# Performance of Reciproc Blue R25 Instruments in Shaping the Canal Space without Glide Path



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## Abstract

**Introduction:** This study assessed the frequency in which Reciproc Blue R25 instruments (VDW, Munich, Germany) reached the full working length (WL) of mandibular molar canals without a glide path. The influence of the type of electric motor (ie, conventional corded or cordless) on the instrument's performance was also assessed. **Methods:** One hundred mandibular molars with slight to moderate root canals were selected and randomly assigned into 1 of 2 experimental groups according to the type of electric motor used: conventional corded (VDW Silver, VDW) or cordless motors (VDW.CONNECT Drive, VDW). Therefore, 50 molars and 154 root canals were selected for each motor. Reciproc Blue R25 instruments were used until reaching two thirds of the estimated WL. Then, a size 10 K-file was passively inserted to determine the full WL. No active instrumentation movement was performed with a size 10 K-file. Independently, whether a size 10 K-file reached the apex or not, Reciproc Blue R25 instruments were used to complete canal preparation. When the Reciproc Blue R25 instrument was able to reach the full WL, the case was classified as "reaching the full working length" (RFWL). If the instrument was not able to reach the full WL, the case was classified as "not reaching the full working length" (NRFWL). The chi-square test of goodness of fit was used to verify whether the observed frequencies of RFWL and NRFWL adhered to the expected ones. A 5% cutoff level of significance was considered for statistical assumptions. **Results:** Reciproc Blue R25 instruments were able to reach the full WL in 304 root canals (98.70%). The chi-square test revealed the observed frequencies of RFWL and NRFWL to be significantly different from the expected frequencies ($\chi^2 = 292{,}208$, $P = .000$). The frequency of RFWL and NRFWL was exactly the same for both types of electric motors. No instrument fractured, and a single file deformed. In 50 of 308 root canals, a size 10 K-file was unable to passively reach the full WL. From these 50 canals, Reciproc Blue R25 instruments were able to reach the full WL in 47 of them. **Conclusions:** Reciproc Blue R25 instruments were able to reach the full WL in a high frequency of cases. The type of electric motor used did not interfere in the frequency of RFWL cases. No instrument fractured, and a single file deformed. *(J Endod 2019;45:194–198)*

## Key Words

Glide path, reciprocation, Reciproc Blue, root canal instrumentation

**Significance**

Reciproc Blue R25 instruments were able to reach the full working length of mandibular molar canals without a glide path in a high frequency of cases.

The glide path is commonly defined as a series of clinical procedural steps to preshape the canal space from the entrance orifice to its physiological terminus (1, 2). This procedure has a clear role of confirming that there is a free pathway with a minimal size to allow the flow of a rotary nickel-titanium (NiTi) instrument, rendering safety and predictability to the mechanical preparation (1, 2). The mechanism whereby the glide path works is by preventing the taper lock phenomenon; thus, the instrument's life span increases, whereas fracture rates and shaping errors decrease (3–7). It is fair to say that the glide path was the transoperative procedure that rendered the shaping of the root canals with rotary NiTi systems viable.

The reciprocating movement was introduced in 2008 and raised new perspectives on mechanical canal preparation. Nowadays, there is a well-built knowledge base showing the benefits of reciprocation over rotary movement (8–12). One point deserves special attention because it stands for its unique ability—the capacity to safely prepare most of the ordinary root canals with no glide path using just 1 reciprocating instrument. The best example is the M-Wire Reciproc R25 instrument (VDW, Munich, Germany), which is often able to smoothly advance toward the apex without the necessity of any sort of preshape (9). In function of the reciprocating motion per se, the instrument tends to follow the naturally existent canal path down to the apex (13). Currently, there are *in vitro* and *in vivo* evidences showing that more than 90% of standard root canals can be prepared with the M-Wire Reciproc R25 instrument without any previous glide path (9, 14–16). For these reasons, the manufacturer of Reciproc no longer strictly recommends glide path preparation before its use.

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Following the trend of the current innovations in the metallurgical field, the second generation of Reciproc instruments (Reciproc Blue; VDW) was launched. It is made of blue NiTi wire generated by an innovative thermal treatment, which consists in a heating-cooling proprietary treatment that regulates the phase transition temperatures and results in a blue visible titanium oxide layer in the instrument surface (17). Moreover, this thermal treatment controls the phase transition temperature, creating a predetermined shape memory alloy. It is already known that this thermal treatment rendered the Reciproc Blue instrument softer than its predecessor (17), and this feature may impact the overall instrument cutting and shaping abilities. To date, the performance of Reciproc Blue R25 instruments is unknown regarding the necessity of a glide path for ordinary cases.

Recently, a cordless endodontic motor was launched onto the market (VDW.CONNECT Drive; VDW). According to the manufacturer, this innovative motor combines modern wireless communication technology with a reliable performance. Besides being cordless, this motor has 1 major difference compared with its predecessors VDW Silver (VDW) and VDW Gold (VDW)—the RECIPROC REVERSE comfort function. This is a 2-step indicator that gives early acoustic feedback of increased friction on the instrument, which has the potential of being useful for users (https://www.vdw-dental.com/en/products/detail/vdwconnect-drive). However, to the best of the authors' knowledge, no study has been performed comparing the efficiency and reliability of these different motors.

Therefore, the present study was designed to assess the frequency of cases in which Reciproc Blue R25 instruments are able to reach the full working length (WL) in mandibular molar canals without a glide path. In addition, the influence of the type of the electric motor (ie, conventional corded or cordless) on the instrument's performance was also assessed. The hypotheses tested were the following:

1. the Reciproc Blue R25 instrument is able to reach the full WL of mandibular molars canals without a glide path in a high frequency of cases and
2. there is no influence of the type of electric motor on the instrument's performance.

## Materials and Methods

### Sample Size Calculation

Based on a similar study by De-Deus et al (9), the effect size for the Reciproc Blue R25 instrument to reach the full WL was determined to be 0.296. Using the chi-square family and the goodness of fit test (G*Power 3.1 for Macintosh; Heinrich Heine, Universität Düsseldorf, Düsseldorf, Germany) with additional parameters of alpha error = 0.05 and beta power = 0.95, a minimal sample size of 149 root canals was indicated.

### Sample Selection

After the approval of the local research ethics committee, 250 first and second mandibular molars presenting 18–21 mm in length were selected. Teeth with caries, immature apices, cracks, resorptive defects or root fillings were excluded. The inclusion criteria were composed of teeth with slight to moderate curvature (ranging from 0°–20°) according to Schneider's method (18) and with completely visible root canals on the radiograph. As a result, 100 mandibular molars were selected, with a total of 308 root canals. All root canals (mesial and distal roots) from each tooth were included.

To test the influence of the type of electric motor, the specimens were randomly assigned into 1 of 2 experimental groups: conventional corded (VDW Silver, software version 1.1) and cordless motors (VDW.CONNECT Drive). For both motors, the manufacturer's preset configuration "RECIPROC ALL" was used. Therefore, 50 molars and 154 root canals were selected for each motor.

### Root Canal Procedures

A specialist in endodontics with 3 years of experience performed all procedures. In order to exclude instruments that could have critical production defects, each 1 of the Reciproc Blue R25 instruments was inspected in a surgical microscope with 15× magnification, and none were excluded. Moreover, no glide path or any other instruments were used prior in the root canals. The WL of each root canal was estimated using a preoperative digital radiograph. After orifice openings, each tooth was mounted on a specific apparatus (IM do Brazil; São Paulo, SP, Brazil) to simulate the alveolar socket and allow connection of the metal lip clip of an apex locator (Root ZX; J Morita USA Inc, Irvine, CA) to enable an electronic measurement of the WL (19). After that, the shaping of the root canals was performed using the Reciproc Blue R25 instrument in a pecking motion with a 3-mm amplitude limit; after 3 pecking movements, the instrument was removed from the canal and cleaned, and the root canal was irrigated with 1 mL 5.25% sodium hypochlorite for 1 minute. Afterward, the Reciproc Blue R25 instrument was used until reaching two thirds of the estimated WL. At this time, a size 10 K-file (Dentsply Sirona Endodontics, Ballaigues, Switzerland) was passively inserted into the canal following the manufacturer's recommendations with the purpose of electronically determining the full WL. No active instrumentation movement was performed at all with a size 10 K-file.

Independently, whether a size 10 K-file reached the apex or not, the Reciproc Blue R25 instrument was then used to complete the canal preparation. When the Reciproc Blue R25 instrument reached the full WL, the case was classified as "reaching the full working length" (RFWL). In cases in which the Reciproc Blue R25 instrument was not able to reach the full WL by observation of considerable resistance, the preparation was stopped after 3 trials to go toward the apex, and the case was classified as "not reaching the full working length" (NRFWL). The number of root canals in which the Reciproc Blue R25 instrument did not reach the full WL were recorded and tabulated in an Excel (Microsoft, Redmond, WA) data sheet as either RFWL or NRFWL.

### Micro-CT Analysis

The teeth that had some root canal in which the Reciproc Blue R25 instrument did not reach the full WL were scanned in a micro–computed tomographic (micro-CT) device (SkyScan 1173; Bruker microCT, Kontich, Belgium) at 90 kV and 88 mA with an isotropic resolution of 7.48 $\mu$m using a 1-mm-thick aluminum filter. Each projection was acquired in 1000 milliseconds and a 0.4° rotation step through 360° rotation around the vertical axis. The scans were taken to reveal the root canal anatomy and to clarify potential reasons for the inability of the Reciproc Blue R25 instrument to reach the full WL.

### Statistical Analysis

The number of Reciproc Blue R25 instruments that were classified as RFWL and NRFWL was recorded as well as the number of instrument fractures or deformations. The observed frequencies of RFWL and NRFWL were considered for statistical analysis. The chi-square test of goodness of fit (SPSS for Windows v17.0; SPSS Inc, Chicago, IL) was used to verify whether the observed frequencies of RFWL and NRFWL adhered to the expected ones. A 5% cutoff level of significance was considered for statistical assumptions.

## Results

Overall, Reciproc Blue R25 instruments were able to reach the full WL in 304 root canals (98.70%). The chi-square test revealed the observed frequencies of RFWL and NRFWL to be significantly different from the expected frequencies ($\chi^2$ = 292,208, $P$ = .000). Because the frequency of RFWL and NRFWL was exactly the same for both motors, the assumption of different performance influenced by the type of electric motor was not statistically tested, and the results were taken together regardless of the type of electric motor used. No instrument fractured, and a single file deformed (Fig. 1*A* and *B*). A full description of the data is shown in Table 1.

In 50 of 308 root canals, a size 10 K-file was unable to passively reach the full WL. From these 50 canals, Reciproc Blue R25 instruments were able to reach the full WL in 47 of them, and the chi-square test certified significance for this observation ($\chi^2$ = 38.720, $P$ = .000). Micro–CT images showing the potential causes of NRFWL cases are displayed in Figure 2*A–H*.

## Discussion

The present results showed that Reciproc Blue R25 instruments were able to reach the full WL without a glide path in a high frequency of cases (98.70%). Therefore, the first tested hypothesis was accepted. Reciproc Blue R25 instruments were unable to reach the full WL without a glide path in only 4 canals out of 308, and of those, only 2 of them had no apparent anatomic reason to possibly explain this inability (Fig. 2). These results are in line with recent *in vitro* and *in vivo* studies, which showed that the M-Wire Reciproc R25 instrument was able to reach the full WL without a glide path in a high frequency of cases (9, 14–16). De-Deus et al (9) were the first to assess the ability of M-Wire Reciproc R25 instruments to reach the full WL without a glide path; the authors concluded that this instrument was able to reach the full WL in 96.40% and 90.70% of straight and moderately curved root canals of mandibular molars, respectively. Afterward, a series of clinical studies confirmed the ability of this reciprocating instrument to reach the full WL without a prior glide path procedure. In a prospective case series report, Zuolo et al (14) showed that M-Wire Reciproc R25 instruments were able to reach the full WL of second mesiobuccal maxillary first and second molars in 85.63% of the cases. From a pool of 673 canals, Rodrigues et al (15) showed that M-Wire Reciproc instruments were able to reach the full WL in 96.28% of cases overall, with a full WL rate of 95.3%, 98.5% and 97.6% in narrow (using M-Wire Reciproc R25 instruments), medium (using M-Wire Reciproc R40 instruments; VDW), and large (using M-Wire Reciproc R50 instruments; VDW) canals, respectively. In addition, Bartols et al (16) showed that M-Wire Reciproc instruments were able to reach the full WL in 96.3% and 93.80% of the root canals after root canal treatments and retreatments, respectively. These results led us to believe that M-Wire Reciproc and Reciproc Blue manufacturer's recommendation to not use any glide path instrument before preparation makes sense because the predictability of RFWL is high when using these instruments. Other manufacturers of single-file reciprocating systems, such as WaveOne (Dentsply Sirona Endodontics) and WaveOne Gold (Dentsply Sirona Endodontics), recommend a glide path before preparation. These differences might be mainly explained by differences in the instruments cross section and tip design, which in the case of Reciproc instruments may allow a better scouting ability than the WaveOne and WaveOne Gold instruments. Such issues should be better explored in future studies.

**TABLE 1.** Full Description of Data

| Reciproc Blue R25 | VDW Silver | VDW.CONNECT Drive |
|---|---|---|
| Number of instrumented teeth | 50 | 50 |
| Number of instrumented canals | 154 | 154 |
| Number of RFWL canals | 152 | 152 |
| Number of NRFWL canals | 2 | 2 |
| Fractures | 0 | 0 |
| Deformations | 1 | 0 |
| % of RFWL | 98.70 | 98.70 |

NRFWL, not reaching the full working length; RFWL, reaching the full working length.

In this study, no instrument fractured and only 1 deformed during the maneuvers to reach the full WL in 308 instrumented root canals. In fact, these results are not surprising because the reciprocating motion per se has been proven to be safer regarding cyclic fatigue and torsional fracture when compared to continuous rotary motion (8, 10, 20, 21). As a result, the life span of the instrument with this motion has been proven to be longer (22). Plotino et al (23) showed a total of 8 fractured M-Wire Reciproc R25 instruments during the treatment of 1696 cases and 3780 root canals, which represent 0.47% of the number of instruments used and 0.31% of the root canals treated. Moreover, Rodrigues et al (15) showed 3 instrument fractures after performing root canal treatment in 277 teeth. It is important to emphasize that both clinical studies (15, 23) followed the manufacturer's directions for the use of Reciproc instruments without creating a prior glide path with hand instruments. Along with reciprocating kinematics, the thermal treatment of the NiTi alloy used in Reciproc Blue instruments has been linked to an improved performance regarding cyclic fatigue resistance (17, 24, 25) and in the angular rotation to fracture (26) when compared with M-Wire Reciproc instruments, which may result in a lower incidence of fractures. Taken together, these conditions may explain the absence of instrument fractures in this study.

One may argue that when a size 10 K-file was taken to the WL, a glide path may have been created. However, as previously reported, a true glide path implies an active shaping procedure in which the root canal cross section should be bigger than the tip of the first NiTi rotary instrument used (1, 2). Thus, an enlargement of the root canal should be provided to at least a size 15 or 20 in order to consider a smooth glide path creation for mechanical instrumentation. In the current study, a size 10 K-file was used passively during WL determination, which does not characterize a glide path procedure.

The present results also showed that a size 10 K-file, taken passively during WL determination, was not able to reach the full WL in 50 root canals. Of these 50 canals, Reciproc Blue R25 instruments were able to reach the full WL in 47 of them. Therefore, it shows a great scouting ability of Reciproc Blue R25 instruments, even in cases in

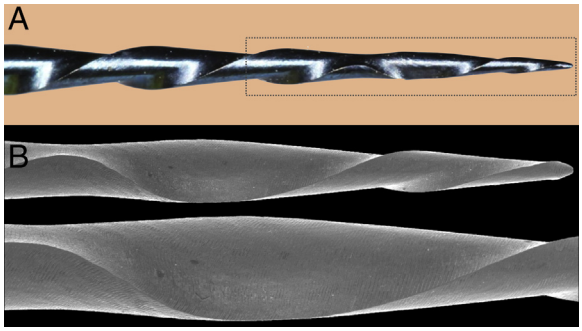


**Figure 1.** (*A*) A photograph of the single deformed Reciproc Blue R25 instrument. (*B*) A scanning electron microscopic image of the deformed Reciproc Blue R25 instrument.

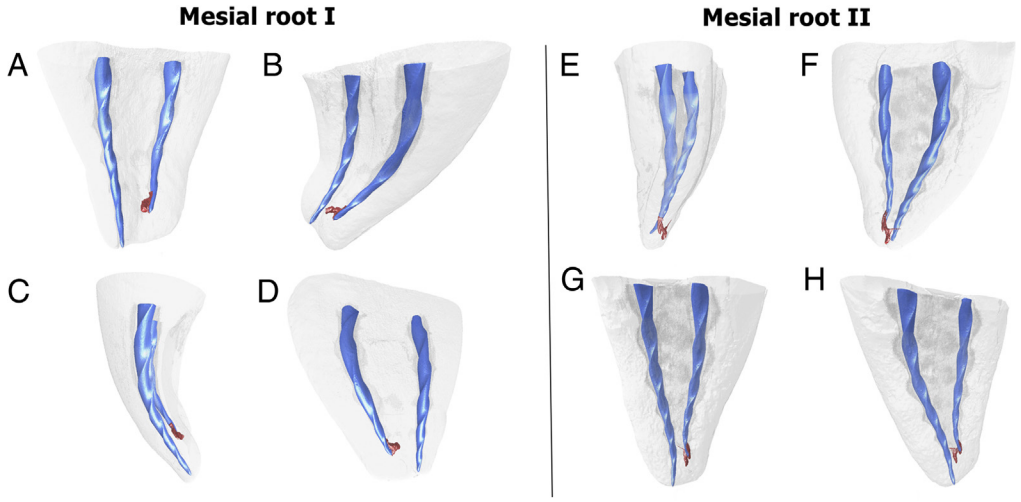


**Figure 2.** Three-dimensional micro-CT images of Reciproc Blue R25 instruments inside 2 mesial roots. Mesial root I: the Reciproc Blue R25 instrument was able to reach the full WL in the mesiobuccal canal, whereas it could not reach the full WL in the mesiolingual canal. (*A*) The distal view of the root showing an abrupt paraforaminal exit. (*B* and *C*) Lateral views showing an abrupt exit of the apical foramen to the distal face of the root. (*D*) The mesial view of the root. Mesial root II: the Reciproc Blue R25 instrument was able to reach the full WL in the mesiobuccal canal, whereas it could not reach the full WL in the mesiolingual canal. (*E*) The lateral view showing an abrupt curvature of the apical foramen exiting to the mesial face of the root. (*F*) The mesial view of the root showing the foraminal exit. (*G* and *H*) Distal views showing the apical foramen exiting to the mesial face of the root.

which a size 10 K-file was not able to reach the full WL. This outcome makes root canal enlargement a less sensitive procedure when compared with the technically demanding glide path procedure, rendering the shaping a more predictable and less prone to error transoperative step. This has been proved in previous studies, which showed a lower risk of accidents during canal preparation with reciprocating instruments, even when performed by undergraduate students (27, 28). Moreover, it seems that operator experience does not influence the defect rates of reciprocating instruments (27).

In the current study, the influence of the type of electric motor (conventional corded or cordless) on the instrument's performance was also evaluated. In theory, both motors should perform similarly, and this is what the manufacturer claims. However, the cordless motor is based on a completely new technology in the framework of endodontic electric motors that has never been tested before. Therefore, this cordless technology was tested to confirm that it has no impact in the motor performance and, thus, in the efficiency of the instrument in RFWL. Because the frequency of RFWL and NRFWL was exactly the same for both electric motors, the second tested hypothesis was also accepted.

During the study of the frequency of a given event in a population, a control group is not necessarily required. For instance, in the present study, a chi-squared statistical procedure was enough to certify the significance of the observed frequency. Thus, no control group was included because the main purpose of this study was limited to observe the frequency in which Reciproc Blue R25 instruments were able to reach the full WL of mandibular canals without a glide path when the selection of the Reciproc Blue instruments is based on an adequate preoperative radiograph according to the manufacturer's recommendation.

The 4 teeth in which the full WL was not reached were scanned in a micro-CT device, and 3-dimensional image analysis showed that 2 of them presented peculiar anatomic characteristics (apexes terminating in extreme abrupt paraforaminal exits); no apparent reasons were found to explain why Reciproc Blue R25 instruments did not reach the full WL in the other 2 cases (Fig. 2). It is important to emphasize that in cases in which the instruments were not able to reach the full WL by observation of considerable resistance, the procedures were stopped after 3 trials to go toward the apex. It is possible that if the negotiation procedures were continued in these 2 cases, the full WL could have been reached.

## Conclusions

Reciproc Blue R25 instruments were able to reach the full WL in a high frequency of cases. The type of electric motor used did not interfere in the frequency of RFWL. No instrument fractured, and a single file deformed.

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*The authors deny any conflicts of interest related to this study.*

## References

1. West JD. The endodontic Glidepath: "secret to rotary safety". Dent Today 2010;29:90–3.
2. Ruddle CJ, Machtou P, West D. Endodontic canal preparation: new innovations in glide path management and shaping canals. Dent Today 2014;33:1–7.
3. Berutti E, Negro AR, Lendini M, Pasqualini D. Influence of manual preflaring and torque on the failure rate of ProTaper rotary instruments. J Endod 2004;30:228–30.
4. Berutti E, Cantatore G, Castellucci A, et al. Use of nickel-titanium rotary PathFile to create the glide path: comparison with manual preflaring in simulated root canals. J Endod 2009;35:408–12.
5. Patiño PV, Biedma BM, Liébana CR, et al. The influence of a manual glide path on the separation rate of NiTi rotary instruments. J Endod 2005;31:114–6.
6. Pasqualini D, Bianchi CC, Paolino DS, et al. Computed micro-tomographic evaluation of glide path with nickel-titanium rotary PathFile in maxillary first molars curved canals. J Endod 2012;38:389–93.
7. D'Amario M, Baldi M, Petricca R, et al. Evaluation of a new nickel-titanium system to create the glide path in root canal preparation of curved canals. J Endod 2013;39:1581–4.

8. De-Deus G, Moreira EJ, Lopes HP, Elias CN. Extended cyclic fatigue life of F2 ProTaper instruments used in reciprocating movement. Int Endod J 2010;43:1063–8.
9. De-Deus G, Arruda TE, Souza EM, et al. The ability of the Reciproc R25 instrument to reach the full root canal working length without a glide path. Int Endod J 2013;46:993–8.
10. Kiefner P, Ban M, De-Deus G. Is the reciprocating movement per se able to improve the cyclic fatigue resistance of instruments? Int Endod J 2014;47:430–6.
11. Silva EJ, Sa L, Belladonna FG, et al. Reciprocating versus rotary systems for root filling removal: assessment of the apically extruded material. J Endod 2014;40:2077–80.
12. Saber SE, Nagy MM, Schafer E. Comparative evaluation of the shaping ability of WaveOne, Reciproc and OneShape single-file systems in severely curved root canals of extracted teeth. Int Endod J 2015;48:109–14.
13. Yared G. Canal preparation using only one Ni-Ti rotatory instrument: preliminary observations. Int Endod J 2008;41:339–44.
14. Zuolo ML, Carvalho MC, De-Deus G. Negotiability of second mesiobuccal canals in maxillary molars using a reciprocating system. J Endod 2015;41:1913–7.
15. Rodrigues E, De-Deus G, Souza E, Silva EJ. Safe mechanical preparation with reciprocation movement without glide path creation: result from a pool of 673 root canals. Braz Dent J 2016;27:22–7.
16. Bartols A, Robra BP, Walther W. The ability of Reciproc instruments to reach full working length without glide path preparation: a clinical retrospective study. PeerJ 2017;19:e3583.
17. De-Deus G, Silva EJ, Vieira VT, et al. Blue thermomechanical treatment optimizes fatigue resistance and flexibility of the Reciproc files. J Endod 2017;43:462–6.
18. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271–5.
19. De-Deus G, Belladonna FG, Souza EM, et al. Scouting ability of 4 pathfinding instruments in moderately curved molar canals. J Endod 2016;42:1540–4.
20. Pedullà E, Grande NM, Plotino G, et al. Influence of continuous or reciprocating motion on cyclic fatigue resistance of 4 different nickel-titanium rotary instruments. J Endod 2013;39:258–61.
21. Tokita D, Ebihara A, Miyara K, Okiji T. Dynamic torsional and cyclic fracture behavior of profile rotary instruments at continuous or reciprocating rotation as visualized with high-speed digital video imaging. J Endod 2017;43:1337–42.
22. You SY, Bae KS, Baek SH, et al. Lifespan of one nickel-titanium rotary file with reciprocating motion in curved root canals. J Endod 2010;36:1991–4.
23. Plotino G, Grande NM, Porciani PF. Deformation and fracture incidence of Reciproc instruments: a clinical evaluation. Int Endod J 2015;48:199–205.
24. Topçuoğlu HS, Topçuoğlu G. Cyclic fatigue resistance of Reciproc Blue and Reciproc files in an s-shaped canal. J Endod 2017;43:1679–82.
25. Silva EJ, Vieira VT, Gabina TT, et al. The impact of using a pneumatic contra-angle device on the lifespan of M-Wire- and Blue-treated instruments. Clin Oral Investig 2018 [Epub ahead of print].
26. Silva EJ, Hecksher F, Antunes HD, et al. Torsional fatigue resistance of blue-treated reciprocating instruments. J Endod 2018;44:1038–41.
27. Shen Y, Coil JM, Mo AJ, et al. WaveOne rotary instruments after clinical use. J Endod 2016;42:186–9.
28. Caballero-Flores H, Nabeshima CK, Binotto E, Machado ME. Fracture incidence of instruments from a single-file reciprocating system by students in an endodontic graduate programme: a cross-sectional retrospective study. Int Endod J 2018 [Epub ahead of print].