing-flex) that reacts at different temperatures. The file has an initial taper of .01 in its martensite phase when it is cooled; however, upon exposure to body temperature (35° C), the taper changes to .04 according to the molecular memory of the austenite phase [6]. The name of the other file system used in this study is VDW Rotate (VR) (VDW, Munich, Germany). It is a rotary system manufactured with a proprietary heat-treated "blue-wire" nickel-titanium (Ni-Ti) alloy and a double-bladed adapted S-shaped cross-section design. According to the manufacturer, the design of the instruments and their increased flexibility reduce canal transportation and preserve root canal anatomy [9].

In the field of endodontics, gutta-percha (GP) has become indispensable due to its availability, ease of manipulation, biocompatibility, cost-effectiveness, as well as novel procedures that are easy to adapt for clinical use [10]. Today, the 2 main techniques of obturation are hydraulic (single cone, SC) and thermogenic (warm vertical compaction, WVC). The simplest and most used method is cold lateral compaction (CLC). However, CLC technique is considered the gold standard; it has significant drawbacks. The WVC method is the preferred option by endodontic specialists. It involves heating the GP until it softens and changes phase, allowing it to customize to the prepared root canal wall. Previous studies [11,12] showed that this technique uses more heated GP and less sealers, allowing any brand of sealer to be used.

The aim of this in vitro study was to compare the gutta-percha amounts used by 2 root canal obturation methods (SC and CWC) in simulated root canals shaped with 4 different NiTi file systems (PTN, PTU, VR, and XPS). The null hypothesis tested was that there are no differences in used gutta-percha amounts among the used shaping and obturation methods.

Material and methods

A total of 80 transparent acrylic blocks (TABs) (Dentsply Maillefer) with simulated single root canals were used. As the study was conducted on transparent acrylic blocks and did not involve human participants or animal subjects, ethical approval was not required. All the simulated root canals were approximately 17 mm in length and had a 2% constantly increasing taper with a curvature of 30 degrees. The root canals were initially scouted with a size 10 K-type file until its tip was visible at the apical foramen, and the working length (WL) was set 0.5 mm shorter. Before the instrumentation, a glide path was established with a #15 K-file to the WL for each root canal. The TABs were then randomly assigned to 4 groups (n = 20) based on the used NiTi file systems PTN, PTU, VR, and XPS.

PTN Group: Glide path was prepared using a ProGlider file after confirmation with a size 15 K-file (Mani Inc., Tochigi, Japan). Instrumentation was initiated with X1 (17/.04), followed by X2 (25/.06), and completed with X3 (30/.07). All files were operated in continuous rotation at 300 rpm and 2 Ncm torque.
PTU Group: Glide path was prepared using the Slider (16/.02) file. Instrumentation was performed using the Shaper (20/.04), Finisher F1 (20/.07), Finisher F2 (25/.06), and Finisher F3 (30/.09). All files were operated in continuous rotation at 400 rpm and 4.0 Ncm torque.
VR Group: Glide path was prepared using VR 15/.04. Instrumentation was performed with VR 20/.05, 25/.04, and 30/.04 files. All files were operated in continuous rotation at 350 rpm and 2.0 Ncm torque.
XPS Group: Glide path was confirmed with a size 15 K-file. Instrumentation was performed using a single XPS file (30/.01). The file was operated in continuous rotation at 800 rpm and 1 Ncm torque. In this group, TABs were immersed in water bath at 35 °C to let XPS file behave in its intended performance where, upon exposure to intracanal temperature, the martensitic phase of the file converts to the austenitic phase, and this will expand the file in a way that will produce preparation taper of 4% throughout the canal length.
During all instrumentation procedures, a #10 K-type file was used to remove the debris and maintain patency by passing the file to the canal foramen after each NiTi file was used. The canal was irrigated with 1 mL of distilled water between each file shaping using a side-vented 27-gauge needle (Monoject, Tyco Healthcare, Mettawa, IL, USA) 1 mm short of the WL and then dried with paper points (Dentsply Maillefer).
After that, TAB weights were measured on a precision scale (XB 220A; Kunz Precisa, Zofingen, Switzerland). Samples were weighed 3 times with an accuracy of 0.0001 g, and the average of the 3 measurements was calculated. These shaped TABs were then randomly assigned to 2 subgroups (n = 10) based on the used root canal obturation techniques [single cone (SC) and continuous wave compaction (CWC)].
SC Groups: The matching SC (gutta-percha cone size for PTN 30.07, PTU 30.09, VR 30.04, XPS 30.01) taper was gently inserted into the canal with an up-and-down motion until it reached the WL, and excess gutta-percha was completed by removing the gutta-percha 1 mm below the canal orifice using Fast-Pack Pro (Eighteeth, Orikam, China) with a heated plugger. In this study, a root canal sealer was not used due to experimental planning.
CWC Groups: After the root canal instrumentation, the WL was checked with the master cone used in SC groups. The Fast-Pack-Pro device (Eighteeth, Changzhou, China) connected to the down-pack unit of the Eighteeth Cordless Obturation System-Fast Fill was adjusted to be 4 mm shorter than the WL. The master cone was cut 1 mm shorter than the WL with a heated plugger and applied to the root canal. Then, the heated plugger was advanced in the apical direction, and the apical region was obturated. Obturation was completed in 2 stages with gutta-percha in the Eighteenth gutta-percha cartridge connected to the remaining root canal cavity back-fill unit and heated to 200 °C. Heated gutta-percha was vertically condensed with a plugger. The root canal obturation was completed by removing the gutta-percha 1 mm below the canal orifice. In this study, a root canal sealer was not used due to experimental planning.
After the obturation, the TABs' weights were measured on a precision scale again. Samples were weighed 3 times with an accuracy of 0.0001 g, and the average of the 3 measurements was calculated.
The distribution characteristics of the data obtained in the study were evaluated using the Shapiro-Wilk test, and a normal distribution was confirmed for all groups ($P > 0.05$). Therefore, parametric tests were preferred. One-way analysis of variance (One-Way ANOVA) was conducted to compare the

groups. The ANOVA results indicated a statistically significant difference among the groups ($P < 0.05$). To determine which groups accounted for this difference, the Tukey HSD post-hoc test was applied.

Results

The means, standard deviations, p value, and Tukey HSD post-hoc test results for the 8 groups are presented in the table below ($P < 0.05$).

Table 1. Mean differences, standard deviations, and post-hoc test results for all groups.

Group	Mean (± SD)	p value
PTU-CWC	0.0248 ± 0.0032^{d}	*< 0.001*
PTU-SC	0.0104 ± 0.0046^{ab}	*< 0.001*
VR-CWC	0.0189 ± 0.0042^{c}	*< 0.001*
VR-SC	0.0146 ± 0.0038^{bc}	*< 0.001*
PTN-CWC	0.0168 ± 0.0043^{c}	*< 0.001*
PTN-SC	0.0109 ± 0.0022^{ab}	*< 0.001*
XPS-CWC	0.0178 ± 0.0041^{c}	*< 0.001*
XPS-SC	0.0083 ± 0.0027^{a}	*< 0.001*

Significance level of differences between groups (One-Way ANOVA test).a, b, c, d: Indicate distinct groups based on Tukey's post-hoc test.

The highest mean weight difference was observed in the PTU-CWC group (0.0248 ± 0.0032), which was found to be statistically different from all other groups ($P < 0.05$). The XPS-SC group exhibited the lowest mean weight difference. It was statistically different from most other groups ($P < 0.05$), except for the PTU-SC and PTN-SC groups, with which it showed no significant difference. The PTU-SC and PTN-SC groups demonstrated similar results. A statistically significant difference was found between the SC and CWC within the VR group. These results indicate that the amount of root canal filling material significantly varies depending on the applied obturation technique. When thermoplastic techniques were compared, the PTU group demonstrated the highest mean filling amount and was found to be statistically different from the other groups ($P < 0.05$). No statistically significant differences were observed among the PTN, VR, and XPS CWC groups. These findings suggest that while thermoplastic techniques generally exhibit similar performance, the PTU system stands out as significantly different within this group.

Table 2. Mean differences, standard deviations, and post-hoc results for CWC groups.

Group	*Mean (± SD)*	*p value*
PTU	0.0248 ± 0.0032^{a}	*< 0.001*
VR	0.0189 ± 0.0042^{b}	*< 0.001*
PTN	0.0168 ± 0.0043^{b}	*< 0.001*
XPS	0.0178 ± 0.0041^{b}	*< 0.001*

Significance level of differences between groups (One-Way ANOVA test).a, b: Indicate distinct groups based on Tukey's post-hoc test

Table 3. Mean differences, standard deviations, and post-hoc results for SC groups.

Group	*Mean (± SD)*	*p value*
PTU	0.0104 ± 0.0046^{a}	*< 0.001*
VR	0.0146 ± 0.0038^{b}	*< 0.001*
PTN	0.0109 ± 0.0022^{a}	*< 0.001*
XPS	0.0083 ± 0.0027^{c}	*< 0.001*

Significance level of differences between groups (One-Way ANOVA test).a, b, c: Indicate distinct groups based on Tukey's post-hoc test.

Among the SC techniques, the highest mean filling amount was observed in the VR group. This group showed statistically significant differences from the XPS-SC and PTN-SC groups. The PTU-SC and PTN-SC groups demonstrated similar values. The XPS-SC group had the lowest filling amount and was found to be significantly different from all other groups ($P < 0.05$). These findings indicate that both the single cone technique and system-specific characteristics may influence the effectiveness of canal obturation.

Discussion

The instrumentation of the root canal is one of the most important steps in endodontics, in order to obtain a pathway suitable for the subsequent action of irrigants and the following obturation of the root canal [3]. Complexity of the root canals, curvatures in different root regions, curvature degrees or blockages due to various reasons can negatively affect the success of the root canal obturation as well as the instrumentation process [1]. Most obturation procedures combine gutta-percha and sealer. In root canal obturation, gutta-percha is used with various cold or warm obturation techniques, and the sealer is used to cover the gaps between the gutta-percha and the dentin, as well as between the gutta-perchas themselves. For a good obturation, a major portion of the root canal should be obturated with gutta-percha, and the sealer should be used sparingly. Formerly, the lateral condensation technique was commonly used for root canal obturation. In this technique, after the main gutta-percha cone was placed, the remaining spaces were obturated with auxiliary cones. In addition, simple levels of SC, other cold and warm obturation techniques were used. With the widespread usage of NiTi endodontic file systems, gutta-perchas of the same dimensions as the files used have been made, with the goal of entirely occlusing the area created by the NiTi file. Thus, a modern SC technique has found a new area of use in endodontics. Also, more controlled and advanced warm obturation techniques have become popular again in recent years [13].

There are many studies [13-19] comparing the quality of teeth shaped with NiTi endodontic files and root canal obturation with different techniques. When we look at these research, we notice that the outcomes are significantly varied. For example, Alshehri et al. [13] reported that the SC technique created fewer voids than the warm gutta-percha techniques. Despite this, several authors [14-17] argue that there is no substantial difference between these techniques. According to the other some authors [18-20] warm obturation techniques fill the canal space more effectively than SC technique. There are also studies [3,21,22] in literature comparing the effects of endodontic NiTi file systems on the obturation quality of root canals. Schäfer et al. [21] evaluated the obturation quality of carrier-based, SC, and lateral compaction techniques in root canals shaped with different kinematics. As a result, they stated that gutta-percha core-carrier system contained more filling in the canal in all groups regardless of the shaping system. Again, in another study [3] they concluded that less voids were created at 2, 4 and 6 mm of the canal in the study group shaped with Mtwo files and filled with SC technique. They claimed that each file system employed produced more voids near the coronal 1/3 and produced fewer voids in canals filled using the lateral compaction technique. Capar et al. [22] in their study comparing the SC technique of the canals shaped with NiTi rotary systems, they obtained different results in each file system despite the kinematic differences. They stated that a gap was formed in each group and there was no difference between the groups due to kinematics. In contrast to the experimental methods used above, some studies [23-27] in literature compared filling density by weighing the amount of gutta-percha. They used TABs to compare various obturation procedures. The TABs were weighed after instrumentation and obturations. According to the common results demonstrated that the warm obturation techniques resulted in a significantly greater density compared with cold techniques. In this study we used filling density by weighing the amount of gutta-percha experimental method and investigated the impact of two obturation techniques (SC and CWC) on the amount of gutta-percha used in root canal filling, following canal shaping with 4 different NiTi file systems (PTN, PTU, VR, and XPS. The results demonstrated that both the choice of NiTi file system and the obturation technique significantly influenced the amount of gutta-percha used, with notable variations observed across the experimental groups. For this reason, the null hypothesis tested was rejected. Consistent with previous studies [23-27], the CWC technique produced significantly higher filling amounts compared to the SC technique across all file systems tested. This outcome is expected given the thermoplastic nature of the CWC technique, which allows for better adaptation and compaction of the gutta-percha within the canal space, especially in the presence of canal irregularities and curvatures.

Among the CWC groups, the PTU-CWC group recorded the highest mean filling amount (0.0248 ± 0.002), which was statistically different from the other 3 file systems. No significant differences were observed among the PTN, VR, and XPS groups under CWC conditions. PTU performance could be attributed to the shaping characteristics of the PTU system, which includes enhanced flexibility, controlled memory, and a progressive taper design. In contrast, the SC technique showed greater variability in performance among the different file systems. The VR-SC group produced the highest filling volume within the SC groups, whereas the XPS-SC group demonstrated the lowest (0.0083 ± 0.0027). The comparatively poor performance of XPS in the SC group may be explained by its minimal shaping approach, which aims to preserve dentin by maintaining a conservative canal preparation. The VR system's higher gutta-percha fill in the SC technique could be a result of its file geometry and preparation profile, which may produce a canal shape that more effectively matches the gutta-percha cone dimensions, thereby improving fill without the need for thermoplastic compaction.

In the literature, TABs, 3D tooth models, and natural teeth have been used to examine the effectiveness of root canal files and filling techniques [27-29]. Many features of natural teeth, such as the root canal length/width/curvature or presence of resorption/calcification, are difficult to standardize. Additionally, while dentin hardness varies from tooth to tooth, the hardness of resin blocks is consistent. They are transparent, providing for a good view of the changes that occur during and after the procedures and facilitating computer-based measurements. For these reasons, TABs were used in this study.

Schneider [30] defines the classification of the curvatures in the root canal as 5° and below as straight, 10° to 20° as moderately curved, and 25° and above as highly curved. In our study, all the simulated root canals were approximately 17 mm in length and had a 2% constantly increasing taper with a curvature of 30°, which are clinically considered moderately difficult according to Schneider.

In this study, only gutta-percha was used during the filling of the root canals in the TABs. Root canal sealer was not used. This can be considered as one of our limitations. Due to reasons such as adjusting the amount of sealer to be used during the experiment, difficulty in ensuring homogeneous distribution in the canal, and inability to prevent apical or coronal overflow, sealer was not preferred. There are previous studies [23-27] with similar designs in the literature. We believe that further studies are needed and that it would be appropriate to support similar laboratory studies with clinical research.

Conclusions

Based on the results of the present study, it can be concluded that the amount of root canal filling significantly varies depending on the NiTi file system and obturation technique used. Thermoplastic techniques generally produced similar results; however, the PTU system provided significantly greater filling amounts. In SC techniques, the VR system exhibited the highest, and the XPS system showed the lowest filling effectiveness. These findings align with prior literature emphasizing the importance of both instrumentation and obturation technique in achieving optimal canal filling. The volume of obturation material not only affects the quality of the seal but also correlates with the potential for voids and microleakage.

Conflict of Interest: None to declare.

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