Step by Step Analysis of Root Canal Instrumentation with ProTaper®

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ABSTRACT

The purpose of this study was to investigate influence of each file step of ProTaper® system on canal transportation.

Twenty simulated canals were prepared with either engine-driven ProTaper® or manual ProTaper®. Group R-resin blocks were instrumented with rotary ProTaper® and group M-resin blocks were instrumented with manual ProTaper®. Pre-operative resin blocks and post-operative resin blocks after each file step preparation were scanned. Original canal image and the image after using each file step were superimposed for calculation of centering ratio. The image after using each file step and image after using previous file step were superimposed for calculation of the amount of deviation. Measurements were taken horizontally at five different levels (1, 2, 3, 4 and 5 ㎜) from the level of apical foramen.

In rotary ProTaper® instrumentation group, centering ratio and the amount of deviation of each step at all levels were not significantly different ($p > 0.05$). In manual ProTaper® instrumentation group, centering ratio and the amount of deviation of each step at all levels except of 1 ㎜ were not significantly different ($p > 0.05$). At the level of 1 ㎜, F2 file step had significantly large centering ratio and the amount of deviation ($p < 0.05$).

Under the condition of this study, F2 file step of manual ProTaper® tended to transport the apical part of the canals than that of rotary ProTaper®. [J Kor Acad Cons Dent 31(1):50-57, 2006]

Key words: ProTaper, Step by step, Canal transportation, Centering ratio, The amount of deviation

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Ⅰ. Introduction

The aim of root canal instrumentation is to create a tapered shape with adequate volume to allow effective irrigation and obturation[1]. The ideal preparation of the root canal is a funnel shaped form with the smallest diameter at the apex and the widest diameter at the orifice[2]. However, traditional stainless steel (SS) instruments often failed in achieving these objectives, especially when in severely curved canals[3-5]. The bigger the size of the SS instrument, the more it tends to straighten up canal curvature in narrow and curved canal. It causes some problems like ledge, zip, perforation, and canal transportation which

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lead endodontic failure[6].

In order to eliminate some of the shortcomings of these SS instruments, rotary nickel-titanium (Ni-Ti) instruments have been developed. These instruments are two to three times more flexible than SS instruments and also markedly superior to SS instruments in terms of angular deflection and maximum torque to failure[7,8]. These new instruments have been found to be better than SS instruments in maintaining the original anatomy, shape and position of the apical foramen[9]. According to Glosson *et al.*[10] these instruments produce a better-centered and rounder canal preparation in comparison with SS instruments.

Many rotary Ni-Ti file systems have been introduced to the market. Most of these Ni-Ti file systems - e.g. ProFile® (Dentsply Maillefer, Ballaigues, Switzerland), K3™ (SybronEndo, Glendora, France), Hero642® (Micromega, Besancon, France) - have a constant tapered shaft design, while they have various rake angles and radial lands respectively[11-13]. Recently introduced ProTaper® system (Dentsply Maillefer, Ballaigues, Switzerland) which sales in two way of rotary and manual type, has been found to incorporate instruments of progressive multitaper design with sharp cutting blades. And it was designed to provide the fewest number of instruments that would afford improved flexibility, efficiency and safety[14]. It was claimed that ProTaper® system provides a continuous tapered preparation of the root canal, without significant transportation of the original position[15].

However, after the ProTaper® system was introduced, the possibility of more or less severe canal transportation produced by active cutting action was discussed. Peter *et al.*[16] showed that the ProTaper® system tends to transport canals slightly larger than other file systems with a passive cutting action by micro CT evaluation of shaped canal studies. Lee and colleagues[17] demonstrated that ProTaper® files remove too much canal structure and cause severe canal transportation than other files by the study using resin blocks.

The purpose of this study was to investigate that a certain file steps in the ProTaper® system influences on canal transportation mainly through analysis of root canal instrumentation step by step.

Ⅱ. Materials and Methods

Twenty simulated root canals in clear resin blocks (Endo Training Bloc; Dentsply Maillefer, Ballaigues, Switzerland) were used for this study. The root canals had a mean canal length of 17 ㎜ and mean curvature of 40° as determined by Schneider's method[18].

The canals were divided into two groups according to instrument. Group R-resin blocks were instrumented with rotary ProTaper® and group M-resin blocks were instrumented with manual ProTaper®.

1. Image taking of pre-operative blocks

The resin blocks were scanned in a reproducible position with a scanner (Scanjet® C8510A, Hewlett-Packard, California, USA). Aqueous red ink was injected into the canals to enhance the image contrast.

2. Instrumentation

Before the Ni-Ti files were used, the canals were explored with stainless steel #10 hand K-files until the tip was visible at the apical foramen. The working lengths were established to be 1 ㎜ short from the apical foramen. Canals were prepared with a crown-down method according to the recommended sequences of the manufacturers. RC-Prep® (Stone Pharmaceuticals, Philadelphia, USA) was used as a lubricant. During the procedures, all simulated canals were verified the patency with #10 hand K-file. The root canals were irrigated after each instrument use with normal saline dispensed through a 27-gauge needle (ENDO-EZE®, Ultradent, South Jordan, Utah, USA). Preparation sequence summarized at Table 1.

Table 1. Preparation sequence

Sequence	File	Working length (㎜)
1	S1	To resistance
2	SX	To resistance
3	S1	Working length
4	S2	Working length
5	F1	Working length
6	F2	Working length

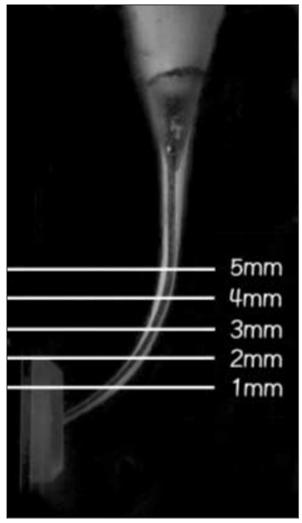

Figure 1. The horizontal lines mean the five measuring levels.

2-1. Rotary ProTaper® instrumentation

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. Rotary ProTaper® instruments were withdrawn when resistance was felt and changed for the next instrument. According to the manufacturer's recommendation, the measured length was 13 ㎜ when light resistance was felt using ISO stainless steel #15 K-file. Shaping file no.1 (S1) was used first to 13 ㎜ length. Then auxiliary shaping file (SX) was used to same length, followed by shaping files no.1 (S1) and no.2 (S2) to the working length for the shaping of the coronal two thirds of the canal. The apical one third was finished by using finishing files no.1 (F1) and no.2 (F2) sequentially to the working length.

2-2. Manual ProTaper® instrumentation

According to the manufacturer's recommendation, manual ProTaper® was inserted with clockwise rotation and gentle inward pressure until it started to bind against the canal wall. Next, the file was withdrawn with counterclockwise rotation regularly to remove debris and check flutes. Instrumentation sequence was the same in rotary ProTaper® instrumentation.

3. Image taking of post-operative blocks

After each file step preparation, aqueous methylene blue solution was injected into the enlarged canals. Acquired resin blocks were scanned again in a reproducible position. Original canal image and the image after using each file step were superimposed for calculation of centering ratio. The image after using each file step and image after using previous file step were superimposed for calculation of the amount of deviation. All of these superimposed images were assessed on a 17 inch TFT-LCD monitor (Sync Master® CX701N, Samsung, Suwon, Korea) using Adobe® Photoshop software and were observed at a magnification of 156 times. Measurements were taken horizontally at five different levels (1, 2, 3, 4 and 5 ㎜) from the level of apical foramen (Figure 1).

4. Measurement techniques

4-1. Centering ratio

Centering ratio was calculated using the following method: the absolute value of net transportation divided by whole width of the post-instrumented canal. Generally, centering ratio is calculated by comparing pre-and post-instrumented images after finishing the root canal preparation (Figure 2). But at this study, centering ratio was calculated after using each file; O-S1 file step, O-S2 file step, O-F1 file step and O-F2 file step.

4-2. Amount of deviation (The absolute value of net transportation)

Net transportation was determined from the discrepancy between outward and inward-instrumented width (Figure 2). At this study, the amount of deviation was calculated with the superimposed images using each file step image and previous file step image; O-S1 file step, S1-S2 file step, S2-F1 file step and F1-F2 file step.

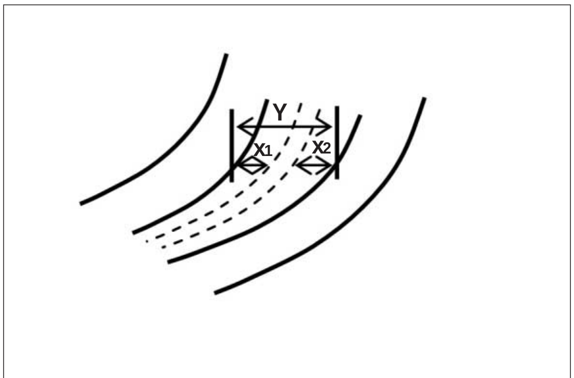

Figure 2. This drawing represents a measuring method. X1 represents the maximum extent of canal movements in one direction and X2 is the movement in the opposite direction. Y is the diameter of prepared canal by each step.

Centering ratio = |X1-X2|/Y × 100

Amount of deviation = |X1-X2|

5. Statistical analysis

Statistical analysis of the collected data was performed with ANOVA and Scheffe's multiple range test by SPSS™ version 10.0 (SPSS Inc., Chicago, IL, USA). Differences revealed in the data were designated as significant at $p < 0.05$.

Ⅲ. Results

1. Centering ratio of each step

In rotary ProTaper® instrumentation group, the centering ratio of each step at all levels were not significantly different ($p > 0.05$).

In manual ProTaper® instrumentation group, there were no significant differences in all levels except of 1 ㎜ ($p > 0.05$). At the level of 1 ㎜, the O-F2 file step showed the largest value, followed by O-F1 file step, O-S2 file step and O-S1 file step. It was significantly different between O-F2 file step and O-S1 file step ($p < 0.05$, Table 2).

2. Amount of deviation of each step

In rotary ProTaper® instrumentation group, amount of deviation of each step at all levels were not significantly different ($p > 0.05$).

Table 2. Centering ratio of each step (Mean ± SD)

Distance from apex		1 ㎜	2 ㎜	3 ㎜	4 ㎜	5 ㎜
O*-S1 file step	R†	11.9 ± 14.6 b b§	7.9 ± 10.0	8.6 ± 7.6	10.3 ± 14.4	18.2 ± 21.5
	M‡	12.8 ± 8.6 a b	14.4 ± 8.8	14.5 ± 9.5	10.9 ± 11.7	13.0 ± 10.0
O-S2 file step	R	17.4 ± 14.1 b b	15.5 ± 11.5	12.8 ± 14.0	17.0 ± 15.7	21.5 ± 21.2
	M	20.9 ± 13.0 ab	22.3 ± 12.5	21.0 ± 15.8	17.4 ± 12.4	13.6 ± 13.9
O-F1 file step	R	21.9 ± 15.7 b b	16.4 ± 14.1	12.0 ± 16.6	22.7 ± 14.8	25.0 ± 20.4
	M	26.1 ± 12.1 ab	26.5 ± 14.6	24.8 ± 16.3	20.0 ± 10.7	19.2 ± 13.8
O-F2 file step	R	26.5 ± 17.4 b b	19.6 ± 13.0	13.3 ± 14.2	27.7 ± 8.4	29.7 ± 16.0
	M	38.8 ± 22.7 b b	30.8 ± 22.9	26.2 ± 15.0	23.5 ± 14.9	28.6 ± 11.8

O*, Original canal

R†, Rotary ProTaper® instrumentation group

M‡, Manual ProTaper® instrumentation group

§ Significantl differences between steps ($p < 0.05$, Scheffe's test) were indicated by different superscripts alphabets.

Table 3. Amount of deviation (㎛) of each step (Mean ± SD)

Distance from apex		1 ㎜	2 ㎜	3 ㎜	4 ㎜	5 ㎜
O*-S1 file step	R†	42 ± 49 a§	30 ± 40	32 ± 29	42 ± 57	89 ± 104
	M‡	46 ± 30 a	52 ± 35	53 ± 35	42 ± 44	62 ± 48
S1-S2 file step	R	56 ± 57 a	43 ± 43	47 ± 39	60 ± 16	43 ± 27
	M	44 ± 52 a	59 ± 39	76 ± 56	69 ± 43	24 ± 38
S2-F1 file step	R	47 ± 48 a	38 ± 43	41 ± 28	45 ± 34	40 ± 33
	M	46 ± 56 a	42 ± 45	30 ± 26	36 ± 22	61 ± 47
F1-F2 file step	R	91 ± 78 a	55 ± 40	47 ± 39	79 ± 54	66 ± 34
	M	184 ± 108 b	132 ± 118	53 ± 27	73 ± 53	79 ± 43

O*, Original canal

R†, Rotary ProTaper® instrumentation group

M‡, Manual ProTaper® instrumentation group

§ Significantl differences between steps ($p < 0.05$, Scheffe's test) were indicated by different superscripts.

In manual ProTaper® instrumentation group, there were no significant differences in all levels except of 1 ㎜ ($p > 0.05$). At the level of 1 ㎜, the F1-F2 file step showed largest value, followed by S2-F1 file step, O-S1 file step and S1-S2 file step. F1-F2 file step was significantly different from results of other steps ($p < 0.05$, Table 3).

Ⅳ. Discussion

Recently introduced ProTaper® system represents a new generation of Ni-Ti instruments currently available. The basic series of ProTaper® files comprise six instruments, three shaping and three finishing files. The shaping files have a progressive taper sequence (increasing from tip to coronal) whereas the finishing files show a decreasing taper profile. It is claimed that the progressive taper sequence should enhance the flexibility of the files in the middle and at the tip region and that the decreasing taper sequence should enhance the strength of the files[19]. The manufacturer claims that these files are specially designed to instrument difficult, highly calcified, and severely curved root canals[20].

The manual ProTaper® system that was launched recently has served a dual purpose. On the one hand it has introduced nickel-titanium to the clinician, who had previously wished to try the method but did not feel comfortable making the quantum leap to rotary NiTi system and on the other, it has been aimed as additional armamentarium for the clinician using rotary NiTi system, faced with more delicate, complex preparation or acute canal curvatures in apical regions[21]. Manual ProTaper® system has two advantages compared to rotary ProTaper®. First, it can be used in abrupt curvature with prebent instrument when pathway established by traditional hand files. Second, instrument separation is low due to good tactile feedback[22].

Several researches have studied for the safety and the efficiency of ProTaper® system. The study using mathematic models have demonstrated that ProTaper® instruments work longer in a super elastic phase than do instruments with a U-file design, allowing for high performance and less risk[23]. According to Calberson *et al.*[24], ProTaper® instruments performed acceptable tapered preparations in all canal types. Iqbal *et al.*[25] reported that ProTaper® system is able to optimally enlarge root canal with minimal transportation and loss of working length in *in vitro* study compared with ProFile® system.

On the other hand, recently published study[26] demonstrated that varying degrees of canal straightening and transportation towards the outer aspect of the curvature were evident when curved canal enlarged with ProTaper® instruments. Schäfer *et al.*[27] reported that ProTaper® tended to transport towards the outer aspect of the canal curve. Peters *et al.*[16] reported that ProTaper® design may also increase the incidence of procedural errors and overall canal transportation whilst the modified cutting flute of ProTaper® instruments may reduce friction and consequently torque.

Based on the results of this study, in rotary ProTaper® instrumentation group, centering ratio and the amount of deviation of each file step were not significantly different. To the contrary, in manual ProTaper® instrumentation group, F2 file step at apical 1 ㎜ level had significantly large centering ratio and the amount of deviation.

Consequently, F2 file step of manual ProTaper® tended to transport the apical part of the canals than that of rotary ProTaper®. One possible explanation for this result may be related uneven rotational speed and torque, because clinicians use manual ProTaper® at their convenience.

Finishing files are greater in diameter than other Ni-Ti files at the same level of the root canal because of progressively different parabolic tapers[28]. This results in thicker and stiffer instruments. And they cause high lateral forces in curved canals. These restoring forces attempt to return the file to its original shape and act on the outer side on the canal wall during preparation, result in canal straightening and ledging. Therefore, manufacturer recommended that clinicians take the finishing files to the estimated length only once and remove them as soon as possible for proper shaping and to prevent canal aberrations[28].

Previous studies[27,28] comparing rotary ProTaper® system with other rotary Ni-Ti system have been reported about greater canal transportation tendency of rotary ProTaper® system. In the present study, no statistically significant differences were observed in canal transportation tendency of each file step of rotary ProTaper® system. But F2 file step of manual ProTaper® system showed greater canal transportation tendency at apical 1 ㎜ level. Consequently, it is expected that clinicians can use rotary ProTaper® more accurately than manual ProTaper®.

Ⅴ. Conclusion

In manual ProTaper® instrumentation group, F2 file step had significantly large centering ratio and the amount of deviation at the level of 1 ㎜ ($p < 0.05$).

Under the condition of this study, F2 file step of manual ProTaper® tended to transport the apical part of the canals than that of rotary ProTaper®.

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국문초록

ProTaper를 이용한 근관 형성의 단계별 분석

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이 연구의 목적은 ProTaper® system을 사용하였을 때, 각 단계별로 근관 형성 결과를 분석 하는 것이다.

20개의 레진 블락을 근관 성형 방법에 따라, 엔진 구동형 ProTaper®로 전체 근관을 성형한 군을 R군, 수동형 ProTaper®로 전체 근관을 성형한 군을 M군으로 하였다. 근관의 술 전, 술 후 이미지를 각 파일 단계별로 스캔한 후, 중심이동률 산출을 위해 원래의 근관 이미지와 각 단계의 파일 사용후의 이미지를 각각 중첩하였고, 근관의 변위량 산출을 위해 각 단계의 파일 사용후의 이미지와 직전 파일 사용후의 이미지를 중첩하였다. 근단공으로부터의 수직거리 1, 2, 3, 4 그리고 5 ㎜ 위치에서 중심이동률과 근관의 변위량을 측정하였다.

실험 결과, R군의 모든 지점에서 각 단계별 중심이동률과 근관 변위량은 각각 유의한 차이가 없었다 ($p > 0.05$). M군에서 1 ㎜를 제외한 모든 지점에서 각 단계별 중심 이동률과 근관 변위량은 각각 유의한 차이가 없었다 ($p > 0.05$). 그러나 M군의 1 ㎜ 지점에서 F2 file step은 통계학적으로 큰 중심 이동률과 근관 변위량을 보였다 ($p < 0.05$).

본 연구의 결과에서 엔진 구동형 ProTaper® 사용 시에는 각 파일 단계별 근관 변위 정도에 유의한 차이가 없었으나, 수동형 ProTaper®로 근관 성형을 하였을 때, F2 file step에서 특히 근관 변위가 크게 나타났다.

주요어: ProTaper, 단계별, 근관변위, 중심이동률, 변위량