COMPARISON OF SCREW-IN EFFECT FOR SEVERAL NICKEL-TITANIUM ROTARY INSTRUMENTS IN SIMULATED RESIN ROOT CANAL

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ABSTRACT

Screw-in effect is one of the unintended phenomena that occurs during the root canal preparation with nickel-titanium rotary files. The aim of this study was to compare the screw-in effect among various nickel-titanium rotary file systems.

Six different nickel-titanium rotary instruments (ISO 20/.06 taper) were used: K3™ (SybronEndo, Glendora, CA, USA), M_{two} (VDW GmbH, München, Germany), NRT with safe-tip and with active tip (Mani Inc., Shioya-gun, Japan), ProFile® (Dentsply-Maillefer, Ballaigues, Switzerland) and ProTaper® (Dentsply-Maillefer, Ballaigues, Switzerland). For ProTaper®, S2 was selected because it has size 20. Root canal instrumentations were done in sixty simulated single-curved resin root canals with a rotational speed of 300 rpm and single pecking motion. A special device was designed to measure the force of screw-in effect. A dynamometer of the device recorded the screw-in force during simulated canal preparation and the recorded data was stored in a computer with designed software (LCV-USE-VS, Lorenz Messtechnik GmbH, Alfdorf, Germany). The data were subjected to one-way ANOVA and Tukey's multiple range test for post-hoc test. P value of less than 0.05 was regarded significant.

ProTaper® produced significantly more screw-in effects than any other instruments in the study ($p < 0.001$). K3™ produced significantly more screw-in effects than M_{two}, and ProFile® ($p < 0.001$). There was no significant difference among M_{two}, NRT, and ProFile® ($p > 0.05$), and between NRT with active tip and NRT with safe one neither ($p > 0.05$).

From the result of the present study, it was concluded, therefore, that there seems significant differences of screw-in effect among the tested nickel-titanium rotary instruments. The radial lands and rake angle of nickel-titanium rotary instrument might be the cause of the difference. [J Kor Acad Cons Dent 35(4):267-272, 2010]

Key words: Dynamometer, Nickel-titanium rotary file, Screw-in effect, Simulated resin root canal

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Ⅰ. Introduction

The objective of root canal preparation is to clean and shape the root canal system, while maintaining the original configuration. After root canal preparation, the canal shape needs to be a continuously tapering, conical, funnel-shaped canal with the smallest diameter at the end-point and the largest at the orifice.[1)]

During the late 1980s and 1990s, various types of endodontic instruments were developed with nickel-titanium alloys to effectively achieve the above mentioned objective of root canal preparation. Walia *et al.*[2)] initially investigated the endodontic files fabricated from nickel-titanium blanks. They found that, due to the low modulus of elasticity, nickel-titanium

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files have two to three times more elasticity than stainless steel files. Reports on the efficacy and shaping ability of nickel-titanium rotary files have demonstrated their potential for root canal treatment.[3-6] Nickel-titanium instruments have a decreased tendency for canal transportation and therefore remain better centered.[7] Most studies have expected that these new instruments may enhance endodontic treatment with respect to both its quality and speed.

On the other hand, there are some behavioral aspects that operators need to understand in nickel-titanium rotary instrumentation. Tendency to screw into the canal is one of them. This phenomenon is accentuated during root canal preparation especially when continuously rotating nickel-titanium instruments are used. Because rotary instrumentation lacks tactile sense, control of the working length is more difficult during rotary instrumentation than hand instrumentation. For this reason, the screw-in effect during rotary instrumentation may cause overinstrumentation beyond the apical foramen. Undoubtedly instrumentation beyond the apical foramen reduces the success rate.[8-11)]

Gutierrez *et al.*[12] using scanning electron microscopy, found that overinstrumentation of root canals of human teeth provoked different types of apical cementum perforations and/or the production of zipping. By chance, many root canals can be inadvertently prepared beyond the apical foramen, which can be deleterious to the periapical tissues to heal in teeth with infected canal. Bacteria must have been pushed out of the foramen whenever a file penetrated the apex of an infected root canal. If bacteria and dentinal chips on the flutes of the files are pushed out of the main foramen, they may remain in the periapical tissues when the instrument is withdrawn from the root canal. Bacteria were seen attached firmly on the dimples of the resorptive lacunae, which correspond to inflammatory resorption of the root.[13] Histopathological studies demonstrated overinstrumentation may cause persisting inflammatory response and postoperative pain or trigger a foreign body reaction.[14,15] The high percentage of bacteria in the flutes of files used in overinstrumented human teeth with infected root canals carry a potential risk for postoperative pain, clinical discomfort and flare-ups.

Because the screw-in effect of nickel-titanium rotary instruments may cause these overinstrumentation-induced side effect, the screw-in effect of each rotary instruments needs to be evaluated. Therefore, the aim of this study was to compare the screw-in effect among several nickel-titanium rotary file systems.

Ⅱ. Materials and methods

Sixty simulated resin root canals in clear resin blocks (REF A 0177, Dentsply-Maillefer, Ballaigues, Switzerland) were used, which have 34 to 35 degree curves and a mean canal length of 18 mm. They were divided into 6 groups according to the instrument used. Nickel-titanium rotary file systems were K3™ (SybronEndo, Glendora, CA, USA), M_{two} (VDW GmbH, München, Germany), NRT with safe-tip and one with active tip (Mani Inc., Shioya-gun, Japan), ProFile® (Dentsply-Maillefer, Ballaigues, Switzerland) and ProTaper® (Dentsply-Maillefer, Ballaigues, Switzerland) (Table 1). To have the same taper and tip size of the instrument, instruments with taper of 0.06 and size 20 were selected for each system. For ProTaper®, S2 was selected because it has size 20. All canals were prepared using a reduction speed contra-angle with an electric motor (SurgiMotor II, Aseptico Co., Woodinville, WA, USA). Ten canals were prepared in each group using a constant speed of 300 rpm. The contra-angle handpiece was mounted on the newly designed device and single pecking movement was generated. The depth of penetration each time was 1.0 mm from the first point that the file met the canal wall.

1. Measurement of screw-in force

The measuring device (Figure 1) was designed so that the axial stress induced by a pecking movement causes raising of the resin blocks. The instruments were automatically introduced into the canal to contact the walls of the simulated canals and the blades cut the canal wall. The stress amplitudes were very low because machining load for this type of material

Table 1. Characteristic of the nickel-titanium rotary systems used in the study

System	Manufacturer	Characteristics
K3™	SybronEndo, Glendora, CA, USA	Asymmetrically radial lands and unequal width
		Slightly positive rake angle
		Unequal flute width and depth
		Variable helical angle
Mtwo	VDW GmbH, München, Germany	Sharp blade
		Negative rake angle
		Progressive pitch
		Variable helical angle
NRT files	Mani Inc., Shioya-gun, Japan	Radial land
		Quasi-rectangular cross-section
		Negative rake angle
		Constant helical angle and pitch
ProFile®	Dentsply-Maillefer, Ballaigues, Switzerland	Three equal radial lands
		U-shaped grooves around the shaft
		Negative rake angle at the cutting edge
		Constant helical angle and pitches
ProTaper®	Dentsply-Maillefer, Ballaigues, Switzerland	Sharp blade
		Convex triangular cross-section,
		Negative rake angle
		Variable helical angle and pitches

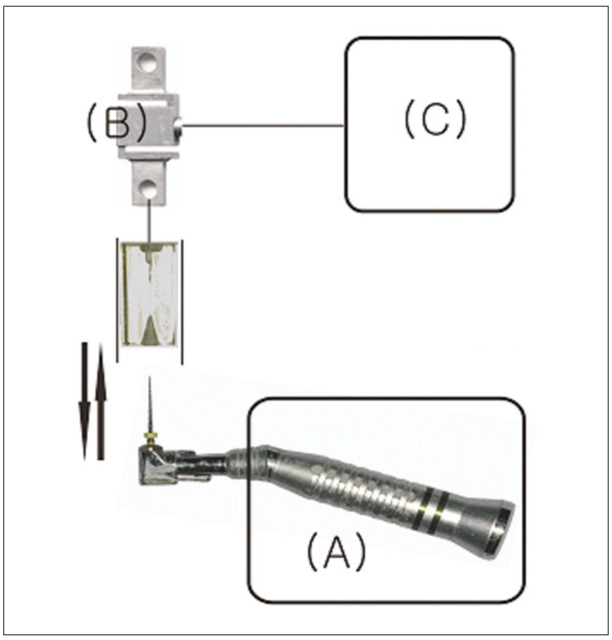

Figure 1. Custom-made device for the measurement of the screw-in effect. (A) A part generating a single pecking movement with a constant speed of 300 rpm, (B) Compression/Tension sensor, (C) Computer (data storage, analysis).

are negligible. When the instruments are withdrawn after a pecking movement, there occurs a force against it, which resists the withdrawal of the instrument from the root canal. This resistance force was measured by the device. The dynamometer (K1368-10N, Lorenz Messtechnik GmbH, Alfdorf, Germany) in the device recorded the transmitted force in mA. The generated signals (mA) were amplified with Sensor-interface with USB (LCV-USB, Lorenz Messtechnik GmbH, Alfdorf, Germany) and transferred to the computer software. The transferred signals were recorded with a software (LCV-USE-VS, Lorenz Messtechnik GmbH, Alfdorf, Germany).

2. Statistical analysis

The data on the forces were analyzed using one-way ANOVA to determine the difference between groups (SPSS 13.0). Tukey's multiple range test was also carried out for a post-hoc test. P value of less than 0.05 were regarded significant.

Table 2. Screw-in force (N, Mean ± S.D.)

Groups	N	Screw-in Force	
K3™	10	1.37 ± 0.19	b
M_{two}	10	0.43 ± 0.22	a
NRT-active tip	10	0.97 ± 0.24	a, b
NRT-safe tip	10	1.00 ± 0.29	a, b
ProFile®	10	0.38 ± 0.18	a
ProTaper®	10	4.32 ± 1.08	c

a, b, c: The same letters are not significantly different by Tukey's multiple range test at the 0.05 level.

Ⅲ. Results

The screw-in force is shown in Table 2. ProTaper® produced significantly more screw-in effects than any other instruments in the study ($p < 0.001$). K3™ produced significantly more screw-in effects than M_{two} and ProFile® ($p < 0.001$).

There was no significant difference in screw-in effect among M_{two}, NRT, and ProFile® ($p > 0.05$). There was no significant difference between NRT with active tip and NRT with safe tip either ($p > 0.05$).

Ⅳ. Discussion

Some factors may influence on the tendency of screw-in. When continuously rotating mode is used, nickel-titanium instrument can screw into the root canal. Various parameters were suggested to limit the tendency to screw-in.[16] Constant pressure, slight pecking movement, controlled rotational speed and torque, and instrument cross-sectional design were included in these suggestions. Li *et al.*[17] recommended the use of a slow, continuous pecking movement to reduce stresses. They stated that a pecking motion may be a crucial factor in preventing the breakage of nickel-titanium rotary instrument. The pecking movement is intended to regularly disengage the instrument and allow the instrument to return to its normal state before continuing the preparation.[17] In this study, a pecking distance of 1 mm was used. This is a suggested distance by most of the manufacturers commonly in clinical situation. If constant pressure is applied, the instrument may be gradually screwed into the canal. However, when light force is applied, this phenomenon can be reduced.[18]

Various aspect of file design may affect screw-in effect. Every permanent rotating system has the tendency to screw into the canal. To overcome this problem, cutting edges of nickel-titanium rotary systems were flattened, modified, or shortened. ProFile® nickel-titanium rotary instruments have radial land. According to manufacturers, each instrument was designed to reduce the screw-in effect: the flattened edges of ProFile®, the modified edges of K3™, and the varying the taper of ProTaper®.

Screw-in effect is one of the draw-backs in nickel-titanium rotary instrumentation. To overcome or control this in the canal, the amount of the force needs to be evaluated in each instrument system. In the present study, some instruments showed significantly greater screw-in effect than others. Some instruments showed similar screw-in effect with others. This result may be needed for the clinician to know before choosing any instrument system for the rotary instrumentation. Also these information may alert the clinician to be careful not to overinstrumentate due to the screw-in effect during instrumentation. In the present study, six types of instruments were used. Their designs are different each other. Their designs may be taken into consideration for the explanation of the difference in their screw-in effect.

First, file systems in the study have different cross-sectional geometry. ProFile® and NRT have flat radial lands. M_{two} and ProTaper® have sharp blade. K3™ has unique asymmetrical radial land. Existence of flat radial lands may be related to reducing the screw-in effect. This finding is consistent with Oh *et al.*[19] They states that active file system with variable pitch and helical angle had more screw-in effect than passive file system. It seems that radial lands play more important role in reducing screw-in effect.

ProFile® and NRT have flat radial land and negative rake angle. M_{two} has sharp blade and negative rake angle, ProTaper® has sharp blade and positive rake angle while K3™ has unique asymmetrical radial land and slightly positive rake angle. Therefore, positive rake angle may be related to the screw-in effect.

Second, file systems in the study have different helical angles. The angle of the helix corresponds to the angle between the blades and the central axis of the instrument. ProFile® (26°), NRT (41°), K3™ (30°) files have constant helical angle, while ProTaper® (15°〈) and M_{two} (25°〈) files have variable helical angle. Therefore, there seems no significance with the helical angle in the study.

Third, files in the study have various pitch length. M_{two} file has the longest pitch length at apical 2 mm, followed by ProFile®, ProTaper®, NRT, and K3™. In this study, there seems no significance with pitch length.

Diemer and Calas[20] stated that a varying helical angle and a longer pitch may help in preventing screw-in. Their explanation was that a longer pitch reduces the helical angle, which in turn considerably reduces screw-in. Their explanation is inconsistent with the result in present study. But, they used one kind of Ni-Ti instrument (HERO, Micro-mega, Besancon, France) that have the same cross-sectional geometry and different pitch length.

From the result of the present study, it was concluded, therefore, that there was significant differences of screw-in effect among the tested nickel-titanium rotary instruments. The radial lands and rake angle of nickel-titanium rotary instrument might be the cause of the difference.

References

1. Schilder H. Cleaning and shaping the root canal. Dent Clin Nor Am 18:269-296, 1974.
2. Walia H, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 14:346-351, 1988.
3. Glosson CR, Haller RH, Dove SB, del Rio CE. A comparison of root canal preparations using nickel-titanium hand, nickel-titanium engine-driven, and K-flex endodontic instruments. J Endod 21:146-151, 1995.
4. Huh YJ, Kim SK. Change in root canal configuration using different file types and techniques. J Kor Acad Conserv Dent 22:291-304, 1997.
5. Park WK, Lee HJ, Hur B. Shaping ability of nickel-titanium rotary files. J Kor Acad Cons Dent 29(1):44-50, 2004.
6. Yun HH, Kim SK. A comparison of the shaping abilities of 4 nickel-titanium rotary instruments in simulated root canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 95:228-233, 2003.
7. Short JA, Morgan LA, Baumgartner JC. A comparison of canal centering ability of four instrumentation technique. J Endod 23:503-507, 1997.
8. Swartz DB, Skidmore AE, Griffin Jr JA. Twenty years of endodontic success and failure. J Endod 9(5):198-202, 1983.
9. Sjögren U, Hägglund B, Sundqvist G, Wing K. Factors affecting the long-term result of endodontic treatment. J Endod 16(10):498-504, 1990.
10. Smith CS, Setchell DJ, Harty FJ. Factors influencing the success of conventional root canal therapy-a five-year retrospective study. Int Endod J 26:321-333, 1993.
11. Malueg LA, Wilcox LR, Johnson W. Examination of external apical root resorption with scanning electron microscopy. Oral Surg Oral. Med Oral Pathol 82:89-93, 1996.
12. Gutierrez JH, Brizuela C, Villota E. Human teeth with periapical pathosis after overinstrumentation and overfilling of the root canals: a scanning electron microscopic study, Int Endod J 32:40-48, 1999.
13. Tronstad L, Andreasen JO, Hasselgren G, Kristerson I, Ris T. pH changes in dental tissue after root canal filling with calcium hydroxide. J Endod 7(1):17-21, 1981.
14. Nehammer CF. Treatment of the emergency patient. Br Dent J 158:245-248, 1985.
15. Seltzer S, Soltanoff W, Sinai I, Goldenberg A, Bender IB. Biologic aspects of endodontics. Part III. Periapical tissue reaction to root canal instrumentation. Oral Surg Oral Med Oral Pathol 26(4):534-546, 1968.
16. Peter M., Di Fiore. A dozen way to prevent nickel-titanium rotary instrument fracture. J Am Dent Assoc 138;196-201, 2007.
17. Li UM, Lee BS, Shih CT, Lan WH, Lin CP. Cyclic fatigue of endodontic nickel titanium rotary instruments: static and dynamic test. J Endod 28(6):448-451, 2002.
18. Gulabivala K, Abdo S, Sherriff M, Regan JD. The influence of interfacial forces and duration of filing on root canal shaping. Endod Dent Traumatol 16;166-74, 2000.
19. Oh SH, Park JK, Hur B, Kim HC. Comparison of screw-in effect of three NiTi file systems used by undergraduates. J Kor Acad Cons Dent 31(6):477-484, 2006.
20. Diemer F, Calas P. Effect of pitch length on the behavior of rotary triple helix root canal instruments. J Endod 30(10):716-718, 2004.

국문초록

모형 레진 근관에서 수종의 전동 니켈-티타늄 파일에 대한 screw-in effect 비교

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Screw-in effect는 니켈-티타늄 전동 파일을 사용한 근관형성시 나타나는 현상으로 근관형성을 어렵게 한다. 이 연구의 목적은 다양한 니켈-티타늄 전동 파일들 사이의 screw-in effect를 비교하고자 하는 것이다.

본 연구에서는 여섯 가지의 다른 니켈-티타늄 전동 파일 기구들, 즉, K3™ (SybronEndo, Glendora, CA USA), M_{two} (VDW GmbH, München, Germany), 삭제능이 있는 첨단을 가진 것과 삭제능이 없는 첨단을 가진 NRT (Mani Inc., Shioya-gun, Japan), ProFile® (Dentsply-Maillefer, Ballaigues, Switzerland), 그리고 ProTaper® (Dentsply-Maillefer, Ballaigues, Switzerland)가 사용되었다. 기구가 동일한 경사도와 크기를 가지게 하기 위해, 각 기구는 경사도 0.06, size 20을 선택하였으며, ProTaper®의 경우에는 이와 유사한 S2를 사용하였다. 각 기구당 10개씩 총 60개의 투명레진 블록의 모조 단일 만곡근관(REF A0177, Dentsply-Maillefer, Ballaiguez, Switzerland)에서, 전동파일의 회전속도는 분당 300회전으로 하고, 단일 pecking 동작이 되게 하여 기구조작을 하였다. 장치를 고안하여 일정한 힘의 pecking 동작을 재현하고 screw-in effect의 힘을 측정하였다. 고안한 장치의 dynamometer가 근관형성 과정동안 screw-in force를 측정하였고, 기록된 data는 고안된 소프트웨어를 이용하여 컴퓨터에 저장되었다. 데이터는 one-way ANOVA로 통계처리를 하였고, Tukey's multiple range test를 사용하여 95% 수준에서 유의성을 검정하였다.

ProTaper®가 가장 큰 screw-in effect를 나타내었다($p < 0.001$). K3™는 M_{two}와 ProFile® 보다 큰 screw-in effect를 나타내었다($p < 0.001$). 그러나 M_{two}, NRT와 ProFile® 사이에서는 유의한 차이가 나타나지 않았고($p > 0.05$), 삭제능이 있는 첨단을 가진 NRT와 삭제능을 가지지 않는 첨단을 가진 NRT 사이에도 유의한 차이를 나타내지 않았다.

이상의 연구결과를 통해 볼 때, 실험에 사용된 수종의 Ni-Ti 전동파일들 사이에서 screw-in effect의 차이가 나타날 것으로 보이며. 특히, Ni-Ti 전동파일의 radial lands와 rake angle이 screw-in effect의 차이를 나타낼 수 있을 것으로 생각된다.

주요단어: 니켈-티타늄 전동화일, 모형 레진근관, Dynamometer, Screw-in effect