

## Comparison of shaping ability between single length technique and crown-down technique using Mtwo rotary file

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### ABSTRACT

The aims of this study were to compare the shaping effect and safety between single length technique recommended by manufacturer and crown-down technique using Mtwo rotary file and to present a modified method in use of Mtwo file.

Sixty simulated root canal resin blocks were used. The canals were divided into three groups according to instrument and the manner of using methods. Each group had 20 specimens. Group MT was instrumented with single length technique of Mtwo, group MC was instrumented with crown-down technique of Mtwo and group PT was instrumented with crown-down technique of ProTaper. All of the rotary files used in this study were operated by an electric motor. The scanned canal images of before and after preparation were superimposed. These superimposed images were evaluated at apical 1 to 8 mm levels. Angle changes were calculated. The preparation time, weight loss, instrument failure and binding, canal aberrations, and centering ratio were measured. Statistical analysis of the three experimental groups was performed with ANOVA and Duncan's multiple range tests for post-hoc comparison and Fisher's exact test was done for the frequency comparison.

In total preparation time, group MT and group MC were less than group PT. In the aberrations, group MT had more elbows than those of group MC and group PT. The binding of group MC was least and group MT was less than group PT ( $P < 0.05$ ).

Under the condition of this study, crown-down technique using Mtwo rotary file is better and safer method than single length technique recommended by the manufacturer. [J Kor Acad Cons Dent 32(4):385-396, 2007]

**Key words** : Mtwo file, Single length technique, Crown-down technique, Shaping ability, Binding

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## I . INTRODUCTION

Root canal preparation with nickel-titanium (NiTi) rotary instruments is easier and faster than with hand instruments<sup>1)</sup>. NiTi instruments have two to three times higher elastic flexibility and a superior resistance to torsional fracture, compared with similar-sized conventional stainless steel instruments<sup>1-5)</sup>. Also, rotary instrumen-

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tation facilitates the maintenance of the original canal shape and the position in space of the apical foramen<sup>6)</sup>. Therefore those instruments can effectively produce a well-tapered root canal form sufficient for obturation with minimal risk of transporting the original canal, and are useful to the preparation of curved root canals<sup>1,3-5,7)</sup>.

Various NiTi instrument systems have been introduced in the market: ProTaper (Dentsply Maillefer, Ballaigues, Switzerland), ProFile (Dentsply Maillefer, Ballaigues, Switzerland), Hero642 (Micromega, Besancon, France), K3 (SybronEndo, Glendora, France), etc. Generally, crown-down instrumentation sequence has been recommended for most of the rotary NiTi instruments, in which larger files precede smaller ones to progress further apically in turn<sup>8)</sup>. The coronal preflaring might help to reduce the incidence of canal aberrations, and provide a better conical and tapered preparation that makes irrigation and spreader penetration easier<sup>9)</sup>. Also, this technique is mandatory to reduce intracanal friction and thus to minimize the risk of instrument separation<sup>10)</sup>.

Recently, new rotary NiTi instruments with different configuration and design have been marketed as Mtwo (VDW, Munich, Germany). The Mtwo instruments have a S-shaped cross-sectional design and a non-cutting safety tip. These instruments are characterized by a positive rake angle with two cutting edges. Moreover, Mtwo instruments have an increasing pitch length from the tip to the shaft. According to the manufacturer, the instruments should be used in a Single Length Technique and they claimed that it is easier than other method using variable working

length. That means all files of the instrumentation sequence should be used to the full length of the root canal. This instrumentation technique is different from general method of rotary NiTi instruments<sup>10)</sup>.

The Mtwo instruments cut dentine with their entire length and could advance all the way to the apex from the beginning of the sequence; consequently they are likely to be stressed more than other NiTi rotary instruments used in a crown-down progression then to make more canal aberrations and increase the risk of torsional fracture<sup>11)</sup>.

Thus the aims of this study were to present a method of crown-down technique using Mtwo instruments and to compare the shaping ability and safety between single length technique and crown-down technique using Mtwo rotary instruments.

## II . MATERIALS AND METHODS

### 1. Simulated root canals

Sixty 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 mm and mean curvature angle of 40°.

Aqueous methylene blue dye was injected into the canal to enhance the contrast of the pre-instrumentation image. These resin blocks were scanned in a reproducible position with a scanner (Scanjet C8510A; Hewlett-Packard, California, USA), and then the data were stored in a personal computer.

**Table 1.** Classification of groups

Group	Instrument	Manner of using	Sample number
MT	Mtwo	Single length technique	20
MC	Mtwo	Crown-down technique	20
PT	ProTaper	Crown-down technique	20

## 2. Classification of groups

The simulated canals were divided into three groups according to the used instrument and the manner of using methods (Table 1). Each group had 20 specimens. Group MT resin blocks were instrumented with single length technique of Mtwo, group MC resin blocks with crown-down technique of Mtwo and group PT resin blocks with crown-down technique of ProTaper.

## 3. Preparation

All of the rotary NiTi files used in this study were operated by an electric motor (X-Smart; Dentsply Maillefer, Ballaigues, Switzerland) set at 250 r.p.m. and torque of 2.2 N without auto-reverse function to count the frequencies of instrument binding. These setting values were within the range suggested at the manufacturer's operation manuals. The use of files was also in accordance with the manufacturer's recommendation.

During the preparation, canals were verified the patency with #10 K-Flexofile (Dentsply Maillefer, Ballaigues, Switzerland), then irrigated, and lubricated with RC-prep (Stone Pharmaceuticals, Philadelphia, USA) repeatedly after instrumentation. Files were wiped regularly with a sponge to remove resin debris. All files used in this study

were new. The root canals were copiously irrigated with water dispensed through a 27-gauge needle (ENDO-EZE; Ultradent, South Jordan, USA) after using each instrument. After filing, apical gauging was verified with #25 K-Flexofile.

### 1) Group MT

The Mtwo file system is composed of .04 / #10, .05 / #15, .06 / #20 and .06 / #25 for basic sequence and .05 / #30, .04 / #35, .04 / #40 and .07 / #25 for further shaping.

In group MT, all Mtwo instruments were used to the full length of the canals according to the manufacturer's instructions of basic sequence using a gentle in-and-out motion. The instrument was used as following sequence (Table 2).

Once the instrument had negotiated to the end of the canal and had rotated freely, it was removed.

### 2) Group MC

The instrumentation sequence of group MC was designed through the preliminary test of preparation using simulated canal of resin block.

In group MC, Mtwo instruments were used in crown-down manner. Instruments were withdrawn when resistance was felt and changed to the next instrument. The instrument was used as following sequence (Table 2).

**Table 2.** The using sequences of each experimental group

Sequence	Group MT		Group MC		Group PT	
	File	WL	File	WL	File	WL
1		WLM	.07 / #25	restricted depth	S1	restricted depth
2	.04 / #10	full length	.06 / #20	further depth	WLM	
3	.05 / #15	full length	WLM		S1	full length
4	.06 / #20	full length	.05 / #15	full length	S2	full length
5	.06 / #25	full length	.07 / #25	WL - 3 mm	F1	full length
6			.06 / #20	full length	F2	full length
7			.07 / #25	WL - 2 mm		
8			.06 / #25	full length		

WL: Working Length

WLM: Working Length Measurement

### 3) Group PT

ProTaper instruments were also used in crown-down manner according to the manufacturer's instructions using a gentle in-and-out motion (Table 2).

## 4. Image taking and superimposition

After the root canal preparation was completed, enlarged canals were filled with Vitapex (Neo Dental Chemical Products co., LTD, Tokyo, Japan) to enhance the contrast of the post-instrumentation image. Then the resin blocks were scanned again using the reproducible position. The pre- and post-instrumented canal images were superimposed on one another with the guide of attached label using Adobe Photoshop ver.7.0 (Adobe, San Jose, California, USA) (Figure 1). These superimposed images of  $2736 \times 944$  pixel size were inspected on the TFT-LCD monitor (SyncMaster CX1565N; Samsung, Suwon, Korea) of  $1024 \times 768$  screen resolutions. These images were used to evaluate the centering ratio and canal curvature (Figure 2).

## 5. Measurement and calibration

### 1) Reduction of root canal curvature

The reduction of root canal curvature after preparation was calculated with the Schneider method<sup>12,13</sup>.

### 2) Centering ratio

Instrumented widths were measured linearly from the pre-instrumented point to the post-instrumented wall inwardly and outwardly. Measurements were taken horizontally at eight different levels (1, 2, 3, 4, 5, 6, 7 and 8 mm) from the level of apical foramen (Figure 3). These values were used to calculate the instrumented canal width and post-instrumented canal diameter<sup>14</sup>.

The centering ratio was computed to evaluate the movement of root canal's center after preparation. The ratio was calculated using the following method: the absolute value of net transportation divided by whole width of the post-instru-

mented canal. The centering ratio is a measure of the ability of an instrument to stay centered in the canal<sup>15-17</sup>.

### 3) Canal aberrations

Assessments were made according to the presence of various types of canal aberrations such as apical zip, elbow and ledge using the scanned post-instrumented images.

### 4) Weight loss

The weights of resin blocks were measured before and after preparation using ANALYTICAL Plus Balance (AP110; OHAUS, Pine Brook, NJ, USA). Loss of the weight was calculated by subtracting the post-instrumented weight from the pre-instrumented one.

### 5) Instrumentation time

Instrumentation time was recorded in seconds by one assistant. The recorded time excluded the time for irrigation, changing instruments and patency.

### 6) Instrument binding

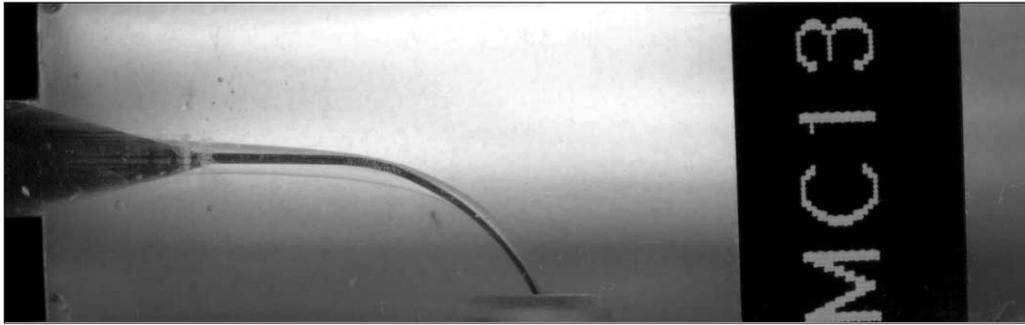
The frequencies of instrument locking were counted during the full sequence of instrumentation.

### 7) Instrument distortion

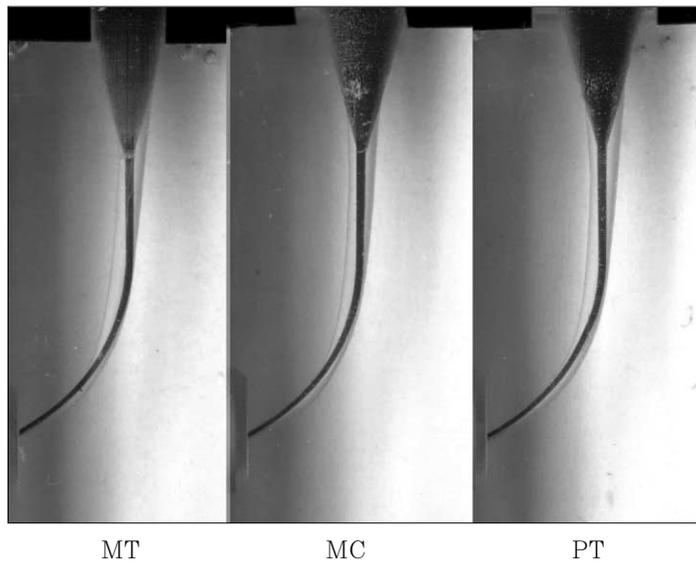
After root canal preparation, the distortion of NiTi file was evaluated under the OPMI pico Surgical Microscope (Carl Zeiss, Oberkochen, Germany) at 25-fold magnification.

## 6. Statistical analysis

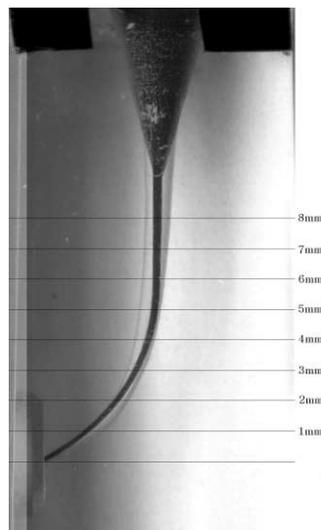
Statistical analysis of the collected data was performed with SPSS version 10.0 (SPSS Inc., Chicago, IL, USA). Mean scores for each group were statistically compared using ANOVA and Duncan's Multiple Range Test for post-hoc comparison. The Fisher's exact test was done for evaluation of canal aberration and instrument binding. Differences revealed in the data were designated as significant at  $p < 0.05$ .



Purple: Pre-instrumented canal, Yellow: Post-instrumented canal  
**Figure 1.** Sample of superimposed image.



**Figure 2.** The representative images of three superimposed groups.



**Figure 3.** The horizontal lines mean the 8 measuring levels.

### III . RESULTS

#### 1. Reduction of canal curvature

There was no significant difference in the reduction of root canal curvature (degree) between groups ( $p > 0.05$ ) (Table 3).

#### 2. Centering ratio

Three superimposed images of pre- and post-instrumented blocks are represented in Figure 2. The centering ratio of each level had no significant

difference between groups ( $p > 0.05$ ) (Table 4).

#### 3. Canal aberrations

The group MT showed more elbows than group MC and group PT ( $p < 0.05$ ) (Table 5). Ledge was not occurred in any group.

#### 4. Weight loss

There was no significant difference in weight loss of resin block after preparation between groups ( $p > 0.05$ ) (Table 6).

**Table 3.** Reduction of canal curvature (degree)

Group	MT	MC	PT	p-value
Mean $\pm$ SD	3.950 $\pm$ 0.930	3.975 $\pm$ 0.866	4.200 $\pm$ 1.018	0.653

There was no significant difference between groups ( $p > 0.05$ ).

**Table 4.** Centering ratio at each level (Mean  $\pm$  SD)

Level	MT	MC	PT	p-value
1	52.49 $\pm$ 11.56	52.84 $\pm$ 09.00	52.08 $\pm$ 12.13	0.976
2	34.02 $\pm$ 20.14	37.56 $\pm$ 15.26	34.87 $\pm$ 17.90	0.808
3	22.00 $\pm$ 19.46	15.32 $\pm$ 11.27	17.13 $\pm$ 14.21	0.369
4	43.14 $\pm$ 19.44	38.26 $\pm$ 18.24	38.55 $\pm$ 17.11	0.640
5	50.35 $\pm$ 16.35	44.55 $\pm$ 19.06	42.22 $\pm$ 16.02	0.313
6	35.95 $\pm$ 15.59	28.07 $\pm$ 15.99	24.58 $\pm$ 15.99	0.076
7	19.72 $\pm$ 13.09	14.96 $\pm$ 12.13	13.72 $\pm$ 11.04	0.264
8	14.52 $\pm$ 10.71	13.29 $\pm$ 10.23	14.94 $\pm$ 10.34	0.875

There was no significant difference between groups in all levels ( $p > 0.05$ ).

**Table 5.** Canal aberrations

Group	MT	MC	PT	p-value
Zip & Elbow	10/20 <sup>A</sup>	3/20 <sup>B</sup>	2/20 <sup>B</sup>	0.010

A,B: Groups identified by different superscript alphabets are significant different ( $p < 0.05$ ).

### 5. Instrumentation time

In instrumentation time, the group MT and group MC required shorter preparation time than group PT ( $p < 0.05$ ). Despite of the frequency of instrument change, group MC showed no significant difference with group MT (Table 7).

### 6. Frequency of instrument binding

The group MC had the least frequency of file binding and the group PT had the most ( $p < 0.05$ ) (Table 8).

**Table 6.** Weight loss (gram)

Group	MT	MC	PT	p-value
Mean $\pm$ SD	.0056 $\pm$ .0124	.0027 $\pm$ .0006	.0042 $\pm$ .0042	0.496

There was no significant difference between groups ( $p > 0.05$ ).

**Table 7.** The preparation time in each system (sec)

Group	MT	MC	PT	p-value
Mean $\pm$ SD	153.65 $\pm$ 27.28 <sup>A</sup>	154.15 $\pm$ 7.29 <sup>A</sup>	215.45 $\pm$ 25.76 <sup>B</sup>	0.000

A,B; Groups identified by different superscript alphabets are significant different ( $p < 0.05$ ).

**Table 8.** Frequency of instrument binding

Group	MT	MC	PT	p-value
Mean $\pm$ SD	1.50 $\pm$ 1.14 <sup>B</sup>	0.70 $\pm$ 0.73 <sup>A</sup>	2.35 $\pm$ 1.66 <sup>C</sup>	0.000

A,B,C; Groups identified by different superscript alphabets are significant different ( $p < 0.05$ ).

**Table 9.** Instrument distortion

Group	MT	MC	PT	p-value
Distortion	2/20	0/20	0/20	0.322

There was no significant difference between groups ( $p > 0.05$ ).

## 7. Instrument distortion

In group MT, there were 2 files of distortion. These 2 files were .04 / #10. But, there was no significant difference between three groups ( $p > 0.05$ ) (Table 9). Instrument fracture was not occurred in any group.

## IV. DISCUSSION

Recent advances in the field of endodontics have led to the use of nickel titanium rotary instruments in dental practice. The NiTi rotary instrumentation has several advantages compared to stainless steel hand instrumentation<sup>1)</sup>. During the last a few years the number of users has increased significantly and many new systems have been on the market. When a new system is introduced, clinicians should keep the manufacturer's recommendation and the basic principle of canal preparation for successful clinical application.

The Mtwo system is one of the NiTi instruments currently available. The manufacturer's recommended instruction for usage of Mtwo rotary instruments is different from general method of other NiTi rotary system. The Single Length Technique suggested by manufacturer seems to induce more stress to the instruments and more screwing.

The purposes of this study were to compare the shaping effect and safety between single length technique and crown-down technique and to suggest more safe method using Mtwo rotary instrument.

The ProTaper system is an active file system which has the flute of blade type and Mtwo system has same type of flute. The cross-section of Mtwo file is S-shape while that of ProTaper is triangular<sup>18)</sup>. There were a few reports about Mtwo rotary<sup>11,18,19)</sup>, however, several researches have been studied for the safety and the efficiency of crown-down technique using ProTaper system<sup>20-22)</sup>. The study using mathematic models have demonstrated that ProTaper instruments work longer in a super elastic phase than instruments with a U-

file design, allowing for high performance and less risk<sup>20)</sup>. According to Calberson et al.<sup>21)</sup>, ProTaper instruments performed acceptable tapered preparations in all canal types. Iqbal et al.<sup>22)</sup> reported that ProTaper system is able to optimally enlarge root canal with minimal transportation and loss of working length in vitro study compared with ProFile system. Thus, the ProTaper instruments served as controls in order to ensure the results obtained from Mtwo rotary instrument with crown-down technique under identical experimental conditions.

There was no significant difference in the reduction of root canal curvature (degree), centering ratio of each level and weight loss of resin block after preparation between three experimental groups.

From the view point of centering ratio, the smaller the ratio, the better the instrument remained centered in the canal<sup>15-17)</sup>. In the present study, the centering ratios at the levels of 1 mm and 5 mm indicate that all experimental groups deviated severely. Several researches<sup>23-25)</sup> about ProTaper reported the large centering ratio and transportation tendency after completion of root canal preparation at apical portion.

Mtwo system also showed similar apical deviation and coronal straightening regardless of using manner. It might be resulted from morphologic similarity of file flute and cutting tendency to ProTaper. The change in using sequence of Mtwo instrument makes no difference in qualitative and quantitative outcomes of root canal preparation. From the viewpoint of apical centering, regardless of using manner of Mtwo instruments, it is demanded to use carefully especially in apical canal portion as well as ProTaper.

One of the main problems inherent in the rotary preparation by clinicians is the instrument fracture<sup>9)</sup>. In this study, there was no statistical difference in instrument distortion that occurred only group MT, which can be interpreted due to using new files in each canal<sup>26)</sup> and the adoption of torque control motors for the experiment<sup>26,27)</sup>. The fact that none of the Mtwo files fractured after enlargement of canal may be due to the

increasing pitch length from the tip to the shaft of these instruments<sup>8</sup>). As already reported, a varying pitch length along the working part of the instrument reduces the screw-in tendency of the file to minimize the risk of instrument fracture<sup>28</sup>).

However, some care should be taken using the Mtwo files with single length technique because of the occurrence of permanent deformations of the group MT. Although no statistical difference between groups, two Mtwo instruments were deformed permanently in group MT. Consequently, if the files are used repeatedly, instruments could be fractured.

In instrumentation time, the group MT and group MC required shorter preparation time than group PT. Despite of the frequency of instrument change, the group MC showed no significant difference from group MT. Although the preparation by group MC needed three more files than group MT, group MC needed no more preparation time. It seemed that enlarged coronal canal by crown-down usage of Mtwo file would facilitate the access to apical canal and this could shorten the time lapse of each step in group MC than that of group MT. In other studies<sup>14,24</sup>) to compare ProTaper and other instruments, instrumentation time with ProTaper was shorter than other systems under identical experimental conditions. But in this study, the Mtwo file showed shorter preparation time than ProTaper, regardless of using method of Mtwo file. This result could not be compared to other study because there was no report to compare these two systems.

The group MT showed more elbows than group MC and group PT. There was no ledge formation in any group. The aberration (elbow) might leave a significant portion of un-instrumented canal wall which would be difficult to obturate<sup>29</sup>). In ProTaper system, tooth structure can be removed excessively when this instrument is left in the canal too long with its active design<sup>21</sup>). It is therefore of utmost importance to follow the manufacturer's instructions and not to leave the ProTaper to prepare the root canal for longer than 1 second or not to use the ProTaper too much when reaching the desired working length<sup>14</sup>). This precaution

would also be applied in Mtwo instruments of group MT in which showed more aberrations.

These aberrations might be produced by the using manner of single length technique. It is assumed that group MT might make apical aberrations similar to many aberrations in apical shaping of step-back technique resulted from insufficient coronal flaring. The coronal preflaring might help to reduce the incidence of canal aberrations in group MC. And these aberrations can be diminished more through several pre-clinical trial uses especially with newly introduced instrument.

The group MC had the least frequency of file binding and the group PT had the most. The Mtwo system was used, in group MT, according to the sequence suggested because each of these instruments is claimed to be able to enlarge the whole canal. The resin debris attached to file flute was shown in entire file length in group MT but a portion of flute in group MC. The Mtwo instruments of group MT cut dentine with their entire length and could advance all the way to the apex from the beginning of the sequence, consequently they are likely to be stressed more than the instruments used in a crown-down progression<sup>11</sup>). In crown-down technique, the use of larger and high taper instruments initially can lead to an unobstructed apical access for the smaller files<sup>30</sup>). This principle can make safe usage of NiTi file with minimal binding or screwing and most of NiTi systems follow this manner of sequence. In the preliminary investigation for modification of the recommended sequence, the .04 / #10 file was revealed to work less in the simulated canal because the favorable coronal flaring attained already with .07 / #25 file and .06 / #20 file before working length measurement. Then in MC group, the .04 / #10 file was omitted. These modified sequences seemed to lessen the binding frequency.

The crown-down technique of instruments reduced contact area and reduced engagement zone. Torque was correlated with apically directed force and contact areas<sup>31</sup>). As binding increases, torsional stress by locking file tip into canal wall

seems to introduce the high torsional stress and exceeds the elastic limit that leads to plastic deformation and ductile fracture<sup>32)</sup>. Likewise, group MT seems to introduce more torsional stresses as the binding increases. According to Sattapan et al<sup>32)</sup>, the taper lock effect is believed to occur when instruments with the same taper, but varying tip diameters in step-back method, are wedged into a canal, possibly leading to torsional overloading of the instrument tip. The Mtwo file in group MT showed much more taper lock effect than group MC, especially in the instant of reaching at working length.

The single length technique of group MT seems to be similar to the apical shaping procedure from initial apical file to master apical file in step-back method. The Quantec file, one of the systems early introduced, used a sequence of same working length through the apical preparation stage of gradually increasing taper with same apical tip size<sup>33)</sup>. This system is not used in these days because it seems to have high risk of fracture from taper lock.

The frequency of binding, in this study, might be influenced by operator's proficiency. The operator proficiency, undoubtedly, is a significant factor in reducing fracture incidence of NiTi rotary instruments, probably by avoiding the screwing<sup>31)</sup>. The untrained operator probably exerts excess apical pressure on instrument in the canal. Consequently, the instruments locks into the canal and are subjected to high level torque. Instrument deformation occurs and the incidence of separation increase significantly. The preclinical training is a prerequisite to increase the reliability of the instrumentation technique as well as keeping the technical guidelines strictly.

The simulated canals in clear resin blocks were used to control the experimental conditions of this study that might influence the shaping abilities of the instruments. The simulated canals in resin blocks used in this study does not permit the action of the instruments in root canals of real teeth because of differences in the surface texture, hardness and cross-section. However, resin blocks allow a direct comparison of the shaping

ability of different instruments and studies on extracted teeth fully confirmed observations made on resin blocks<sup>3,5)</sup>. As use of simulated canals in resin blocks would have more binding of instruments, the study of with the use of real teeth will be necessary.

From the present results of this study, we can suggest that crown-down technique using Mtwo rotary file not only showed similar shaping ability to single length technique recommended by manufacturer but also seemed to have more safety.

## V. CONCLUSION

Under the limited condition of this study, crown-down technique using Mtwo rotary file not only showed similar shaping ability to single length technique recommended manufacturer but also seems to have more safety to minimize the binding or screwing which can induce the torsional fracture.

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## 국문초록

### Mtwo 전동 파일을 사용한 single length technique과 crown-down technique의 근관성형 효율 비교

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이 연구의 목적은 Mtwo 전동 파일의 사용에 있어서 제조사가 제안한 single length technique과 crown-down technique의 근관성형효율과 안전성을 비교하고 Mtwo 전동 파일의 변형된 사용방법을 제안하고자 하는 것이다. 기구의 종류와 사용방법에 따라 60개의 레진 블록 근관 모형 (Endo Training Bloc: Denstply Maillefer, Ballaigues, Switzerland)을 세 군으로 나누어 20개씩 표본을 성형하였다. MT군은 Mtwo 파일 (VDW, Munich, Germany)을 제조사의 추천방법인 single length technique으로, MC군은 Mtwo 파일을 crown-down technique으로 형성하였고, 대조군인 PT군은 ProTaper (Denstply Maillefer, Ballaigues, Switzerland)를 사용하였다. 모든 기구는 250 r.p.m., torque 2.2 N로 고정된 전동 모터 (X-smart: Denstply Maillefer, Ballaigues, Switzerland)로 사용하였다. 근관 성형 후, 스캐너로 근관 형성 전후의 이미지를 채득하여 중첩 비교함으로써 근단부로부터 1, 2, 3, 4, 5, 6, 7, 8 mm 높이에서의 중심변위율을 산출하였다. 순수 기구조작 시간 및 기구조작 동안의 binding 빈도를 기록하였다. 근관 성형 후, 레진 블록의 무게 감소를 측정하였고 근관 성형에 사용된 파일의 파절이나 변형 및 근관 성형 후 형태의 이상을 조사하였다. 세 실험군의 측정 및 산출된 자료를 일원배치 분산분석 및 Duncan's Multiple Range Test로 사후 검정을 시행하여 비교하였으며, Fisher's exact test으로 근관의 이형성, 기구의 변형 그리고 기구 binding 등 발생 빈도를 유의 확률 95%에서 통계 검정하였다.

그 결과는 다음과 같다.

1. 근관의 만곡도 감소, 중심변위율, 레진 블록의 무게 감소, 기구 변형 등은 세 군간에 유의한 차이가 없었다 ( $p > 0.05$ ).
2. 기구 조작 시간은 보면 MT군과 MC군이 PT군보다 짧았다 ( $p < 0.05$ ).
3. Elbow는 MT군이 MC군에서 PT군보다 더 많이 형성되었다 ( $p < 0.05$ ). Ledge는 세 군 모두에서 나타나지 않았다.
4. 파일 binding 횟수는 MC군이 가장 적고 PT군이 가장 많았다 ( $p < 0.05$ ).

이상의 결과를 볼 때, Mtwo 전동 파일을 crown-down technique으로 사용하는 것이 single length technique과 유사한 성형 효율을 보이면서도 더 안전할 것으로 추정된다.

**주요어:** Mtwo file, Single length technique, Crown-down technique, 성형 능력, Binding