Comparison of screw-in effect of three NiTi file systems used by undergraduates

Seung-Hei Oh, Jeong-Kil Park, Bock Hur, Hyeon-Cheol Kim*

Department of Conservative Dentistry, School of Dentistry, Pusan National University, Busan, Korea

ABSTRACT

The purposes of this study were to compare the apical terminus width of simulated curved root canal prepared with three NiTi file systems used by undergraduates for evaluation the effects of flute angle and pitch or radial land on reducing screw-in effect and to determine more safe NiTi file system for inexperienced operators.

Fifty inexperienced undergraduate students prepared 150 simulated curved root canals in resin blocks with three NiTi file systems ; ProFile®, Hero Shaper®, K3™. The electric motor set at a speed of 300 rpm and torque of 30 in a 16 : 1 reduction handpiece was used. The simulated root canal was prepared to ISO #25 sizes with each file system. The scanned images of pre- and post-instrumented canal of resin block were superimposed. To evaluate the screw-in effect of three NiTi file systems, apical terminus width of root canal was measured from superimposed images and statistical analysis was performed.

There were significant differences in three NiTi file systems. ProFile® had significantly smaller width than Hero Shaper® and K3™ ($P < 0.05$), but no significant difference was observed between K3™ and Hero Shaper®.

Under the condition of this study, active file system (Hero Shaper®, K3™) with variable pitch and helical angle had more screw-in effect than passive file system (ProFile®) with constant pitch and helical angle. It seems that the radial lands play more important role in reducing screw-in effect.

(J Kor Acad Cons Dent 31(6):477-484, 2006)

Key words: NiTi file, Screw-in effect, Variable pitch, Helical angle, Radial land

- Received 2006.7.13., revised 2006.9.06., accepted 2006.11.8. -

I. INTRODUCTION

The role of root canal instrumentation in successful endodontic treatment is to clean the canal of organic debris and to shape the canal for three-dimensional hermetic obturation and effective chemical irrigation. The ideal preparation for a root canal is a continuously tapered funnel shaped with the smallest diameter at the apex and the widest diameter at the orifice[1]. Apical enlargement is performed to ensure cleanliness and improve obturation[2].

Rotary nickel-titanium (NiTi) instruments have been shown to prepare the root canal rapidly, and

* Corresponding Author: **Hyeon-Cheol Kim**

Department of Conservative Dentistry
School of Dentistry, Pusan National University,
10, 1ga, Ami-Dong, Seo-Gu, Busan, Korea
Tel: 82-51-240-7454 Fax: 82-51-528-8105
E-mail: golddent@pusan.ac.kr

※ 본 연구는 2006년도 부산대학교병원 임상연구비 지원으로 이루어졌음.

maintain the canal shape and working length with few aberrations during root canal preparation[3]. They are available in various designs that differ in tip and taper design, rake angles, helical angles, pitch, and presence of radial lands. Numerous studies have shown that NiTi rotary instruments can effectively produce a well-tapered root canal form sufficient for obturation, with minimal risk of transporting the original canal[4-7].

Many rotary NiTi file systems have been introduced to the market. Most of these NiTi file systems - e.g. ProFile® (Maillefer, Dentsply, Ballaigues, Switzerland), K3™ (SybronEndo, California, USA), Hero Shaper® (Micromega, Besancon, France) - have a constant tapered shaft design, while they have various rake angles and radial lands[8-10]. The ProFile® can be categorized as a passive instrument, while the K3® and Hero Shaper® are active instruments with an active cutting motion[11]. Current evidences show that files with sharp cutting edges do not affect the instrument's ability to stay centered, even in curved canal[3]. Nevertheless, certain active file systems have the tendency to dangerously screw into canal, especially when they have a constant taper, pitch, and helical angle[12]. It has been claimed that continuous changing the pitch and helical angle over the length of the cutting blades of an instrument could reduce the screw-in effect[13,14].

If screw-in effect has occurred during canal preparation, it is difficult to manage and preserve working distance especially in novice operator. Due to the over instrumentation by screw-in effect, operators could not make apical stop fits with the width of last apical shaping file tip at apical constriction area. It means that apical terminus width became wider than that of as we want and apical stop would be destroyed. Then ideal obturation would not be attained and it will block the way to successful endodontic treatment.

It is hard to find out the study that has compared screw-in effect of various NiTi file system in terms of the maintaining ability of apical terminus width of curved canals. Numerous authors have reported the advantages of rotary preparation with NiTi instruments over hand preparation, both for experienced and for inexperienced operators[15,16]. However, few studies have addressed the screw-in effect of NiTi file systems. This effect jeopardizes the safe usage of NiTi file, especially in novice operators.

The purposes of this study were to compare the apical terminus width of simulated root canal prepared with three NiTi file systems (ProFile®, Hero Shaper®, K3™) used by undergraduates for evaluation the effects of flute angle and pitch or radial land on reducing screw-in effect and to determine more adequate NiTi file system for inexperienced operators.

Ⅱ. MATERIALS AND METHODS

Fifty senior students at the Dental College of Pusan National University (Busan, Korea) with no practical experience using NiTi file systems in root canal preparation participated in this study. The regular curriculum instruction in root canal shaping procedures consists of six hours of lecture and eight hours of model (extracted tooth) exercises with stainless-steel files. It was all of experience before the procedures. In addition to the lectures on basic and practical endodontics of the

Table 1. Design of each file system

	ProFile®	Hero Shaper®	K3™
Rake angle	Slight Negative	Slight Positive	Slight Positive
Radial land	Yes	No	Yes
Helical flute angle	Consistent	Variable	Variable
Flute pitch	Consistent	Variable	Variable

regular curriculum, the students received two hours of lecture and watched video about the three NiTi file systems used in this study. Respective instrumentation procedures were demonstrated before the start of the experiment.

The students prepared simulated curved root canals in resin blocks (Endo Training Bloc; Dentsply Maillefer, Ballaigues, Switzerland) using the three NiTi file systems ProFile®, Hero Shaper®, K3™. The characters of each NiTi file system were summarized in Table 1.

Specimen and instrumentation

Simulated root canals

The simulated root canal resin blocks (Endo Training Bloc; Dentsply Maillefer, Ballaigues, Switzerland) used in this study had a vertical length of 14 ㎜ straightly from the level of apical foramen to orifice level and the root canals had about 16 ㎜ of working length and about 40 ° curvature angle. Before instrumentation aqueous methylene blue solution was injected into the canals to enhance the image contrast. These resin blocks were scanned at a resolution of 1600 dpi (Scanjet® C8510A; Hewlett-Packard, California, USA), and then the image data was stored in a personal computer.

Instrumentation

Working lengths were measured with stainless steel #10 hand K-files until the tip was visible at the apical foramen. All canals were prepared to a working distance of 16 ㎜. All NiTi files used in this study were new ones. These files were used in the manner of manufacturer's recommendation. The electric motor (Tecnika®; ATR, Pistola, Italy) set at a speed of 300 rpm and torque of 30 (Tecnika motor setting value) in a 16 : 1 reduction handpiece was used. These settings were within the range suggested by the manufacturer. The root canal was prepared to ISO #25 size with each file system. The instrumentation sequence of each system is summarized in Table 2. During the procedures, all simulated canals were verified the patency with #10 hand K-file. After each instrument the root canals were irrigated with normal saline and lubricated with the RC-prep® (Stone Pharmaceuticals, Philadelphia, USA).

Assessment of canal preparation and specimen selection

After root canal preparation was completed, Vitapex® (Neo Dental Chemical Products co., LTD, Tokyo, Japan) was injected into the enlarged canals. Acquired resin blocks were scanned again at a resolution of 1600 dpi. Pre- and post-instrumented canal images were superimposed on one another using Adobe® Photoshop version 7.0 (Adobe, San Jose, California, USA). Superimposition of pre-and postoperative specimen was aided through label placed in the side of the resin block. The superimposed images were assessed on a 17 inch TFT-LCD monitor (SyncMaster® CX701N; Samsung, Suwon, Korea). Assessments were made according to the presence

Table 2. The instrumentation procedures of the Ni-Ti file systems

ProFile®	Hero Shaper®	K3™
OS3(.06/40)	Endoflare (.12/25)	Orifice opener (.12/25)
.06#25 to resistance	.06#20 to resistance	.06#40 to resistance
.04#25 to resistance	.04#20 to resistance	.04#35 to resistance
Measure working length	Measure working length	.06#30 to resistance
.04#20 to working length	.04#20 working length	Measure working length
.04#25 to working length	.04#25 working length	.04#25 working length
.06#20 to working length	Apical gauging with #25	Apical gauging with #25
Apical gauging with #25		

of various types of canal aberrations such as apical zip, elbow, ledge and obstruction.

Measurement

Using Adobe® Photoshop software all of these superimposed images were observed at 156× magnification. To evaluate the screw-in effect of three NiTi file systems, apical terminus width of root canal was measured to the nearest 10 ㎛ using superimposed images (Figure 1).

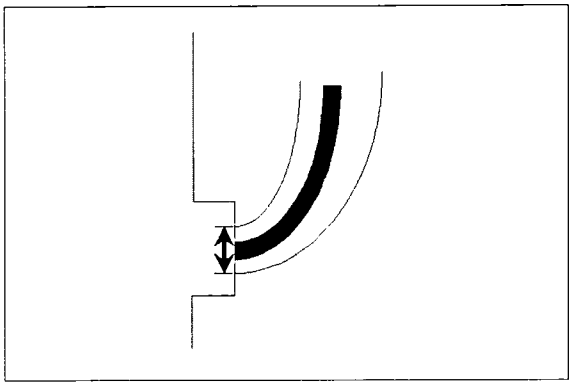

Figure 1. Measuring of apical terminus width using superimposed images.

Statistical analysis

Statistical analysis of the collected data was performed with One Way ANOVA and Scheffe's test for post-hoc comparison by SPSS™ version 12.0 (SPSS Inc., Chicago, IL, USA). Differences revealed in the data were designated as significant at $P < 0.05$.

Ⅲ. RESULTS

Canal aberration

Three representative superimposed images of pre-instrumented and post-instrumented blocks are presented in Figure 2.

The results concerning the assessment of canal aberrations are summarized in Table 3. K3™ created more zip and ledges than ProFile® and Hero Shaper®. Incompletely prepared resin blocks which have canal aberration at apical terminus area were excluded from samples. The statistical analysis was performed with the remaining resin blocks.

ProFile® Hero Shaper® K3™

Figure 2. Three representative superimposed images after instrumentation by each NiTi file systems.

Table 3. Incidence of canal aberrations by instrument types

Systems		ProFile®	Hero Shaper®	K3™
Type of Aberration	Zip / elbow	0	1	3
	Ledge	5	2	7
	Obstruction	2	1	3
	Total	7	4	13

Table 4. Mean apical terminus width (㎛) of each system after instrumentation

	ProFile®	Hero Shaper®	K3™
n	43	46	37
Mean ± SD	281 ± 44 [a]	349 ± 50 [b]	353 ± 58 [b]

n : sample size

[ab] : Different letter indicates significant differences between the systems ($P < 0.05$).

Apical terminus width

Although we prepared the resin block to ISO #25 apical size with each file system, the apical terminus width after instrumentation were various. The results in Table 4 show the mean apical terminus width of each file system after instrumentation. There were significant differences in three NiTi file systems. ProFile® had significantly smaller width than Hero Shaper® and K3™ ($P < 0.05$), but no significant differences were observed between K3™ and Hero Shaper®.

Ⅳ. DISCUSSION

Many rotary NiTi file systems have been introduced in the market. Rotary NiTi instruments have been shown to prepare the root canal rapidly, and maintain the canal shape and working length with fewer aberrations[3]. This is due to the combination of the crown-down instrumentation technique, and file design characteristics such as flexibility, flute design, and non-cutting tip[17]. With this various advantages, using of NiTi instruments has been increased clinically.

The ability to maintain the original canal curvature and produce a continuously tapering and conical form with the smallest diameter at the end-point of the preparation is one of the objectives of root canal preparation[1]. To control the working length is important in root canal therapy especially when there is loss of tactile sensation with NiTi rotary instrumentation, therefore the operators expert their best effort try not to overinstrument the canal[18].

Certain active NiTi file systems have the tendency to dangerously screw into canal[12]. If screw-in effect has occurred during canal preparation, working distance could not be controlled. As a results, tip of the file pass through the apical constriction. This means that apical terminus width became wider than the tip's width of last apical shaping file at apical constriction area. And then apical stop would be destroyed. Manufacturers have claimed that continuous changing the pitch and helical angle over the length of the cutting blades of active file systems could reduce the screw-in effect than the file systems with constant pitch and helical angle[13,14]. But it is difficult to find the report of evaluation screw-in effect. This is necessary to investigate the screw-in effect of active file systems.

This study was designed to compare the apical terminus width of simulated root canal prepared

with three NiTi file systems (ProFile®, Hero Shaper®, K3™) used by undergraduates for evaluation the effects of variable flute angle and pitch on reducing screw-in effect under the presumption of screwing could make large apical terminus width.

Johnson[11] classified all rotary instruments as having active, semiactive, or passive cutting blades. The ProFile® system fits into the category of passive instruments. The slight negative rake angle and radial land make the file cut less aggressively than those having cutting blades - e.g. ProTaper®, Hero Shaper®, K3™ - and those having semiactive cutting blades - e.g. Quantec™ [19-21]. Each file system has advantage and disadvantage according to its unique characteristic. These systems essentially differ from one another in the design of the cutting blades and taper of their files.

The ProFile® has three equally spaced U-shaped grooves, and central parallel core inside that may account for the enhanced flexibility. It has 20° negative rake angle at cutting edge and flat radial land to cut dentin in a planning motion. This U-file design of the ProFile® is claimed to have no side cutting ability and maintain the canal center well[19,22].

The K3™ is a rotary instrument with radial land in combination with a radial land relief in combination with a positive rake angle, a flattened noncutting tip, and an asymmetrical constant tapered active file design with variable helical flute and variable core diameter. These are features that are claimed to enhance cutting efficiency, debris removal, and file guidance and strength[13,23,24].

The Hero Shaper® has triple helix cross section with a positive cutting angle. It has no radial land[23]. It has variable pitch and helical angle of the cutting portion. According to manufacturer's report, increasing the blade pitch could remove debris more effectively, reduced threading-in phenomenon[12,14].

The results of this study have shown that there was a significant difference in apical terminus width after instrumentation of each file system. ProFile® had significantly smaller terminus width than Hero Shaper® and K3™.

The reason for this is not obvious but may be explained by its unique file design and cutting ability. The U-file design and radial land of the ProFile® seem to contribute to reduce self-threading of the file into the canal as there is no side cutting ability. It means that the instrument design of the ProFile® system is able to preserve more conservative apical terminus width contrast to Hero Shaper® and K3™. The K3™ also has radial land, nevertheless, it made wider apical terminus width than ProFile®. This might be due to the restoring forces of the metal were the forces in a straight file in a curved canal attempt to straighten the file toward the outer curvature thereby preferentially removing material in this area[17]. Especially K3™ has variable core diameter, its file tip would be stiffer than other NiTi file system. Several studies have been reported that K3 file created slight canal transportations toward the outer aspect of the curvature in the apical region of the severely curved canal[17,25].

And also this result is in disagreement with several observations of other studies in that only small mean changes in working distance occurred with rotary NiTi instruments[3]. This may be due to the operator's experiences. In other studies by experienced showed small amount of over preparation occurred in canal prepared using NiTi instruments[17,18,20]. But in the present study the operators had no experiences of using NiTi files. This may be able to affect the ability to control working distance and maintain finger rest.

Although manufacturers have insisted that variable pitch and helical angle could reduce the screw-in effect[13,14], results of this study suggests that the radial lands do more important role in reducing screw-in effect. The ProFile® with U-file design which has no side cutting ability is more conservative in maintaining apical terminus width. Therefore it is recommended for first choice to undergraduate students who have no experience of using NiTi instruments. If inexperienced operator wants to use Hero Shaper® and K3™, they should pay attention to control work-

ing distance with definite finger rest during canal preparation for achieving accurate apical stop.

Ⅴ. CONCLUSIONS

Under the condition of this presumptive study, active file system (Hero Shaper®, K3™) with variable pitch and helical angle seems to have more screw-in effect than passive file system (ProFile®) with constant pitch and helical angle. The radial lands of passive file system seem to play more important role in reducing screw-in effect. And ProFile® is more conservative in maintaining apical terminus width, it is recommended for first choice for undergraduate students.

REFERENCES

1. Schilder H. Cleaning and shaping the root canal. *Dent Clin North Am* 18:269-296, 1974.
2. Walton RE. Principle and practice of endodontics. 2nd ed., WB Saunders, Philadelphia, p201-203, 1996.
3. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. *J Endod* 30(8):559-567, 2004.
4. Esposito PT, Cunningham CJ. A comparison of canal preparation with nickel-titanium and stainless steel instruments. *J Endod* 21(4):173-176, 1995.
5. Schafer E, Schulz-Bongert U, Tulus G. Comparison of hand stainless steel and nickel titanium rotary instrumentation: a clinical study. *J Endod* 30(6):432-435, 2004.
6. Coleman CL, Svec TA. Analysis of Ni-Ti versus stainless steel instrumentation in resin simulated canals. *J Endod* 23(4):232-235, 1997.
7. Garip Y, Gunday M. The use of computed tomography when comparing nickel-titanium and stainless steel files during preparation of simulated curved canals. *Int Endod J* 34(6):452-457, 2001.
8. Schäfer E. Shaping ability of Hero 642 rotary Nickel-titanium instruments and stainless steel hand K-Flexofiles in simulated curved root canals. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 92(2):215-220, 2001.
9. Hata G, Uemura M, Kato AS, Imura N, Novo NF, Toda T. A comparison of shaping ability using ProFile, GT file, and Flex-R endodontic instruments in simulated canals. *J Endod* 28 (4):316-321, 2002.
10. Ankrum MT, Hartwell GR, Trutt JE. K3 Endo, ProTaper, and ProFile systems: breakage and distortion in severely curved root of molars. *J Endod* 30(4):234-237, 2004.
11. Johnson WB. Contemporary endodontics. Dentsply Asia, Hong Kong, p1-6, 2002.
12. Machtou P, Ruddle CJ. Advancements in the design of endodontic instruments for root canal preparation. *Alpha Omegan,* 97(4):8-15, 2004.
13. Mounce RE. The K3 rotary nickel-titanium file system. *Dent Clin North Am* 48:137-157, 2004.
14. Calas P. HEROShapers®: the adapted pitch concept. *Endod Topic* 10:155-162, 2005.
15. Baumann MA, Roth A. Effect of experience on quality of canal preparation with rotary nickel-titanium files. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 88(6):714-718, 1999.
16. Gluskin AH, Brown DC, Buchanan LS. A reconstructed computerized tomographic comparison of Ni-Ti rotary GT files versus traditional instruments in canals shaped by novice operators. *Int Endod J* 34(6):476-484, 2001.
17. Ayar LR, Love RM. Shaping ability of Profile and K3 rotary Ni-Ti instruments when used in a variable tip sequence in simulated curved root canals. *Int Endod J* 37(9):593-601, 2004.
18. Thompson SA, Dummer PM. Shaping ability of Hero 642 rotary nickel-titanium instruments in simulated root canals. Part 1. *Int Endod J* 33(3):248-254, 2000.
19. Hsu YY, Kim S. The ProFile system. *Dent Clin North Am* 48:69-85, 2004.
20. 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(2):228-233, 2003.
21. Kosa DA, Marshall G, Baumgartner JC. An analysis of canal centering using mechanical instrumentation techniques. *J Endod* 25(6):441-445, 1999.
22. Lloyd A. Root canal instrumentation with ProFile instruments, *Endod Topic* 10:151-154, 2005.
23. Bergmans E, Van Cleynenbreul J, Wevers M, Lambrechts P. Mechanical root canal preparation with Ni-Ti rotary instruments: rationale, performance and safety. Status report for the American Journal of Dentistry. *Am J Dent* 14:324-333, 2001.
24. Gambarini G. The K3 rotary nickel titanium instrument system. *Endod Topic* 10:179-182, 2005.
25. Schafer E, Florek H. Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part1. Shaping ability in simulated curved canal. *Int Endod J* 36(3):199-207, 2003.

국문초록

학생들이 사용한 세 종류 NiTi file systems의 screw-in effect 비교

오승희 · 박정길 · 허 복 · 김현철*
부산대학교 치과대학 보존학교실

학생들이 사용한 세 가지 NiTi file systems (ProFile®, Hero Shaper®, K3™)을 사용하여 성형한 모형 근관의 apical terminus width를 비교하여 flute angle 및 pitch 혹은 radial land가 screw-in effect에 미치는 효과를 알아보고자 하였다.

NiTi file의 사용 경험이 없는 부산대학교 치과대학 4학년 학생 50명이 세 종류의 NiTi file systems- Pro File® (Dentsply Maillefer, Ballaigues, Switzerland), K3™ (SybronEndo, Glendora, France), Hero Shaper® (Micromega, Besancon, France)- 을 사용하여 각 system으로 하나의 근관씩, 모두 150 개의 레진 블락 근관 모형 (Endo Training Bloc; Dentsply Maillefer, Ballaigues, Switzerland)을 16 : 1 감속 handpiece를 장착한 electric motor (Tecnika ATR, Pistola, Italy)를 사용하여 300 rpm의 속도에서 torque는 30 (Tecnika motor setting value)으로 성형하였다. 스캐너로 근관 성형 전 후 이미지를 채득하여 중첩한 후 근단부의 최종 폭경을 측정하였다. 통계분석은 one-way ANOVA와 95% 신뢰도의 Scheffe's multiple range test로 사후 검증하였다.

ProFile®의 근관 성형 후 근단부의 폭이 Hero Shaper® and K3™에 비해 통계학적으로 유의하게 작았다.

본 연구의 결과에서 근단부의 과도한 확대가 variable pitch와 helical angle를 가진active file에 비해 constant pitch와 helical angle을 가짐에도 불구하고 radial land를 가진passive file에서 적게 나타났다. 이 결과로 추정해 볼 때, variable pitch와 helical angle보다는 근본적으로 radial land가 screw-in effect의 예방에 더 큰 역할을 하는 것으로 추정될 수 있다. 따라서 NiTi file의 사용 경험이 없는 초심자의 경우 근단부 폭경의 유지능력이 좋은 ProFile®의 사용이 추천된다.

주요어: 니켈-티타늄 파일, 쐐기 효과, Variable pitch, Helical angle, Radial land