Lifespan of One Nickel-Titanium Rotary File with Reciprocating Motion in Curved Root Canals

Sung-Yeop You, DDS, Kwang-Shik Bae, DDS, PhD, Seung-Ho Baek, DDS, PhD, Kee-Yeon Kum, DDS, PhD, Won-Jun Shon, DDS, PhD, and WooCheol Lee, DDS, PhD

Abstract

Introduction: The purpose of this study was to examine the lifespan of one nickel-titanium (NiTi) rotary file when used in reciprocating motion and to compare the time required for its preparation of a curved root canal using both reciprocating and continuous motion. **Methods:** One hundred twenty curved canals from 60 extracted maxillary and mandibular molars were selected for measuring the mean number of uses. Each canal was prepared with reciprocating motion until the ProTaper F2 single file (Dentsply Maillefer, Ballaigues, Switzerland) reached the working length. One file was used until it was fractured. Another 60 canals were divided into two groups. 30 canals in the continuous rotation motion (CM) group were prepared using continuous rotation following the sequence of ProTaper files, whereas the canals in the reciprocating motion (RM) group ($n = 30$) were prepared with reciprocating motion with the sole use of the ProTaper F2. The total root canal preparation time was measured until the F2 file finally reached the working length in both groups. **Results:** A total of 11 files were used in the preparation of 120 curved root canals. The average lifespan of one F2 file was 10.60 $\pm$ 4.35 canals with the longest lifespan of 21 canals. The total time for canal preparation was 46.42 $\pm$ 18.12 seconds and 21.15 $\pm$ 6.70 seconds in the CM and RM groups, respectively. There was a statistically significant difference between the groups ($p < 0.01$). **Conclusion:** Within the limitation of this study, one F2 file can be safely used to the working length of curved canals at least six times under reciprocating motion. Reciprocating preparation with only one F2 file was much faster than root canal instrumentation with continuous rotation. *(J Endod 2010;36:1991–1994)*

Key Words

Curved root canal, file fracture, lifespan, nickel-titanium file, reciprocating motion

One of the goals of endodontic treatment is thorough cleaning and shaping of the root canal system by removing all the infected pulp tissue, bacteria, and their by-products (1, 2). Nickel-titanium (NiTi) rotary instruments are commonly used for this purpose. The NiTi rotary file has induced a significant progress in endodontic treatment because of its flexibility and high cutting efficiency (3–5). With the instrument placed in the center of the root canal, it has become possible to produce a more rounded and tapered funnel-shaped canal while reducing the incidence of procedural accidents such as transportation and ledge formation (6, 7). Furthermore, NiTi files prepare canals easily and rapidly with minimal straightening (8).

Despite these advantages, the biggest problems of NiTi files are their high cost and unexpected instrument fracture (4, 9). The high cost of NiTi files has forced many clinicians to reuse them, which, in turn, leads to a higher incidence of instrument fracture. A recent retrospective study (10) showed that most file fractures occurred in curved root canals, especially in the mandibular molars.

There have been several studies regarding the frequency of instrument fracture, leading to the continuous improvement of preparation techniques and instrument design in hopes of reducing such accidents during root canal instrumentation (11–13). In this regard, the employment of reciprocating motion instead of the conventional continuous rotation method has been suggested to be advantageous in the preparation of curved canals with the use of one single NiTi file (14). However, it was a single case report of one operator, and there were no well-controlled comparisons with any existing methods.

Therefore, the purpose of this study was to examine the lifespan of one NiTi rotary file when it was used in reciprocating motion. The efficiency of reciprocating motion was also compared with continuous rotation in terms of the time that would be required for the preparation of a curved root canal.

Material and Methods

Preparation of the Tooth

The buccal canals of maxillary molars and the mesial roots of mandibular molars of 90 teeth were used in this study. The curvature of each canal was measured using the method described by Schneider (15), and the canals with curvatures of 20° to 45° were used in the experiment. The access cavities were made with #330 burs, and the working lengths were determined as follows. A #10 K-file was inserted into the root canal until the tip of the file was flush with the apical foramen. From that point, 1 mm was subtracted, and that length was defined as the working length of the root canal. After the working length was determined, a glide path was produced using a #15 K-file.

From the Department of Conservative Dentistry, School of Dentistry and Dental Research Institute, Seoul National University, Seoul, Korea.

Address requests for reprints to Dr WooCheol Lee, Department of Conservative Dentistry, School of Dentistry, Dental Research Institute, Seoul National University, 275-1 Yeongeon-Dong, Jongno-Gu, Seoul, Republic of Korea 110-768. E-mail address: jimin525@snu.ac.kr.

0099-2399/$ - see front matter

doi:10.1016/j.joen.2010.08.040

The Mean Number of Uses in Reciprocating Motion

One hundred twenty canals from 60 of the extracted maxillary and mandibular molars were selected. Each canal was prepared with reciprocating motion (clockwise 140° and counterclockwise 45°) using the Tecnika digital motor (ATR, Pistoia, Italy) until a ProTaper F2 single file (Dentsply Maillefer, Ballaigues, Switzerland) reached the working length. One F2 file was used until it was fractured or deformed, after which it was replaced with a new file. All the root canals were prepared by one single operator. The fractured files were examined under the scanning electron microscope (SEM) (Hitachi S-4700; Hitachi, Tokyo, Japan) at magnifications of ×30; ×200; ×1,000; ×2,000; and ×5,000 for disclosing the fracture mechanism.

Total Preparation Time and Frequency of File Separation

Another 60 canals from 30 of the extracted maxillary and mandibular molars were divided randomly into two groups: the continuous rotation motion (CM) group and the reciprocating motion (RM) group. The canals in the CM group (n = 30) were prepared using continuous rotation following the sequence of ProTaper S1->SX->S1->S2->F1->F2, whereas the canals in the RM group (n = 30) were prepared with reciprocating motion with the sole use of the ProTaper F2. RC-Prep (Premier Dental Products, Norristown, PA) was used in all canal preparations, and canal irrigation was performed with 3.5% NaOCl after the use of each file. A new file was used with each tooth, and after its use, each file was examined to determine whether there was any deformation or fracture.

The total root canal preparation time was measured until the F2 file finally reached the working length, excluding the time it took to change files and irrigate the canals. The results were statistically analyzed using the Student t test.

Results

The Mean Number of Uses in Reciprocating Motion

A total of 11 F2 files were used in the preparation of 120 curved root canals. The average lifespan of one F2 file was 10.60 ± 4.35 canals. The longest lifespan of a single F2 file was 21 canals, and the shortest one was 6 canals (Table 1). When observing the longitudinal view of the fractured file under the SEM, all files had undergone flexural fracture without any deformation (Fig 1). However, the cross-sectional aspect of the fractured area showed a mixture of cracks, fatigue striations, and dimples (Fig 2).

TABLE 1. The Usage Number of All Files in Reciprocating Motion

Instrument	Number of Uses
1	13
2	8
3	14
4	21
5	8
6	9
7	9
8	9
9	6
10	9
11	4*
Total	110†

*Instrument #11 was not separated during the completion of 120 canals. Therefore, the lifespan of this file was not included in data analysis.

†Canals in which files were separated were not counted (10 canals in total).

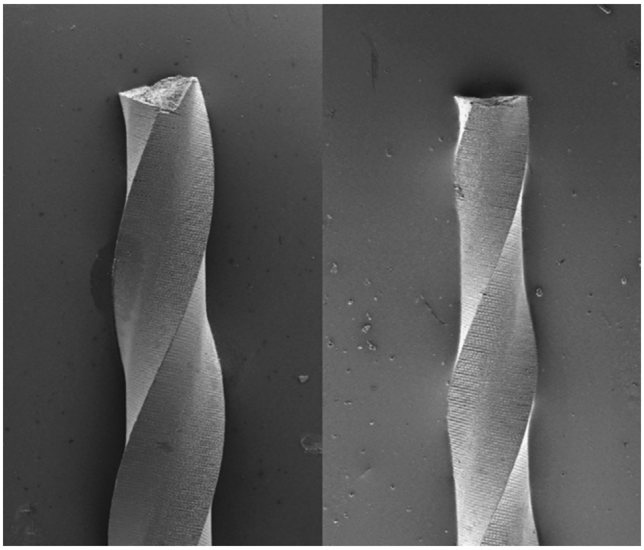

Figure 1. The longitudinal scanning electron microscopic view without any flute deformation around the fracture point (×30).

The Total Preparation Time and Frequency of File Separation

The total time for canal preparation in CM group was 46.42 ± 18.12 seconds, and the total time for canal preparation in RM group was 21.15 ± 6.70 seconds. There was a statistically significant difference between the two groups ($p < 0.01$). Statistical analysis using the Mann-Whitney U test showed no significant difference ($p > 0.05$) in canal curvature between the CM group (28.33° ± 7.63°) and the RM group (31.00° ± 19.20°). Neither deformation nor fracture of the NiTi files was observed in both groups.

Discussion

During the root canal preparation, two or more NiTi rotary files have been used sequentially or in combination according to their shaping characteristics. When using a series of NiTi files, certain files bear more stress than others. For this reason, it is not possible to measure the lifespan of a certain file that reaches the full working length with completion of the root canal preparation. So far, apart from the recommendations to discard the NiTi file when it undergoes deformation or when the operator becomes instinctively insecure about the state of the file, there have been no reports on the fracture incidence of certain types of NiTi files. Therefore, this was the first study determining the lifespan of one master apical size NiTi file that goes to the working length.

The data showed that the longest lifespan of single ProTaper F2 files with reciprocating motion was 21 canals with a mean lifespan of 10.60 canals. In this regard, Shen et al (16) reported on the mean lifespan of ProTaper files from two clinics. To our surprise, the result from one clinic showed that an average of 16.88 canals were prepared with one set of ProTaper files. However, it should be taken into consideration that the teeth included in their study were not limited to only molars. The data from other clinic in their same study revealed that only 2.83 molar cases were safely instrumented with sequential use of 6 ProTaper files. These results showed dramatic differences between uses in curved canals and in straight canals as well as the short lifespan of files in curved canals.

In this study, the minimum extent of ProTaper F2 usage before fracture was after six canal preparations, and this result seems to be

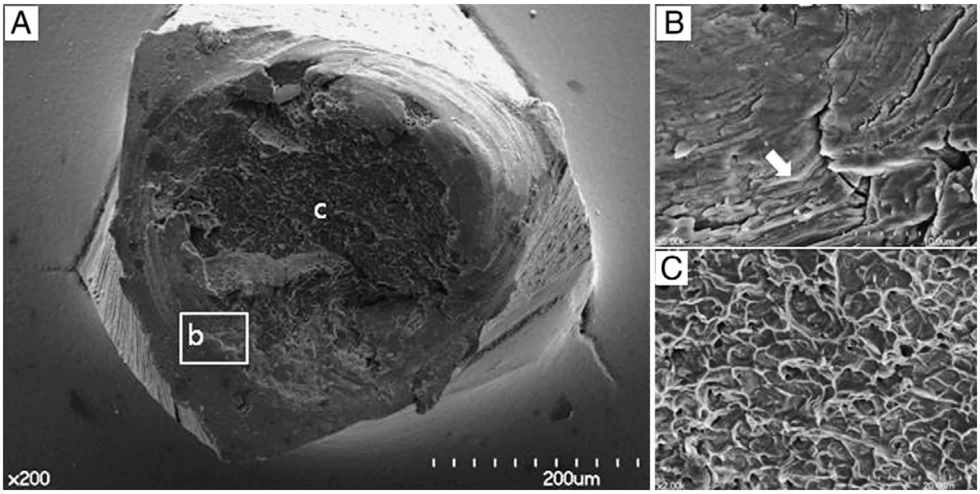

Figure 2. (*A*, ×200) Scanning electron microscopic image of the fracture surface. A high-magnification view of the area b (*box*) shows fatigue striations (*white arrow*) and cracks (*B*, ×5,000). The central area (*C*) shows dimples (*C*, ×2,000).

consistent with Peters et al (17) who suggested that ProTaper files should be thrown away after being used in four to five constricted canals. According to another recent study (18), the lifespan of the ProTaper files was found to be 10 canals when they were used in sequence under continuous rotation, whereas these ProTaper files could be used in up to 13 canals without fracture when reciprocating motion was employed. Among the files used in their experiment, F2 files were shown to be reused in up to 10 canals without fracture under reciprocating motion, and this result was similar to our study in which the mean lifespan of the ProTaper F2 was 10.60 canals. Because no coronal flaring with shaping series of ProTaper file was performed in this study, it would be unwise to compare these results directly. However, considering that the same lifespan was obtained without any help of other sequential files, the results of this study would appear to be extremely favorable in this regard.

When comparing the number of files needed in canal preparation, Varela-Patino et al (18) showed that a total of 23 ProTaper file series were needed to prepare 60 canals with reciprocating motion, and a total of 30 ProTaper file series were needed to prepare 60 canals under continuous rotation motion. In this study, only 11 F2 files were used to prepare 120 canals, and this was a big reduction in the number of files necessary to instrument to the working length. Furthermore, this is in contrast to one's expectations that when using only one master apical size rotary file for the preparation of the entire root canal system, the stress exerted on this NiTI file should easily fracture it (19). These results can be explained by two reasons. First, the torsional stress was reduced by using reciprocating motion. Reciprocating motion prevents the taper lock phenomenon by unsymmetrical repeating of the clockwise and counterclockwise rotations (14, 18). As a result, it reduces torsional fracture, allowing us to understand how reciprocating motion shows better results compared with continuous rotation. The other reason is that the file used in this study was a ProTaper file. ProTaper files are known to resist torsional fracture by uniformly distributing the stress exerted on it (20). However, further research is needed to evaluate not only the stress distribution in other types of files under reciprocating motion but also the cleaning and shaping ability of a single file with reciprocating motion.

Considering the efficiency of reciprocating motion, the total time taken for canal preparation in the RM group was half of that in the CM group. We noted a drastic reduction in the time needed for the preparation of curved canals to the working length with only one master apical size file under the reciprocating motion. This suggests that the reciprocating motion is superior not only in its mean lifespan but also in its cutting efficiency, which is ultimately expected to reduce the operator's fatigue.

According to a report by Sattapan et al (21), fracture of NiTi files occurs in one of two ways: flexural and torsional failure. Flexural fracture occurs because of repeated compression and tension in curved canal. Torsional fracture occurs when binding occurs at a part of the file other than the tip. In the clinical situation, both torsional stress and cyclic fatigue are exerted on files within the root canal, and these two forces influence each other. In fact, NiTi files exposed to torsional stress are prone to fracture at a lower cyclic fatigue (22), and torsional resistance decreases in used files (23). Therefore, these two aspects of file fracture can be simultaneously observed when the cross-sectional area of the fractured file was examined under the SEM (24).

In the present study, dimples, which are representative of a ductile fracture, were observed on one side of the files, whereas cracks and fatigue striations, which are representative of brittle fracture, were observed on the other side. This indicates that even though reciprocating motion was applied to the ProTaper F2 file in this study, the character of file fractures was the result of the combined effect of torsional stress and cyclic fatigue as was observed in other file fractures under continuous rotation.

There can be two possible methods by which we can reduce the torsional fracture of NiTi files. The first method is to use a NiTi file that is more resistant to torsional stress. The NiTi files on the market undergo several tests related to cyclic fatigue and torsional resistance. Of course, those values could show a difference when the files are applied to curved root canals, but they do help with the understanding of the files' basic characteristics. The problem in choosing NiTi files that have a high torsional resistance in most cases is that the cyclic fatigue value and the torsional resistance value are inversely proportional (4, 25). In this regard, Ullmann and Peters (25) reported that larger instruments that have been subjected to some cyclic fatigue should be used with great care or discarded.

The other method for preventing file fracture is to reduce torsional stress in the process of canal preparation. For this purpose, preflaring and the crown-down preparation have been suggested (9). These methods have been known to not only decrease the occurring torsional stress but also shifts the area on which the stress is exerted on (from the tip to the body of the file), further reducing any torsional stress. As it was reported by other studies (14, 18) and reconfirmed in this study, reciprocating motion reduces torsional stress by preventing binding of the file, thereby raising expectations that files could be used longer without fracture.

In conclusion, within the limitation of this study, one F2 file can be safely used to the working length of curved canals at least 6 times under reciprocating motion without any help of other ProTaper files such as SX, S1, S2, and F1. Reciprocating preparation with only one F2 file was much faster than root canal instrumentation with continuous rotation.

References

1. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am 1974;18:269–96.
2. Chugal NM, Clive JM, Spangberg LS. Endodontic infection: some biologic and treatment factors associated with outcome. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:81–90.
3. Gambarini G. Advantages and disadvantages of new torque-controlled endodontic motors and low-torque NiTi rotary instrumentation. Aust Endod J 2001;27:99–104.
4. Pruett JP, Clement DJ, Carnes DL Jr. Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod 1997;23:77–85.
5. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of nitinol root canal files. J Endod 1988;14:346–51.
6. Short JA, Morgan LA, Baumgartner JC. A comparison of canal centering ability of four instrumentation techniques. J Endod 1997;23:503–7.
7. Glosson CR, Haller RH, Dove SB, et al. A comparison of root canal preparations using Ni-Ti hand, Ni-Ti engine-driven, and K-Flex endodontic instruments. J Endod 1995;21:146–51.
8. Schafer E, Schulz-Bongert U, Tulus G. Comparison of hand stainless steel and nickel titanium rotary instrumentation: a clinical study. J Endod 2004;30:432–5.
9. Roland DD, Andelin WE, Browning DF, et al. The effect of preflaring on the rates of separation for 0.04 taper nickel titanium rotary instruments. J Endod 2002;28:543–5.
10. Iqbal MK, Kohli MR, Kim JS. A retrospective clinical study of incidence of root canal instrument separation in an endodontics graduate program: a PennEndo database study. J Endod 2006;32:1048–52.
11. da Silva FM, Kobayashi C, Suda H. Analysis of forces developed during mechanical preparation of extracted teeth using RaCe rotary instruments and ProFiles. Int Endod J 2005;38:17–21.
12. Shen Y, Cheung GS, Bian Z, et al. Comparison of defects in ProFile and ProTaper systems after clinical use. J Endod 2006;32:61–5.
13. Parashos P, Gordon I, Messer HH. Factors influencing defects of rotary nickel-titanium endodontic instruments after clinical use. J Endod 2004;30:722–5.
14. Yared G. Canal preparation using only one Ni-Ti rotary instrument: preliminary observations. Int Endod J 2008;41:339–44.
15. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271–5.
16. Shen Y, Haapasalo M, Cheung GS, et al. Defects in nickel-titanium instruments after clinical use. Part 1: relationship between observed imperfections and factors leading to such defects in a cohort study. J Endod 2009;35:129–32.
17. Peters OA, Peters CI, Schonenberger K, et al. ProTaper rotary root canal preparation: assessment of torque and force in relation to canal anatomy. Int Endod J 2003;36:93–9.
18. Varela-Patino P, Ibanez-Parraga A, Rivas-Mundina B, et al. Alternating versus continuous rotation: a comparative study of the effect on instrument life. J Endod 2010;36:157–9.
19. Varela-Patino P, Biedma BM, Liebana CR, et al. The influence of a manual glide path on the separation rate of NiTi rotary instruments. J Endod 2005;31:114–6.
20. Berutti E, Chiandussi G, Gaviglio I, et al. Comparative analysis of torsional and bending stresses in two mathematical models of nickel-titanium rotary instruments: ProTaper versus ProFile. J Endod 2003;29:15–9.
21. Sattapan B, Nervo GJ, Palamara JE, et al. Defects in rotary nickel-titanium files after clinical use. J Endod 2000;26:161–5.
22. Galvao Barbosa FO, Ponciano Gomes JA, Pimenta de Araujo MC. Influence of previous angular deformation on flexural fatigue resistance of K3 nickel-titanium rotary instruments. J Endod 2007;33:1477–80.
23. Bahia MG, Melo MC, Buono VT. Influence of simulated clinical use on the torsional behavior of nickel-titanium rotary endodontic instruments. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101:675–80.
24. Wei X, Ling J, Jiang J, et al. Modes of failure of ProTaper nickel-titanium rotary instruments after clinical use. J Endod 2007;33:276–9.
25. Ullmann CJ, Peters OA. Effect of cyclic fatigue on static fracture loads in ProTaper nickel-titanium rotary instruments. J Endod 2005;31:183–6.