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Evaluation of compatibility of file and gutta-percha cones in three different endodontic systems using scanning electron microscopy

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Purpose: The aim of this study was to evaluate the matching properties of the gutta-percha (GP) cones and different file systems with variable tapers.

Methods: Fifteen files and GP cones TruNatomy Prime (TRN-P), WaveOne Gold Primary (WOG-P), and Reciproc Blue (Rec-B R25) systems were examined under a scanning electron microscope. Diameter measurements of files and GP cones were made from D1 to D16 using AutoCAD software. Data were analyzed with independent samples t-tests. Statistical significance was determined as $p< 0.05$.

Results: The diameters of the file and GP cones were within the acceptable tolerance range. The file diameter was larger than the GP diameter at all points of incompatibility in the TRN-P system ($p< 0.05$). In the WOG-P group, the file diameter was wider up to the D10 level, while the GP cone diameter was wider at the D11 point and beyond $p<0.05$. In the Rec-B group, the file diameter was wider up to the D6 level, while the GP cone diameter was wider at the D7 point and beyond $p<0.05$.

Conclusion: Three file systems are largely incompatible with the GP cones. In the TRN file system, unlike the other two groups, the GP cone had a narrower diameter than the file at each point.

Keywords: Diameter, reciproc blue, rotary file systems, standardization, TruNatomy, WaveOne Gold.

Introduction

Nickel–titanium (Ni-Ti) rotary files have been used in root canal treatment and are evolving to allow for more effective cleaning and shaping of root canals. The dimensions of endodontic instrument must be accurate and precise for an effective and predictable cleaning and shaping of the root canal system. Ingle created the standardization of the instruments used in root canal treatment, and although the standards were revised over time in this system, it is still used today (1).

In the updated ISO 3630-1 standards, there is no limitation for file systems with variable taper angles, and products are presented to clinicians according to the references determined by the manufacturer (2). Despite the development of production methods and the standardization of endodontic files, there are still great differences in the same dimensions within the produced file and gutta-percha (GP) cone systems themselves. According to the current standards, tolerances range from 0.02 mm for files up to #60, while 0.04 mm for files larger than #60. The range

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for GP cones is from 0.05 mm to 0.07 mm, depending on the cone size (3).

According to the manufacturer's data, Reciproc-Blue (VDW, Munich, Germany) (Rec-B), WaveOne Gold (Dentsply Maillefer, Ballaigues, Switzerland) (WOG), and TruNatomy (Dentsply Maillefer, Ballaigues, Switzerland) (TRN) are file systems that allow preparation in three different sizes. In these systems, the file and GP cones have variable tapers. It is stated that because the file and GP of the same size are fully compatible with each other, it provides optimum obturation (4-6). Many clinicians use an obturation technique that depends on the taper of the canal being the same for instrumentation and obturation (7). If the dimensions of file and GP differs from the manufacturer's claims, preparation of the root canal may not be appropriate. Therefore, incompatible files and GP cone sizes will affect the quality of the canal filling and the longevity of the teeth (1).

Studies on rotary file systems have examined factors such as fracture resistance, shaping ability, and extrusion of debris from the root canal system (8-10). However, a very few studies have evaluated the compatibility of rotary instrument file systems and GP cones suitable for these systems (7,11,12). The aim of this study was to evaluate the compatibility of the diameters of rotary file systems with their own GP cones. The null hypothesis of the study was that there is no difference in diameter from D1 to D16 levels between file and GP cones for three different rotary file systems.

Materials and Methods

After a sample size calculation with G*Power 3.1 software (Heinrich Heine University, Dusseldorf, Germany), in Rec-B R25, Wave One Gold Primary (WOG-P), and TruNatomy Prime (TRN-P) groups, 15 files and GP cones were included. The samples were kept at 23 ± 2°C for at least 1 h before processing, and the samples were coated with gold-palladium (Au-Pd) (4.0 min, 18.0 mA, 1.0/mbar) ions for better imaging. After the samples were prepared, they were placed in a scanning electron microscope (SEM) (EVO MA10., Zeiss, Oberkochen, Germany) for examination, and images were obtained at 35× magnification (Fig. 1).

The AutoCAD 2023 Educational Version (Autodesk Inc., San Rafael, CA, USA) program was used to measure the files and GP cones in the images. The 1 mm scale on the SEM images was referenced in the AutoCAD program. The end regions of the files and GP cones were accepted as the starting point (D0) while the measurements were made. Diameter measurement lines were drawn perpendicular to the length lines every 1 mm. The diameters of the file and GP cones per millimeter from point D1 to point D16 were measured and recorded by a single operator (Fig. 2).

Statistical Analysis

The mean and standard deviation values were calculated for the file and the corresponding GP cones at all diameters. The Shapiro-Wilk test revealed a normal distribution. Data were analyzed using the independent samples t-

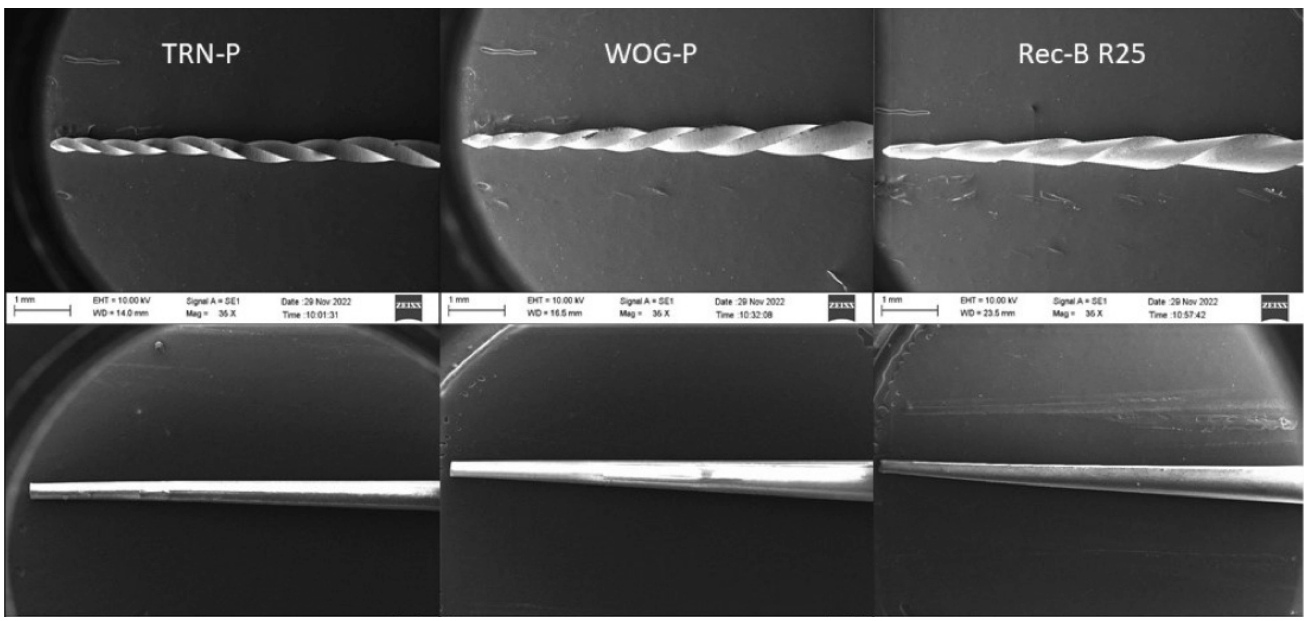

Fig. 1. File and GP cone images of the TRN-P, WOG-P, and Rec-B R25 groups

Table 1. Comparison of all files and corresponding GP cone diameters according to the groups in millimeters (means and standard deviations)

Measuring point (n=15)	TRN-P				WOG-P				Rec-B R25			
	File	GP cone	Direction of significance	p*	File	GP cone	Direction of significance	p*	File	GP cone	Direction of significance	p*
D1	0.3007±0.0320	0.2935±0.0025	F>GP	>0.001	0.3201±0.0038	0.3094±0.0041	F>GP	>0.001	0.3180±0.0044	0.3152±0.0041	F~GP	0.119
D2	0.3215±0.0027	0.3143±0.0032	F>GP	>0.001	0.3820±0.0021	0.3724±0.0036	F>GP	>0.001	0.4007±0.0031	0.3874±0.0047	F>GP	>0.001
D3	0.3625±0.0044	0.3591±0.0039	F~GP	0.064	0.4562±0.0025	0.4467±0.0033	F>GP	>0.001	0.4895±0.0067	0.4757±0.0041	F>GP	>0.001
D4	0.3814±0.0029	0.3706±0.0038	F>GP	>0.001	0.4668±0.0042	0.4563±0.0037	F>GP	>0.001	0.5453±0.0051	0.5340±0.0032	F>GP	>0.001
D5	0.4073±0.0051	0.3937±0.0032	F>GP	>0.001	0.5153±0.0030	0.4956±0.0046	F>GP	>0.001	0.6045±0.0041	0.5942±0.0056	F>GP	>0.001
D6	0.4514±0.0056	0.4364±0.0034	F>GP	>0.001	0.5672±0.0039	0.5568±0.0055	F>GP	>0.001	0.6349±0.0039	0.6259±0.0042	F>GP	>0.001
D7	0.4725±0.0022	0.4631±0.0033	F>GP	>0.001	0.6362±0.0048	0.6340±0.0051	F~GP	0.289	0.6667±0.0053	0.6734±0.0043	GP>F	0.003
D8	0.4941±0.0027	0.4829±0.0042	F>GP	>0.001	0.6971±0.0046	0.6915±0.0038	F>GP	0.003	0.7224±0.0043	0.7278±0.0043	GP>F	0.005
D9	0.5247±0.0028	0.5145±0.0028	F>GP	>0.001	0.7447±0.0062	0.7385±0.0051	F>GP	0.014	0.7728±0.0024	0.7830±0.0024	GP>F	>0.001
D10	0.5545±0.0035	0.5439±0.0028	F>GP	>0.001	0.8086±0.0044	0.8112±0.0055	F~GP	0.203	0.8091±0.0047	0.8172±0.0024	GP>F	>0.001
D11	0.5962±0.0023	0.5837±0.0038	F>GP	>0.001	0.8496±0.0045	0.8600±0.0053	GP>F	>0.001	0.8441±0.0044	0.8536±0.0022	GP>F	>0.001
D12	0.6280±0.0023	0.6140±0.0032	F>GP	>0.001	0.8884±0.0031	0.8931±0.0051	GP>F	0.012	0.8735±0.0031	0.8831±0.0025	GP>F	>0.001
D13	0.6575±0.0037	0.6243±0.0029	F>GP	>0.001	0.9232±0.0052	0.9317±0.0029	GP>F	>0.001	0.9315±0.0035	0.9430±0.0032	GP>F	>0.001
D14	0.7031±0.0032	0.6333±0.0031	F>GP	>0.001	0.9649±0.0032	0.9754±0.0042	GP>F	>0.001	0.9725±0.0028	0.9813±0.0042	GP>F	>0.001
D15	0.7491±0.0045	0.6511±0.0026	F>GP	>0.001	1.0139±0.0038	1.0227±0.0051	GP>F	>0.001	1.0143±0.0020	1.0255±0.0027	GP>F	>0.001
D16	0.7671±0.0052	0.6837±0.0027	F>GP	>0.001	1.0538±0.0022	1.0631±0.0037	GP>F	>0.001	1.0447±0.0023	1.0545±0.0017	GP>F	>0.001

*Independent samples t-test, F: File, GP: Gutta-percha, TRN-P: TruNatomy Prime, WOG-P: WaveOne Gold Primary, Rec-B R25: Reciproc Blue R25

tests using SPSS 21.0 software (IBM Corp, Armonk, NY). Equality and non-equality variances were examined. The alpha-type error was set at $p < 0.05$.

Results

Table 1 shows each group's descriptive statistics regarding the file and corresponding GP cone. Fig. 3 shows the direction of the difference between the GP and the file. In the TRN group, the diameter of the file was significantly larger than the GP cone at all points except the D3 point ($p < 0.001$).

In the WOG group, the diameter of the file was significantly greater than the diameter of the GP cone at points D1–D6 (including D6), D8, and D9 ($p < 0.001$, $p = 0.003$, and $p = 0.014$, respectively). There was no significant difference between file and GP cones at D7 and D10 ($p> 0.05$). The diameter of the GP cone was significantly greater than the diameter of the file at points D11–D16 ($p < 0.05$).

In the REC-B group, there was no significant difference between file and GP cones at D1 ($p> 0.05$). The diameter of the file was significantly greater than the diameter of the GP cone at points D2–D6 (including D6) ($p < 0.001$). The diameter of the GP cone was significantly greater than the diameter of the file at points D7–D16 (including D16) ($p < 0.05$).

Discussion

In this study, compatibility between the files and GP cones of the Rec B R25, WOG P and TRN P Ni-Ti systems. was evaluated. The null hypothesis was rejected because there were statistically significant differences between the file and GP cones at many points between D1 and D16 in each file system.

Ni-Ti files and their corresponding GP cones should have a similar apical diameter (13). The absence of this similarity during the root canal filling process may cause extrusion into the periapical tissues, poor adaptation to the root canal walls, or premature binding with the root canal wall before the apical point (14). This may lead to the failure of treatment due to insufficient root canal obturation (15).

Although the manufacturers state that there is a compatibility between the file systems and the GP cones that they produce, studies in the literature that evaluated the compatibility between them found this to be untrue (7,12,14,16). The recent studies evaluating minimally invasive endodontics and rotary instrument and root canal filling methods have used a diameter equivalent to a #25K file. Rec-B R25, WOG-P, and TRN-P files and GP cones were preferred in our study since their apical diameters are equal to #25K files (8-10,17).

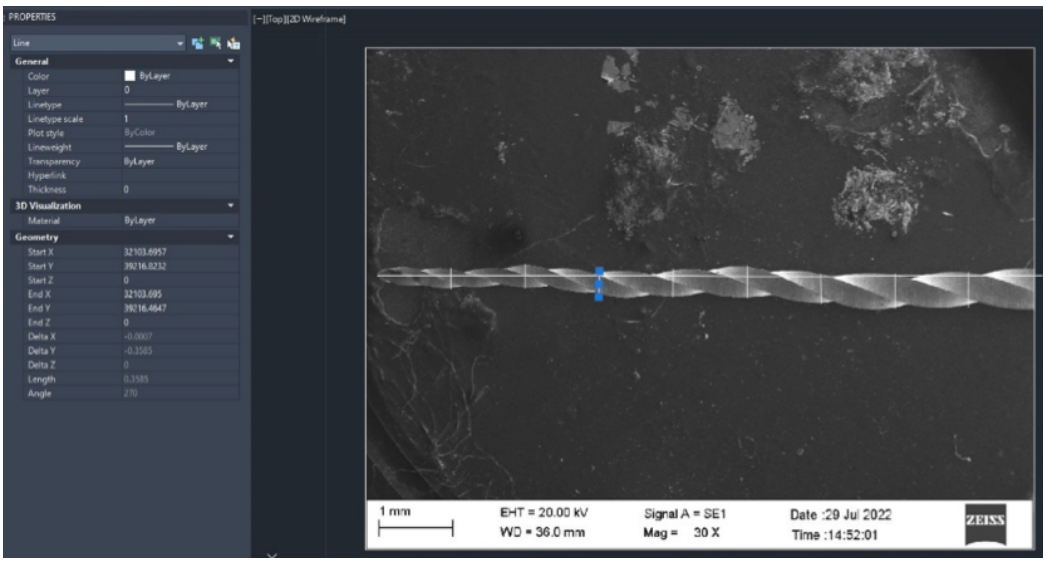

Fig. 2. Measurement of D3 diameter of TRN-P file with AutoCAD

In the literature, there are studies measuring the diameter at different levels of the file and GP cones, as well as studies measuring it at all levels (7,12,16,18). Although the diameter should be measured at 3 and 16 mm from the tip of the file and GP cones according to the ISO 3630-1, the diameters were measured at every mm, since the rotary file and GP cone system used in our study had variable tapers (2). Methods such as caliper, optical microscope, and SEM have been used in prior studies to measure the size of the GP subject and file (7,12,16,18). In our study, the samples were taken under an SEM with a sensitivity of 0.1 mm using 35× magnification for optimal measurement.

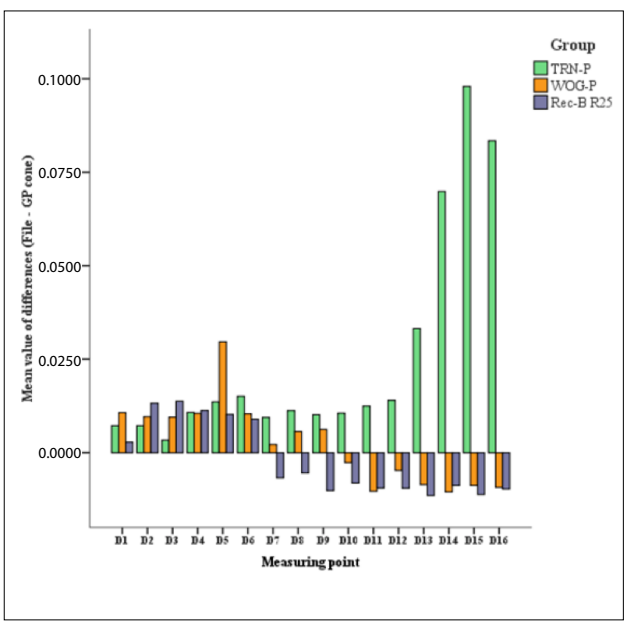

Fig. 3. Differences between the file and the corresponding GP cone diameter and direction of the differences (in millimeters)

The AutoCAD program has been used in various studies in endodontics (11,19,20). AutoCAD was used for the measurements in our study because the images can be enlarged at desired levels, allowing precise measurements, repeat measurements, and different metric systems.

In the evaluated samples, there were statistically significant and insignificant differences between the file and GP cones for the Rec-B R25, WOG-P, and TRN-P groups at various levels for all diameters; however, the measurements of the file and GP cones were within the tolerance levels. In a study by Haupt et al., the diameter of the Reciproc system was evaluated at all levels, and they found that the D14–D16 diameters of the GP cones were larger than the file (12). The results of this study coincide with our results for the Rec-B file, which has the same design, but which the manufacturer offers to the market with the claim that it is more flexible with heat treatment. According to the findings of a similar study in which the WOG-P system was examined, the results at the D11 level were similar to the results obtained in our study. However, although the authors stated that GP cones at the D3 level had a larger diameter than the files, in our study, it was found that the file diameter at the same level was larger than the GP cone (18). GP cones were found to be larger than files at D11, D14, and D16 in two studies, which is similar to our findings (12,18). If the diameters of the GP cones are larger than the file systems, this can lead to premature binding with the root canal walls, especially in the apical region of teeth with long root anatomy, and thus insufficient root canal obturation (12).

For TRN-P, the fit between the file and GP cones was within the tolerance levels, while the file size was found to be significantly larger than GP cones in all dimensions.

This may cause the GP extrusion from the root canal system during obturation process in preparations using the TRN-P system, and the root canal system cannot be three-dimensionally obturated. In a TRN study, fewer GP cones were found in the single-cone technique, which is consistent with our research (21). This study evaluates the compatibility of files and GP cones used only in the root canal system. As a result of the complex structure of this system, further studies using micro-CT are necessary.

Conclusion

It should be noted that there may be a diameter mismatch between the file systems used and GP cones. Obturation should be undertaken by adhering to the working length, and the root canal system should be hermetically filled using different compaction techniques.

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