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Influence of glide path on the screw-in effect and torque of nickel-titanium rotary files in simulated resin root canals

Jung-Hong Ha[1], Sang-Shin Park[2]*

[1]Department of Conservative Dentistry, Kyungpook National University School of Dentistry, Daegu, Korea
[2]School of Mechanical Engineering, Yeungnam University, Gyeongsan, Korea

Objectives: The purpose of this study was to investigate the screw-in effect and torque generation depending on the size of glide path during root canal preparation. ***Materials and Methods:*** Forty Endo-Training Blocks (REF A 0177, Dentsply Maillefer) were used. They were divided into 4 groups. For groups 1, 2, 3, and 4, the glide path was established with ISO #13 Path File (Dentsply Maillefer), #15 NiTi K-file NITIFLEX (Dentsply Maillefer), modified #16 Path File (equivalent to #18), and #20 NiTi K-file NITIFLEX, respectively. The screw-in force and resultant torque were measured using a custom-made experimental apparatus while canals were instrumented with ProTaper S1 (Dentsply Maillefer) at a constant speed of 300 rpm with an automated pecking motion. A statistical analysis was performed using one-way analysis of variance and the Duncan *post hoc* comparison test. ***Results:*** Group 4 showed lowest screw-in effect (2.796 ± 0.134) among the groups (p < 0.05). Torque was inversely proportional to the glide path of each group. In #20 glide path group, the screw-in effect and torque decreased at the last 1 mm from the apical terminus. However, in the other groups, the decrease of the screw-in effect and torque did not occur in the last 1 mm from the apical terminus. ***Conclusions:*** The establishment of a larger glide path before NiTi rotary instrumentation appears to be appropriate for safely shaping the canal. It is recommended to establish #20 glide path with NiTi file when using ProTaper NiTi rotary instruments system safely. (*Restor Dent Endod* 2012;37(4):215-219)

Key words: Glide path; Nickel-titanium file; ProTaper; Screw-in effect; Simulated resin root canal; Torque

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[1]Ha JH, Department of Conservative Dentistry, Kyungpook National University School of Dentistry, Daegu, Korea
[2]Park SS, School of Mechanical Engineering, Yeungnam University, Gyeongsan, Korea
***Correspondence to**
Sang-Shin Park, PhD.
Professor, School of Mechanical Engineering, Yeungnam University
214-1, Dae-dong, Gyeongsan, Korea 712-749
TEL, +82-53-810-3538; FAX, +82-53-810-4627; E-mail, pss@ynu.ac.kr

Introduction

Nickel-titanium (NiTi) instruments are believed to shape root canals more effectively than stainless steel files. It has been shown that NiTi instruments are two or three times more flexible than conventional stainless steel files and have more torsional fracture resistance.[1] These NiTi instruments have also been found to be better than stainless steel instruments in maintaining the original anatomy and the shape and position of the apical foramen.[2,3]

However, despite the advantages of the new instruments, NiTi rotary instruments have several unexpected disadvantages. One of these is the tendency to screw into the canal.[4] This phenomenon happens frequently when the NiTi instruments rotate continuously. It may cause over-instrumentation beyond the apical foramen. Undoubtedly, over-instrumentation reduces the success rate of endodontic treatment.[5-8] In addition, instantaneous increase of torsional stress may happen when screw-in occurs. It may lead to a so-called 'taper lock' effect and separation of instrument.[9]

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The force generated by the pecking motion could be classified into two components.[10] One is the force that comes from the axial stress component. During pecking movement, the blade of the instrument can become lodged into the root canal. In this case, the simulated resin block was lifted up in the opposite direction to that of the instrument's progress because the resin block was given to some freedom to move in the corono-apical direction. Also, when the instruments are withdrawn at the end of the pecking movement, some forces are generated that can restrict with withdrawal of the instrument from the root canal. The sum of these two forces could be referred as the screw-in effect. The other is a force that comes from the rotational stress which is related to the torque. As the simulated resin block was firmly fixed to limit rotational movement, the rotational stress in the interface between an instrument and a root canal was applied to instrument. The transferred rotational stress can be measured in a form of torque by a torque sensor.

Coronal enlargement and pre-flaring to create a glide path is recommended in order to use NiTi rotary instrument safely. It can prevent the torsional fracture of the instruments and the shaping aberrations.[11-13] Previous studies demonstrated that the tendency of screw-in was affected by the flute, pitch, and cross-sectional geometry of instruments.[4,10,14] However, these studies have focused on the mechanical parameters of NiTi rotary instruments and the curvature of canal.[4,10,14] There have been few studies on the relations between the screw-in effect and the glide path. Therefore, the aim of this study was to evaluate the screw-in effect and torque generation as a result of variance in the size of glide path during root canal preparation.

Materials and Methods

Forty Endo-Training Blocks (REF A 0177, Dentsply Maillefer, Ballaigues, Switzerland) were used, which had a size of ISO #15, a 0.02 taper, a 35 degree curvature and a mean canal length of 18 mm. Standard artificial canals in the training blocks were used to minimize the variation in observations. They were divided into 4 groups depending on the size of the provided glide path. ProTaper (Dentsply Maillefer) S1 instruments were used for canal preparation, because ProTaper showed the highest tendency of occurring screw-in effect in a previous study.[4] For group 1, the simulated resin canals were irrigated with distilled water. All files entering the canals were lubricated with Rc-prep (Premier, Plymouth Meeting, PA, USA). The patency was established with #8 K-file (Mani, Utsunomiya, Tochigi, Japan). Then the glide path was established with #13 Path File (Dentsply Maillefer) at the full working length. For group 2, the glide path was established with #13 Path File and #15 NiTi K-file NITIFLEX (Dentsply Maillefer) at the full working length. For group 3, the glide path was established with #13 and #16 Path File, and modified #16 Path File. The modified #16 Path File was made by cutting the tip of #16 Path File at D1 level and was equivalent to ISO #18 as a result. For group 4, the glide path was established with #13, #16, #19 Path File and ISO #20 NiTi K-file NITIFLEX. For group 2, 3, and 4, the other conditions were identical to the conditions for group 1.

Ten canals were prepared for each group. By using the automated preparation protocol, the influence of the operator's expertise and habitual motion during preparation was excluded. To materialize a clinical situation, a custom-made device was produced (Figure 1). All of ProTaper S1 were mounted on this device and synchronized with a torque sensor (Figure 1b). This device can provide constant rotational speed (300 rpm) and pecking movement (speed at 0.5 mm/sec). Automated pecking movement was made by computer programs. The pecking distance was controlled by a control panel (Figure 1c). The pecking movement consisted of 2 mm forward and 1 mm backward at each step. After three steps of pecking movements, the simulated root canals were irrigated with distilled water and the NiTi instruments were lubricated with Rc-prep again. The simulated root canals were mounted on a dynamometer by a mounting jig (Figure 1a). A dynamometer (K1368-10N, Lorenz Messtechnik GmbH, Alfdorf, Germany) and a torque sensor (DR-2477-2.0 Nm, Lorenz Messtechnik GmbH) in the device measured the transmitted force in milli-ampere

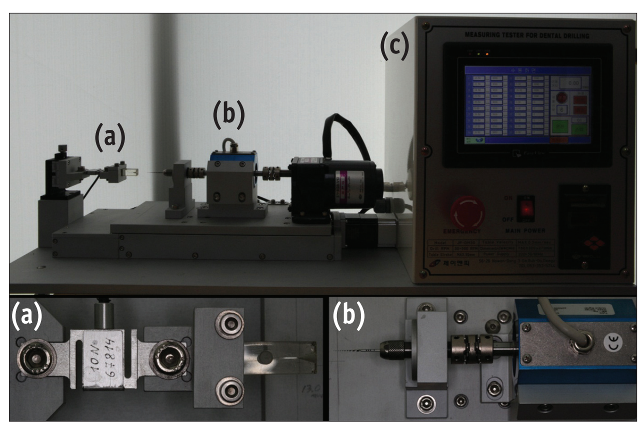

Figure 1. Custom-made device. (a) A simulated root canal was mounted on a tension/compression sensor by using a mounting jig. The generated signals by simulated canals were recorded; (b) ProTaper S1 instrument was synchronized with a torque sensor. The generated torque signals in mA were amplified and transferred to a computer; (c) The pecking distance was controlled by a control panel.

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(mA). The signals were amplified with LCV-USB (Lorenz Messtechnik GmbH) and then transferred to computer files by two pieces of provided software (LCV-USE-VS and VS2, Lorenz Messtechnik GmbH). The acquired data were synchronized and used to produce the plot (Figure 2) (Origin v6.0 Professional, Microcal Software Inc., Northampton, MA, USA). The data were first analyzed using Kolmogrov-Smirnov test to evaluate the assumption of normality. To normalize the data, a statistical analysis was performed using one-way analysis of variance and the Duncan *post hoc* comparison test at a significance level of 95% by using a piece of statistical software (SPSS v19.0, IBM Corp, Somers, NY, USA).

The used instruments for each group were observed under optical microscope (SZ-PT, Olympus, Tokyo, Japan) using 40X zoom to evaluate the deformation of the instrument and the modification of the blade.

Results

The typical strip-chart recording of the screw-in effect and the torque are presented in Figure 2. At the moment the screw-in occurred, the torque values suddenly increased. After that, the torque values returned to the baseline. In most of all groups, the screw-in effect and torque were increased as the file approached to apical foramen. Exceptionally in #20 glide path group, the screw-in effect and torque decreased within 1 mm from the apical foramen (Figure 2d). The maximum value of screw-in effect and torque for each group are shown in Table 1 and Figure 2. Group 4 showed the lowest screw-in effect (2.796 ± 0.134) among the groups ($p < 0.05$). There was no significant difference among the groups 1, 2, and 3. Group 3 and 4 showed lower torque than group 1 and 2. There was no significant difference between group 3 (#18 glide path)

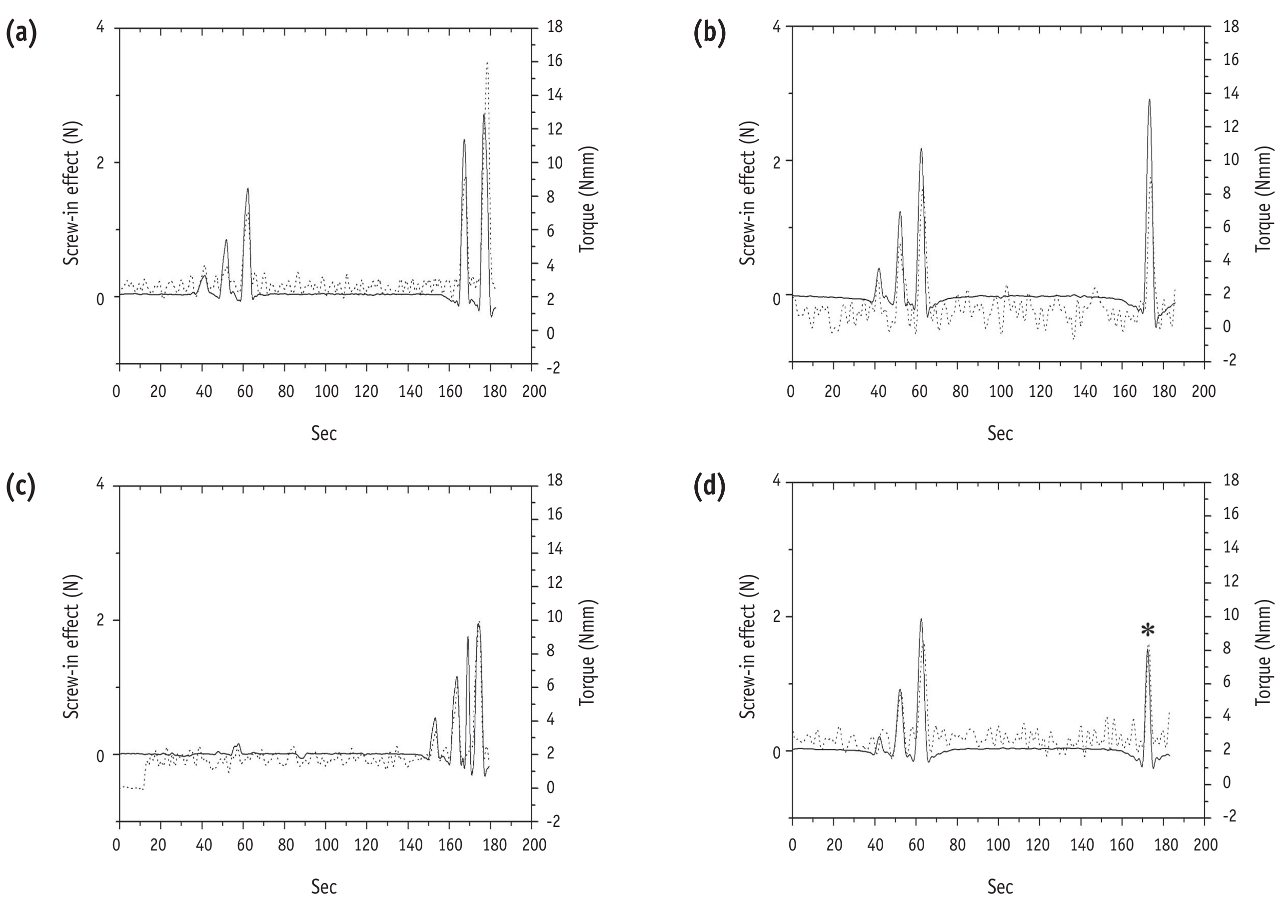

Figure 2. The typical strip-chart recording the screw-in effect (solid line) and torque (dotted line) during preparation. (a) Group 1: #13 glide path; (b) Group 2: #15 glide path; (c) Group 3: #18 glide path; (d) Group 4: #20 glide path. At the moment the screw-in occurred, the torque value suddenly increased. After that, the torque value returned to the baseline. In most groups, the screw-in effect and torque increased as the file approached apical foramen. Exceptionally in group 4, the screw-in effect and torque decreased within 1 mm from the apical foramen (Asterisk).

Table 1. Maximum screw-in effect and torque

	Size of glide path			
	#13	#15	#18	#20
Screw-in effect (N)	3.50 (0.43)[a]	3.48 (0.55)[a]	3.25 (0.61)[a]	2.80 (0.13)[b]
Torque (Ncm)	1.86 (0.34)[a]	1.65 (0.32)[a,b]	1.43 (0.46)[b,c]	1.29 (0.12)[c]

Different superscript letters indicate significant difference between groups in horizontal row ($p < 0.05$).
The numbers in the parentheses are standard deviations.

and group 4 (#20 glide path).

In optical microscope examination, topographical changes of the used instruments were not observed.

Discussion

It was estimated that the tendency of screw-in is harmful for root canal preparation. However, there have been few studies about the screw-in effect. Some factors may influence on the tendency of screw-in. When continuously rotating mode is used, NiTi instrument can be screwed into the root canal. Several parameters have been demonstrated to limit breakage and the screw in.[15] Gulabivala *et al*. stated that it is notably the case when light pressure.[16] The speed of axial movement was 0.5 mm/sec in the present study. If constant pressure is applied on a root canal, the instrument will screw into the root canal even a light pressure was applied. A slight pecking movement prevents the tendency of screw-in and reduces stresses. Pecking movements give the instruments a time interval before the file once again passes through the highest stress area.[17] In this study, a pecking distance which consists of 2 mm forward and 1 mm backward was used. Also, previous researchers stated that the stress was reduced when rotational speed and torque were controlled.[18,19] Rotational speed was controlled at 300 rpm in the present study.

Previous studies have focused the impact of instrument itself.[4,10,14] Ha *et al*. demonstrated that cross-sectional geometry of NiTi rotary instruments may have an influence on screw-in effect.[4] Some instruments showed much greater screw-in effect than others. Existence of flat radial lands may be related to reducing the screw-in effect. The taper of NiTi instrument may have an influence on screw-in effect.[14] The size of the instrument's taper is directly proportional to the amount of screw-in force that is generated. There was no report on the screw-in effect by the modification of root canal morphology. Hence, the design of the present study attempted to investigate the possibilities to modify the root canal. In general, ISO size files have been used clinically. The #13 and #18 size groups were supplemented to evaluate the tendency of torque generation and screw-in force as stepwise increase of the root canal size. The commercially available simulated resin canal blocks used in this study had the tolerance of the manufacturing process. We chose blocks in which the ISO #13 Path File bound at short of the working length.

The force generated by the pecking motion could be classified into an axial component of force and torque. The axial components were the screw-in effect and the apically compressive force. The apically compressive force was negligible in this study. According to the results in the present study, lower values of torque were generated by establishing somewhat larger glide path. This result was in agreement with previous results which concluded the incidence of file breakage was reduced by the use of hand files before introducing rotary files.[12,13] Our finding was consistent with that of Schrader and Peters, that the torque was dependent on the canal size.[20] The simulated canal instrumented with #20 NiTi K-file showed a lesser screw-in effect than any other groups. It was postulated that the larger the size of the created glide path, the lesser the screw-in effect. Also, as NiTi rotary files moved forward, a larger screw-in effect and torque were generated. This might be due to the decreasing surface contact in larger root canal. At the moments that screw-in occurred, the torque applied to instruments was suddenly increased. This might cause unexpectedly file separation. In a situation such as thin dentin structure around apical foramen, the initiation of root crack might occur. In the #20 glide path group, the screw-in effect and torque decreased at the last 1 mm from the apical foramen. It might be related to the difference between glide path (ISO #20) and the tip diameter of ProTaper S1 (ISO #17). In group 3, although the size of glide path (#18) was larger than the tip size of ProTaper S1, the decrease of the screw-in effect and torque did not occur within 1 mm from the apical foramen.

The present study has limitations. First, this study was not investigated for the actual teeth. Second, the groups of #8 and #10 size glide path were not involved because of the absence of suitable simulated resin canal. Further studies are needed to investigate correlations between screw-in effect and strain on root surface.

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Conclusions

Within the limits of our study, it is possible to conclude that the establishment of a larger glide path before NiTi rotary instrumentation appears to be appropriate for reducing the screw-in effect. Especially important to note, by establishing #20 glide path in the canal, the screw-in effect and torque would be reduced near the apical foramen. It would be recommended to establish the #20 glide path with NiTi file when using ProTaper rotary instruments system safely.

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

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