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Comparison of Shaping Ability of T-Endo MUST and WaveOne Gold with Glide Path Instruments: An *In Vitro* Study

T-Endo MUST ve WaveOne Gold'un Rehber Yol Eğeleri ile Şekillendirme Yeteneklerinin Karşılaştırılması: *İn Vitro* Çalışma

Seda FALAKALOĞLU[a], Emre İRİBOZ[b]

[a]Department of Endodontics, Afyonkarahisar Health Sciences University Faculty of Dentistry, Afyonkarahisar, Türkiye
[b]Department of Endodontics, Marmara University Faculty of Dentistry, İstanbul, Türkiye

ABSTRACT Objective: The aim was to compare the shaping ability and the canal straightening of T-Endo MUST and WaveOne Gold reciprocal file systems with glide path files in resin J-shaped root canals. **Material and Methods:** Two groups (n=17) were established. TEM tg (13/.04) + TEM M25 (25/.06) and WOG Glider (15/.02) + WOG Primary (25/.07) were used to prepare the resin simulated canals. A series of preoperative and postoperative images were taken by a digital camera and they were superimposed. The curvature angles and the amount of resin removed from both the inner and the outer wall of the canal into the level of 7 mm from the apical point, with a 1 mm increment were measured. The data were evaluated with independent samples Student's t-test with 5% significance interval. **Results:** There was no statistically difference between TEM and WOG reciprocal files (p>0.05). No instrument fracture or canal aberrations were inspected during canal preparation. **Conclusion:** Within the limitation of this present study, TEM and WOG files maintained the original canal curvature in curved canals. They produced conservative shapes with lower foramen transportation.

Keywords: Endodontics; root canal preparation; root canal therapy

ÖZET Amaç: T-Endo MUST ve WaveOne Gold resiprokal eğe sistemlerinin rehber yol eğeleri ile birlikte rezin J-şekilli kanallardaki şekillendirme kabiliyetini ve kanal düzleştirmesini karşılaştırmaktır. **Gereç ve Yöntemler:** İki grup (n=17) oluşturuldu. Rezin kanalları genişletmek için TEM tg (13/.04) + TEM M25 (25/.06) ve WOG Glider (15/.02) + WOG Primary (25/.07) kullanıldı. İşlem öncesi ve sonrası görüntüler dijital kamera ile çekildi ve üst üste bindirildi. Eğrilik açıları ve kanalın hem iç hem de dış duvarından apikal noktadan 7 mm seviyesine kadar, uzaklaştırılan rezin miktarı 1 mm'lik aralıklarla ölçüldü. Bağımsız örneklem grubuna %5 anlamlılık seviyesine göre Student t-testi uygulanmıştır. **Bulgular:** TEM ve WOG resiprokal eğe sistemleri arasında istatistiksel olarak anlamlı bir fark bulunmamıştır (p>0,05). Kanal genişletilmesi sırasında alet kırığı görülmemiştir. **Sonuç:** Bu çalışmanın sınırlamaları dâhilinde TEM ve WOG, eğimli kanallarda orijinal kanal eğriliğini korumuştur. Daha düşük apikal transportasyon ile konservatif bir kanal genişletmesi gerçekleştirdiler.

Anahtar Kelimeler: Endodonti; kök kanalı hazırlama; kök kanalı tedavisi

Root canal preparation plays an essential role in the good prognosis of endodontic treatment. It is crucial to maintain root canal integrity during the preparation. Nevertheless, this is not always possible due to the tendency of the files used to straighten the root canal during preparation. Root canal anatomy is complex and this situation increases the risk of iatrogenic damage, insufficient cleaning, and unsuccessful treatment.[1] Significant issues regarding nickel-titanium (NiTi) file shaping ability are transportation and curvature straightening.[2] NiTi file systems are successful in efficiency and safety during preparation.[3] Manufacturers continually improve the shaping ability of files by modifying some special features such as the geometric characteristics, the taper, and new alloys.[4-6] Glide path preparation is a critical phase of root canal preparation, in which a path is established that reaches the apical area.[7] Glide path preparation is

Correspondence: Seda FALAKALOĞLU
Department of Endodontics, Afyonkarahisar Health Sciences University Faculty of Dentistry, Afyonkarahisar, Türkiye
E-mail: sedafalakaloglu@gmail.com

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made with stainless steel K-files or NiTi files with a small tip diameter and taper.[8,9] Whereas manual preparation of glide paths can be demanding and time-consuming, NiTi glide path instruments can provide safe glide path preparation with reduced time consumption, especially in curved canals.[10] Artificial root canals in resin blocks have a standardization to prevent differences among extracted teeth. They have the same root canal topography in three dimensions.[2,11]

The WaveOne Gold Glider (WOG Glider; Dentsply Sirona, Switzerland), made of a thermomechanically treated alloy, is a reciprocating glide path file. The file has a parallelogram horizontal cross-section with 2 cutting edges, a 0.15 mm tip diameter, and a 2-6% increasing variable taper.[12] The WaveOne Gold (Dentsply Sirona) is a reciprocal file system with an off-centered parallelogram-shaped cross-section and a progressively decreasing percentage taper design. As a result, it has only 1 or 2 contact points between the cutting edges and the canal wall. This design reduces torque, minimizes the screwing effect on the cutting efficiency, and allows better removal of debris.[13,14]

The T-Endo MUST (TEM; Dentac, İstanbul, Turkey) is a novel reciprocal file system. This system has a glide path file as T-Endo MUST tg (TEM tg). This reciprocal file system is made of a special heat-treated alloy named "tm-wire" by the manufacturer. It has an S-shaped cross-section design. The TEM tg has a 0.13 mm tip diameter and a 4% taper.[15]

To our knowledge, no report has compared the shaping abilities of TEM with those of other NiTi file systems. Thus, this study aims to evaluate the shaping ability and preservation of the original canal curvature of the TEM and WOG with glide path files. The null hypothesis of this study was that there is no difference between the TEM and WOG reciprocating instruments in J-shaped root canals.

MATERIAL AND METHODS

Thirty-four simulated J-shaped canals (Dentsply Maillefer) that have 0.02 taper, 40°-angle single curvature and with 17-mm length were prepared. Each block was coded by a number and was filled with black ink (Pelikan, İstanbul, Turkey) to take an image of the canal. After instrumentation, red ink (Pelikan, İstanbul, Turkey) was filled into resin canals.

The images of the resin blocks were taken under the standardized situation with a EOS 60D (Canon, Taichung, Taiwan) digital camera's objective SIGMA 105 mm 1:2.8 DG macro-lens (Sigma Corp., Fukushima, Japan). The images were saved as JPEG files. After this, the samples were randomly divided into two groups. All samples were concealable with black adhesive tape. Each instrument was used on two canals.

The working length (WL) was determined with a #10 K-file. All preparations of the canals were done by a single endodontist. Distilled water (20 mL) was used for irrigation using a syringe with a 30-G Irri-Flex needle (Produits Dentaires SA, Switzerland) in both groups.

Group 1 (n=17): The resin J-shaped canals were prepared with TEM tg (13/.04), and TEM M25 (25/.06) files were used at 160 (CCW)-40 (CW) at 300 rpm with a torque controlled endomotor (Genius; Ultradent, South Jordan, UT, USA). TEM tg and TEM M25 were introduced into the canal until the WL was achieved.

Group 2 (n=17): The resin J-shaped canals were prepared with a WOG Glider (15/.02), and WOG Primary (25/.07) files were used in "WaveOne ALL" mode using the endomotor (VDW Silver; VDW, Munich, Germany). WOG and WOG Primary were introduced into the canal until the WL was achieved.

After instrumentation, superimposition method was used using Adobe Photoshop CS6 Extended program (Adobe Systems Inc., San Jose, CA, USA). The curved region of the canal was drawn with 7 lines with 1 mm intervals, and 8 measurement sites were determined (AutoCad 2021; Autodesk Inc., San Jose, CA, USA) (Figure 1). The basis point was in the center of the canal at the tip of the apex in the pre-operative image. Images were analyzed by researhers with Image J (Version 1.52u, NIH Wisconsin, Bethesda, Maryland, USA).

The last apical 7 mm of each canal's inner and outer walls was estimated by 2 researchers. The first

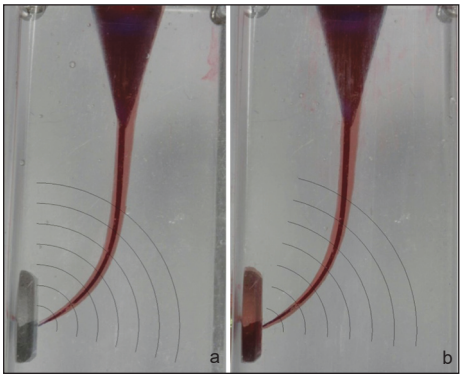

FIGURE 1: Superimposed image of J-shaped canal and with the arcs of the seven apical levels, **a)** T-Endo Must, **b)** WaveOne Gold.

measurement point was set at level 0, and the last measurement point was at level 7. It was also calculated by the difference between 8 different levels of wear of the inner and outer parts of the canal walls. A total of 16 measurements were calculated for each resin canal. If the difference between the determined points is equal to 0, it was decided that there is no transportation on the inner-outer wall.[16]

The angles of the canals were calculated using the Image J in accordance with the Schneider method.[17] The mean values of the difference between the values of the curvature angles before and after preparation were used.

STATISTICAL ANALYSIS

Data were analyzed using the SPSS 21.0 (IBM, Armonk, NY, USA). Mean values and standard deviations were calculated for each measurement point. Data were subjected to the Shapiro-Wilk test to verify normality. The independent samples Student's t-test was used to compare results between the two groups. The level of significance was set at $p<0.05$.

RESULTS

No instrument separation of any file and no other canal aberrations occurred during the study. In addition, no statistically significant differences were observed between curvature angles of the J-shaped canals for each group ($p>0.05$). The mean degree of the J-shaped canals was shown in Table 1.

The mean amount of resin removed at both the inner and outer canal walls was explained in Table 2. Statistical analysis using independent samples Student's t-test revealed that there were no differences at all levels ($p>0.05$). Both groups showed a small deviation from the original shape of the canal. No statistically significant differences were observed at any level, and the mean values of transportation for each group were summarized in Table 3 ($p>0.05$). The intergroup centering ability analysis was summarized in Table 4. A significant value was detected at level 4 of Group 1 compared to Group 2 regarding the centering ratio ($p<0.05$).

TABLE 1: Mean values with their respective values for standard deviation change in angle (degrees) between the groups evaluated.

Change in angle	Groups	Mean±SD	p value
	TEM	129.9694±4.164230	0.509
	WOG	131.0017±4.827130	

SD: Standard deviation.

TABLE 2: Mean and standard deviation values for the amount of removed material detected at 8 different levels (mm).

Level	Inner measure			Outer measurements		
	TEM	WOG	p value	TEM	WOG	p value
0	0.0927±0.08489	0.1063±0.08833	0.651	0.0394±0.06816	0.0371±0.05781	0.914
1	0.1310±0.09114	0.1412±0.07603	0.726	0.0715±0.07812	0.0603±0.04832	0.618
2	0.1598±0.11222	0.1822±0.08709	0.520	0.1051±0.09231	0.0851±0.06044	0.460
3	0.1799±0.11528	0.2091±0.09924	0.436	0.1222±0.12095	0.0663±0.07183	0.111
4	0.2480±0.10634	0.2663±0.10023	0.609	0.1153±0.10362	0.0731±0.10640	0.250
5	0.3368±0.11623	0.3266±0.14536	0.822	0.1108±0.10977	0.0846±0.11215	0.498
6	0.3305±0.14088	0.3194±0.14119	0.820	0.1294±0.09199	0.1081±0.11603	0.558
7	0.2840±0.15224	0.2416±0.14156	0.407	0.1934±0.07811	0.2066±0.10663	0.681

TABLE 3: Mean and standard deviation values for the amount of transportation irrespective of the direction at 8 measurement levels (mm).

Level	TEM	WOG	p value
0	0.0533±0.12739	0.0692±0.11531	0.705
1	0.0595±0.15906	0.0809±0.10982	0.651
2	0.0425±0.20034	0.0971±0.13222	0.355
3	0.0289±0.23685	0.1428±0.14841	0.103
4	0.1023±0.22728	0.1932±0.19297	0.218
5	0.1889±0.26099	0.2419±0.24142	0.543
6	0.2150±0.21414	0.2113±0.24450	0.963
7	0.1088±0.21180	0.0350±0.23711	0.346

TABLE 4: Centering ratio means and standard deviation detected at 8 different levels.

Level	TEM	WOG	p value
0	0.1129±0.25585	0.1257±0.25722	0.885
1	0.2394±0.35109	0.2788±0.30808	0.730
2	0.4161±0.38181	0.3372±0.30588	0.511
3	0.4344±0.36041	0.2163±0.27712	0.057
4	0.5687±0.38515	0.2590±0.28205	**0.012**
5	0.4106±0.31053	0.2672±0.27547	0.164
6	0.5085±0.33186	0.3612±0.25722	0.158
7	0.5385±0.23310	0.5669±0.36329	0.788

p values marked with *mean statistically significant difference between T-endo MUST and WaveOne Gold.

DISCUSSION

In this study, we aimed to evaluate the shaping ability of TEM and WOG in the preparation of curved canals. To evaluate the shaping ability, the amount of resin removed the root canal curvature at last 7 mm, the transportation of the apical foramen, and the conservation of the original curvature of the resin curved root canals were examined. To our knowledge, this study is the first to evaluate the shaping abilities of the new reciprocating file TEM using curved resin canals. The reciprocating movement is provided with higher efficiency by preserving the original curvature than can be achieved with continuous rotary movement.[18] The alloy of the instrument is another determinant that affects the shaping ability of NiTi file systems.[19] According to Gagliardi et al., the Gold and M-wire alloys that increased flexibility of the alloys cause significantly less canal transportation.[19] A previous study reported that the WOG Primary caused less apical transportation, so produced more conservative preparation.[20] Thus, in our study, we preferred WOG Primary to TEM M25 in J-shaped resin root canals.

Single file systems are widely used due to reduced preparation time and several failures related to instrumentation.[13] WOG Primary is significantly successful in creating a glide path in single file systems.[21] The glide path reduces the frictional forces of the file during preparation, preserving its original anatomy.[22,23] Although it has been reported that single file systems pass through the entire WL before the glide path is created in most cases, creating a glide path by using more flexibility and smaller tapered files are recommended, especially in curved canals such as molars.[6,24-26] Therefore, we compared TEM and WOG with glide path files such as TEM tg and WOG Glider.

In this study, the standardization of the J-shaped canal was carried out using resin blocks in order to measure the same length, diameter, curvature angle, and radius of curvature. With natural teeth, different sizes and shapes in the root canal anatomy affect the

results.[27] However, the disadvantages of using resin blocks are that they have much lower surface hardness than dentin. They are subject to softening of the resin due to friction during preparation.[28] This might make it difficult as the instrument progresses along the simulated canal. According to the authors' knowledge of the literature, superposition in resin canals is a commonly accepted method used to evaluate the shaping ability of instrumentations.[20,28]

The results of the present study support the null hypothesis, which proposed no differences in shaping ability between the 2 reciprocating single-file systems. Furthermore, neither file system exceeded the 0.3 mm limit for transportation, which is considered critical for clinical prognosis at any level.[29] Based on the findings of this study, the TEM system did not appear to alter the original anatomy significantly. Therefore, we think that it can be used safely in moderately curved canals. Additionally, it is recommended to create a glide path before preparation when using NiTi file systems. The use of a glide path NiTi system before a single shaping file increases success in respecting the original anatomy.[30] We also think that the absence of a significant difference between two reciprocal file systems in this study is related to the systems' own glide path files.

Bürklein et al. reported that the heat-treated files were associated with minor canal straightening.[14] There is no significant difference regarding canal straightening observed between TEM M25 and WOG Primary. In the authors' opinion, this result occurs because both are heat-treated files. Furthermore, WOG has increased flexibility thanks to Gold wire technology that advanced metallurgy and heat treatment. In addition, WOG files have been reported to have better cyclic fatigue resistance than other reciprocating files.[31] According to our knowledge, in the literature while writing this study, there are no cyclic fatigue studies associated with TEM. Although the cyclic fatigue resistance of the heat-treated technology defined as tm-wire by the manufacturer is not known, similar results have been obtained in terms of the shaping ability in the J-shaped resin canal.

CONCLUSION

TEM and WOG retained the root canal anatomy and were safe for use in J-shaped canals within the limitations of this *in vitro* study. However, due to the differences between the resin material and human dentin, further studies are needed to evaluate the effects of the TEM reciprocal file system, which uses human teeth with different file systems.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Seda Falakaloğlu, Emre İriboz;* ***Design:*** *Seda Falakaloğlu, Emre İriboz;* ***Control/Supervision:*** *Seda Falakaloğlu;* ***Data Collection and/or Processing:*** *Seda Falakaloğlu;* ***Analysis and/or Interpretation:*** *Seda Falakaloğlu;* ***Literature Review:*** *Seda Falakaloğlu;* ***Writing the Article:*** *Seda Falakaloğlu;* ***Critical Review:*** *Emre İriboz;* ***References and Fundings:*** *Seda Falakaloğlu.*

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