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Influence of taper on the screw-in effect of nickel-titanium rotary files in simulated resin root canal

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ABSTRACT

Objectives: The introduction of nickel-titanium alloy endodontic instruments has greatly simplified shaping the root canal systems. However, these new instruments have several unexpected disadvantages. One of these is tendency to screw into the canal. In this study, the influence of taper on the screw-in effect of the Ni-Ti rotary instrument were evaluated.

Materials and Methods: A total of 20 simulated root canals with an S-shaped curvature in clear resin blocks were divided into two groups. ProFile .02, .04, .06 (Dentsply-Maillefer) and GT rotary files .08, .10, .12 (Dentsply) were used in Profile group, and K3 .04, .06, .08, .10, and .12 (SybronEndo, Glendora) were used in K3 group. Files were used with a single pecking motion at a constant speed of 300 rpm. A special device was made 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 computer with designed software. 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.

Results: The more tapered instruments generated more screw-in forces in Profile group ($p < 0.05$). In K3 group, 0.08, 0.10. and 0.12 tapered instruments showed more screw-in force than 0.04 tapered one, and 0.08 and 0.12 tapered instruments showed more screw-in force than 0.06 tapered one ($p < 0.05$).

Conclusions: The more tapered instruments seems to produce more screw-in force. To avoid this screw-in force during instrumentation, more attention may be needed when using more tapered instruments. [J Kor Acad Cons Dent 2010;35(5):380-386.]

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

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Introduction

Canal preparation is one of the major steps in root canal treatment and is directly related to subsequent disinfection and fillings.[1] The goal of root canal shaping is to form a continuously tapered shape with the smallest diameter at the apical foramen and the largest at the orifice so as to allow effective irrigation and filling and not change the original canal curvature.[2]

Because of the stiffness, stainless steel instrument is likely to cause canal aberrations such as zips,

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elbow, ledges and perforations.[3,4] During the late 1980s and 1990s, various types of endodontic instruments were developed with nickel-titanium alloys.[5] The introduction of nickel-titanium alloy for the mechanically driven endodontic instruments has greatly simplified shaping the root canal systems.[5] These new instruments exhibit more elastic flexibility in bending and torsion,[5] and are also markedly superior to stainless steel instruments in terms of angular deflection and maximum torque to failure.[6] These instruments have been found to be better than stainless steel instruments in maintaining the original anatomy and the shape and position of the apical foramen.[7-9]

However, despite the evident advantages of the new technique, Ni-Ti rotary instruments have several unexpected disadvantages. One of these is tendency to screw into the canal.[10] This tendency is particularly accentuated especially when continuously rotating nickel-titanium instruments are used.[11] Because rotary instruments rotate with electric power, control of the working length is more difficult during rotary instrumentation than during hand instrumentation.[10] 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.[5,12-15]

Some kinds of factors have been investigated to be involved in the screw-in effect of Ni-Ti rotary files. Cross-sectional geometry, helical angles, pitch length and taper of files are included in these factors.[16] Diemer et al. evaluated the effect of pitch length on the torsional stress and tendency to screw-in using two instruments with same cross-section (triple helix; 6% taper).[16] Their results showed that increasing the pitch length decreased torsional load sharing and the tendency to screw-in. Schräder et al. compared torques and forces developed by two sequences of nickel-titanium rotary instruments, using only .04 taper instruments or a combination of .04 and .06 tapers, respectively.[17] Their conclusions were an instrumentation sequence encompassing various tapers seems to be safer in torsional and fatigue failure compared to sequence that used only one single taper.

The concept of maximizing cutting efficiency by minimizing surface contact area of the instrument with root canal wall has led to development of variations in taper. It has been suggested that increasing instrument taper while maintaining the same size tip maximize cutting efficiency.[8] However, as the taper increases, the stresses of the instrument were also greater.[18]

In the previous research, the screw-in effect among several Ni-Ti rotary file systems was compared.[10] In addition, the impact of varying instrument taper on screw-in effect needs to be investigated.

Therefore, the purpose of this study was to evaluate the influence of taper on the screw-in effect of nickel-titanium rotary files.

Materials and Methods

1. Nickel-titanium rotary files

A total of 20 simulated root canals with an S-shaped curvature in clear resin blocks (Endo training-Bloc-S; Dentsply-Maillefer, Ballaigues, Switzerland) were used in this study. Specimens were divided into two groups according to nickel-titanium rotary file systems used in this study. ProFile .02, .04, .06 (Dentsply-Maillefer, Ballaigues, Switzerland) and GT rotary files .08, .10, .12 (Dentsply-Maillefer, Ballaigues, Switzerland) were used in Profile group and K3 .04, .06, .08, .10, and .12 (SybronEndo, Glendora, CA, USA) were used in K3 group (Table 1). The tip diameter of the instrument was the same as that for ISO size #20.

2. Measurement of screw-in force

All canals were prepared by using a custom-made device with a 16 : 1 reduction hand-piece powered by an electric motor (SurgiMotor II, Aseptico Corp., Woodinville, WA, USA). The contra-angle handpiece with the rotary file was mounted on the specially designed device (Figure 1) and the files were automatically inserted into the canal of resin block. The smaller tapered instrument was used earlier in each simulated root canals followed by next tapered instrument. The position of resin block was marked

Table 1. Nickel-titanium rotary instruments used in this study

Group	System	Taper	Manufacturer	Characteristics
ProFile	ProFile	0.02	Dentsply	Three equal radial lands
		0.04	Maillefer	U-shaped grooves around the shaft
		0.06	Ballaigues,	Negative rake angle at the cutting edge
	GT rotary files	0.08	Switzerland	Constant helical angle and pitches
		0.10		
		0.12		
K3	K3	0.04	SybronEndo Glendora,	Asymmetrically radial lands
		0.06	CA, USA	and unequal width
		0.08		Slightly positive rake angle
		0.10		Unequal flute width and depth
		0.12		Constant helical angle

New instrument was used for each canal with saline irrigation.

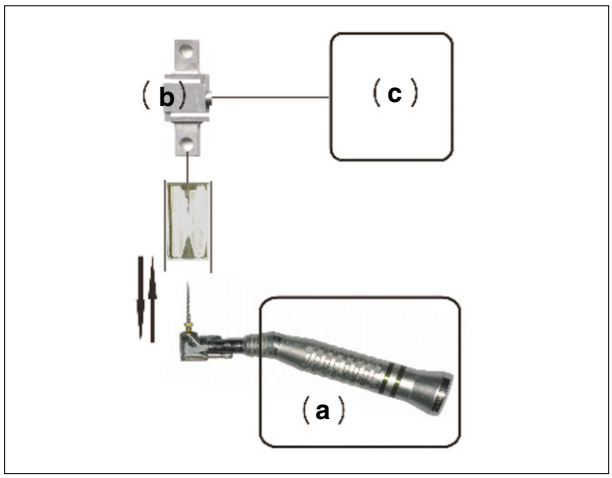

Figure 1. The custom-made device for the measurement of the screw-in effect. The device was composed of a part generating a single pecking movement of the handpiece (a) with a constant speed of 300 rpm, compression/tension sensor (b) and computer (c) for data storage, analysis.

when the file bound the canal at the first time. The resin block was moved 1.0 mm toward the rotary file. 1.0 mm single pecking motion was generated with screw-in of clock-wise direction.

New instrument was used for each canal with saline irrigation.

When the instruments are withdrawn at the end of the pecking movement, a force that resist the withdrawl of the instrument from the root canal is generated. This axial stress causes pulling of the resin blocks. The resistance force is considered as the screw-in force. The dynamometer (K1368-10N, Lorenz Messtechnik Gmbh, Alfdorf, Germany) in the device recorded the transmitted resistance force in mA. The generated signals (mA) were amplified with a 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).

3. Statistical analysis

The data on the forces were analyzed using one-way ANOVA to determine the difference between different taper 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.

Results

Table 2 shows the mean and the standard deviations of screw-in force according to the taper of each file systems.

The more tapered instruments generated more screw-in forces in Profile group ($p < 0.05$). In K3 group, 0.08, 0.10. and 0.12 tapered instruments showed more screw-in force than 0.04 tapered one, and 0.08 and 0.12 tapered instruments showed more screw-in effect than 0.06 tapered one ($p < 0.05$).

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

	Taper	Profile	K3
Screw-in force	.02	0.293 ± 0.017[a]	
	.04	0.382 ± 0.008[b]	0.382 ± 0.013[a]
	.06	0.402 ± 0.016[b]	0.410 ± 0.057[a,b]
	.08	0.437 ± 0.020[c]	0.462 ± 0.029[c]
	.10	0.471 ± 0.013[d]	0.453 ± 0.027[b,c]
	.12	1.037 ± 0.022[e]	0.469 ± 0.030[c]
p-value*		〈 0.001	〈 0.001

*p-values are computed by one-way ANOVA.

[a, b, c, d, e] same characters mean no significant differences by Tukey's multiple comparison at $p = 0.05$ within the group.

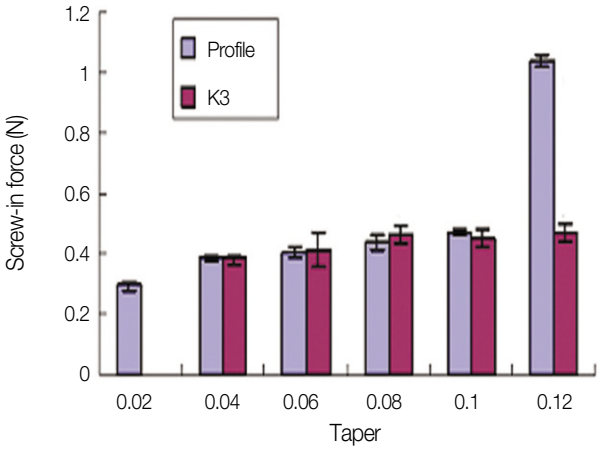

Figure 2. Screw-in force according to the taper of each rotary file systems (mean ± S.D.).

0.12 tapered file of Profile group produced significantly greater screw-in force than any other instruments in the study (Figure 2).

Discussion

Root canal instrumentation with highly flexible rotary Ni-Ti instruments improved preparation quality, determined by better centering ability.[3] This may lead to superior obturation quality and probably to better clinical outcomes.[16] However, Ni-Ti instruments are clinically prone to screw-in depending several factors and this may in turn compromise clinical outcomes. To overcome or control this effect in the canal, factors associated this effect need to be evaluated. In the previous study,[10] the screw-in effect among several Ni-Ti rotary file systems was evaluated. The present study evaluated the effect of the instrument taper, which is one of the factors that may influence on the tendency of screw-in. The result showed a tendency that more tapered instrument generated more screw-in force.

In the present study, simulated canals in resin blocks were used to eliminate variations in canal anatomy without using lubricants which may limit the number of variables and avoid stress measurement because of axial or transversal irrigation force.[19]

One special characteristic of a Ni-Ti rotary instrument is increasing the taper from standardized instrument of 0.02 mm/mm to variable greater tapers up to 0.12 mm/mm. Torque generated and apical force applied were measured in a study[18] using an engine-driven Ni-Ti file, Quantec Series 2000 (Tycom Corp., Irvine, CA, USA) in extracted human teeth. The torque was dependent on the tip size and taper of each instrument, and the canal size. They found that both the torque and apical force were increased with increasing taper (0.02, 0.03, 0.04, 0.05 and 0.06) of the file. However, there was no close relation between torque and apical force. Another study[17] using Profiles in simulated canals showed that both the contact area and torque were increased with increasing taper (0.04 and 0.06) and size (15, 20 25, 30, 35 and 40) of the instruments. The generated apical force were also slightly increased with increasing taper of the instruments, but not with the size of them in the study. In the present study using Profile and K3, the result was similar with the above mentioned studies in that the screw-in effect was increased with increasing taper (0.02, 0.04, 0.06, 0.08, 0.10 and 0.12) of the instruments. Since torque is a force that is generated between the canal wall and instrument, if the torque is increased, the files might have increased resistance in entering the canal. The contact area also might give resistance to the instrument in entering the

canal. However, screw-in force might not increase with increasing resistance. Therefore, it seems that torque might be increased due to contact area is increased with increasing taper or size of the instruments. However, screw-in effect might not be related to the torque directly. On the contrary, screw-in effect might increase with less resistance with less contact area which may be related to the instrument taper.

In the previous study,[18] each canal was instrumented sequentially using all files of #1 to #10. In the present study, the smaller tapered instrument was used earlier in each simulated root canals followed by next tapered instrument. Thus, the instrumentation sequence is different from the study, but the results are similar. Thus, instrumentation sequence seems not much significant to influence on the results.

Feature of file design may affect screw-in effect. ProFile and GT rotary files have radial lands with U-shape and noncutting tips. K3 instrument is reported to have a slightly positive rake angle in combination with a peripheral blade relief for reduced friction and a third radial land to help prevent screwing in.[20] These file systems are similar in respect to have flattened or modified cutting edges to limit screw into the canal. In the present study, the tendency of increasing screw-in force with increasing taper was shown in both Profile and K3 groups. However, it was less clear in K3 group. It may need further investigation whether its design is related to it because it was said that a third radial land was designed to help prevent screwing in.[20] In the present study, 0.12 GT rotary file produced significantly greater screw-in force than any other instruments in this study. With repeated experiment, the result was similar in the study. Because the authors cannot explain it clearly, it needs to be elucidated on the reason. One possibility may be the less contact area to the canal wall with bigger taper in the triple U cross-section geometry. Turpin et al. used theoretical models to show that triple U cross-sections generate localized stresses not only at the cutting edge but also at the center of the instrument.[21] These stresses are much more that those exerted on a triple helix of the same size and diameter but without any flat radial land area.

In conclusion, within the condition of the present study, engine-driven instruments with more taper seem to produce more screw-in effect in both Profile and K3 systems. More attention should be paid when using more tapered rotary instrument to prevent or reduce the screw-in forces so as not to hamper the endodontic success.[22,23] Further studies are needed to investigated on other factors that may be involved in the screw-in effect and to find techniques to control this effect during rotary instrumentation.

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국문초록

모형 레진근관에서 니켈-티타늄 전동 파일의 경사도가 screw-in effect에 미치는 영향

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연구목적: 니켈-티타늄 금속을 근관치료기구에 도입함으로써 근관형성과정이 매우 단순화되었다. 그러나 이러한 새로운 기구는 단점도 함께 가지고 있는데 그 중 하나가 근관내로 기구가 빨려 들어가는 경향이다. 본 연구에서는 니켈-티타늄 전동파일의 경사도가 screw-in effect에 미치는 영향을 평가하고자 하였다.

연구 재료 및 방법: 총 20개의 S-자형 투명레진블록 (Dentsply-Maillefer) 근관에서 두 군으로 나누어 실험하였는데 Profile군에서는 0.02, 0.04 그리고 0.06 경사도의 Profile (Dentsply-Maillefer)과 0.08, 0.10 그리고 0.12의 경사도의 GT Rotary file (Dentsply-Maillefer)을 사용하였고 K3군에서는 같은 경사도의 K3 file SybronEndo)을 사용하였으며, 분당 300회전의 일정한 속도에서 단일 pecking 동작으로 기구조작을 하였다. 특수한 장치를 고안하였으며 장치내 dynamometer를 이용하여 screw-in effect를 측정하여 one-way ANOVA로 통계처리하고 Tuckey's multiple range test로 사후검정하였다.

결과: Profile 군에서는 큰 경사도의 기구가 더 큰 screw-in force를 나타내었고 ($p < 0.05$), K3군에서는 0.08, 0.10. 및 0.12 경사도의 기구가 0.04 경사도의 기구에 비해, 0.08 및 0.12 경사도의 기구가 0.06 경사도의 기구에 비해 더 큰 screw-in force를 나타내었다 ($p < 0.05$).

결론: 기구의 경사도가 클수록 screw-in force가 많이 발생하는 것으로 생각되며, 경사도가 큰 전동화일을 사용시에는 screw-in force를 억제하기 위해 더 많은 주의가 요구될 것으로 생각된다.

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