치의학 박사학위논문

Clinical Efficiency of the Reciprocating Nickel-Titanium Instruments according to the Canal Anatomy

근관형태에 따른 reciprocating Nickel-Titanium instruments의 임상적 효율에 관한 연구

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치의학과 치과보존학 전공

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이 논문을 치의학 박사학위논문으로 제출함

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Abstract

Clinical Efficiency of the Reciprocating Nickel-Titanium Instruments according to the Canal Anatomy

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Introduction

The application of the single-file technique using the reciprocating motion is gaining concern in root canal preparation. The purpose of this research is to compare the efficiency of the reciprocating motion-employing files (RECIPROC and WaveOne) by measuring the working time to achieve complete canal preparation, and to analyze the varying factors that may influence their efficiency.

Materials and methods

One hundred curved root canals of the extracted molars were used. The working length

was determined and the glide path was confirmed using a #15 K-file. Canals shaping was completed to the length either with RECIPROC R25 file (n=50), or with WaveOne Primary file (n=50). The time taken for the file to reach the working length was measured. Each file was repeatedly used in a maximum of 10 canals for comparing the change of the efficiency (preparation time) according to the working length, canal curvature, and number of file re-use. The microscopic surface features of the files after use were observed using a scanning electron microscope (SEM).

Results

WaveOne Primary file showed significantly shorter working time than RECIPROC R25 ($p < .05$). There was a statistically significant correlation between the working time and 3 variables (working length, canal curvature, number of file re-use). There were no significant changes under the SEM on the 2 file groups in the formation and propagation of microcracks or tip abrasions until they were re-used up to 5 canals.

Conclusion

Within the limits of this study, WaveOne Primary had better clinical efficiency than RECIPROC R25 in preparation time. Although the manufacturers recommend discarding the files after single use, they could be re-used more than once.

Key words: preparation time, reciprocating motion, working length, canal curvature, clinical file efficiency, reusability

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Introduction

The use of Nickel-Titanium (NiTi) rotary instruments has become popular in the root canal treatment. Employing the NiTi rotary instruments in the root canal preparation has reduced procedural errors allowing for more predictable and efficient outcomes (1-3). Every clinicians hope for a more efficient-easy and quick-and yet safe method which they can be used to the root canal preparation protocols. In the hopes of satisfying these needs, there have been many improvements in the designs of the NiTi files (1, 4, 5) or the manufacturing methods (6, 7).

The appearance of the single-file technique using the reciprocating motion (8) seems to take these demands of the clinicians into consideration. Recently, two new types of files based on the reciprocating motion have been introduced to the market: RECIPROC (VDW, Munich, Germany), and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland). Each system consists of 3 single-use files. RECIPROC is composed with R25 (ISO 25 size tip and 8% taper), R40 (ISO 40 and 6%), and R50 (ISO 50 and 5%), whereas WaveOne with Small (ISO 21 and 6%), Primary (ISO 25 and 8%), and Large (ISO 40 and 8%). These files are designed to complete the canal preparation with one single-file. For this purpose, RECIPROC R25 or WaveOne Primary file can be selected for the majority of root canal treatment cases.

The efficiency of the file is related to many factors. In this regard, a number of researches have been carried out by focusing on the different variables posed by the files themselves; difference in the efficiency according to the cross-sectional design (5), surface treatment (6, 10), manufacturing method (7), and repeated sterilization (9) of the

files. Kim et al (11) recently demonstrated that WaveOne file showed much better metallurgical property than ProTaper files when it was used in reciprocating motion. However, studies on the surface microstructure of the single-file reciprocating systems and the influences of the factors, such as the nature of root canals in which the files were to be used, are insufficient.

Therefore, the aim of this study is to examine the characteristics of the reciprocating motion-employing files (RECIPROC and WaveOne) after clinical use and to evaluate the efficiency of the file by analyzing the varying factors (working length, root canal curvature, and the number of file re-use) that may influence its efficiency to achieve complete canal preparation.

Materials and Methods

One hundred root canals (the mesial canals of the mandibular molars and the buccal canals of the maxillary molars) of fifty extracted molars have been used in this research. The extracted human teeth were collected from the extract pools of the Department of Oral and Maxillofacial Surgery, Seoul National University Dental Hospital and selected randomly. The teeth, which canals were matched at root apex, were excluded.

The working length was decided by the following method: a #10 K-file was inserted up to the apical foramen and from which 1mm was deducted. Radiographs were taken from two different positions (the bucco-lingual, and mesio-distal) while the #10 K-files were inserted within the canals, and the curvature of each canal was measured according to the Schneider's technique (12). The glide path was formed using a #15 K-file, with RC-Prep (Premier Dental Products, Norristown, PA, USA).

Canals were divided into two groups according to the file types used to prepare the canals. The RECIPROC R25 file was used in the RECIPROC group (n = 50), while the WaveOne Primary file was used in the WaveOne group (n = 50). Canal shaping was completed with the use of each file, along with the VDW.SILVER RECIPROC Motor (VDW) at their respective recommended setting–RECIPROC at the "RECIPROC ALL" mode, and WaveOne at the "WAVEONE ALL" mode. During instrumentation, the files were taken out after three times of pecking motion, and the debris was removed, while the canals were irrigated using a 5.25% NaOCl solution.

The time taken for the file to reach the working length from the moment it was inserted into the canal was measured. The time taken for canal irrigation was not included, with

solely measuring the time taken for mechanical canal shaping. Each file was repeatedly used in a maximum of 10 canals for comparing the change of the efficiency according to the number of file use. In the case of any deformed or fractured files, they were replaced with new ones. All the canals were prepared one by one for each system by an experienced clinician after practicing instrumentation for both systems.

The changes on the surface of the files after use (once, 5 times and 10 times) were observed using a scanning electron microscope (SEM) (Hitachi S-4700; Hitachi, Tokyo, Japan) at magnifications of X30; X200; X500; and X2000. A new file was compared as a control.

All statistical analyses were performed with the R programming language (Ross Ihaka and Robert Gentleman, R Development Core Team, The University of Auckland, New Zealand). The level of significance was set at 5%. When exploring the basic assumptions for normality and equality of variance, the distribution of the working time was skewed, requiring a log transformation of the data. Thus, to control for the covariates and to compare the difference in the working time between the two groups, the statistical method consisted of an analysis of covariance (ANCOVA) was performed.

Results

All 100 files used up to 10 canals showed no visible signs of unwinding of the helical structure or fractures. The below figures are representing typical longitudinal views of RECIPROC R25 or WaveOne Primary used in this study under the SEM (Fig. 1-8). None of the files exhibited plastic deformation after *in vitro* use. There were no significant changes on the 2 file groups in the formation and propagation of microcracks or tip abrasions until they were re-used up to 5 canals (Fig. 3-6). However, some files in both groups re-used up to 10 times (canals) showed slight wear of the tip (apical blunting) and microcracks on the surface (Fig. 7, 8).

There existed no significant difference between RECIPROC and WaveOne groups either in the distribution of the canal curvature or working length ($p > .05$). The teeth in RECIPROC group presented with 16.1 ± 1.5 mm of average working length, and 21.0 ± 7.8° of average curvature, whereas the teeth in WaveOne group presented 15.9 ± 1.7 mm, and 22.6 ± 8.2°, respectively.

When comparing the working time taken to shape the canals, WaveOne Primary files (23.9 ± 12.0 seconds) were significantly faster than RECIPROC R25 files (30.0 ± 12.5 seconds) ($p < .05$). As the working length increased, and as the curvature of the canal increased, the working time taken to shape the canal increased in both files (Fig. 9 and 10). With the number of file use was increased, the working time needed to complete the preparation of each canal was increased (Fig. 11). There was a statistically significant correlation between the working time and 3 variables measured (Table 1).

Discussion

What clinicians want most from their root canal shaping instruments are a resistance to breakage, a fidelity to the original canal path, and an efficiency to canal preparation (4). Efficient instruments save dentists labor and time, which is the reason why clinicians are always on the lookout for better instruments and techniques.

The factors influencing efficiency can be summarized into the following three factors: the instrument used, the technique employed, and the nature of root canals in which the files were used. The cutting ability and the capacity to remove debris depend on the instrument per se. Also, even with the same instrument, the cutting ability may differ according to the number of times the file was used. In this study, not only the efficiency of two different single-file reciprocating instruments was compared, but the change in the efficiency of the files according to the number of times they were used, was also compared. Results showed that the WaveOne Primary files required significantly less working time than RECIPROC R25 files, and this tendency was maintained even after the multiple uses of the files, although the results were irregular in the later parts.

Schafer et al. (5) reported the importance of the cross-sectional design as a factor in influencing the cutting efficiency. In their research, the maximum penetration depth in dentin of five instruments was compared. They demonstrated that the cutting efficiency of Mtwo, which has S-shaped cross-section, was superior to FlexMaster, with a convex triangular cross-section. Considering the cross-sectional design of WaveOne is similar to that of FlexMaster with a modified convex triangular shape, whereas RECIPROC has a mirror image of Mtwo with S-shaped cross-section, it can be expected that RECIPROC is

more efficient than WaveOne in terms of canal preparation time. However, the results revealed otherwise.

This is due to many factors that exert a complex influence on the cutting ability of a file, such as the helical and rake angle, metallurgical properties, and surface treatment of the instruments, not solely the cross-sectional design (7). We cannot discern the effect of each variable has on the results of this study, but it seems that the difference in the design of the two reciprocating files has a more favorable effect on WaveOne, in terms of efficiency. The three-cutting blade of WaveOne might have better cutting efficacy than two-blade RECIPROC. Furthermore, the existence of groove on the side (cross-section) of the file seems to expedite the removal of dentin debris during the preparation. With regard to this issue, the helical angle and cross-sectional area would be valuable to measure for the analysis of this result in the future.

According to the number of times the files have been used, the efficiency was decreased in both files as its number of re-use was increased to five times. But this change did not continuously occur, and from the point when a file was repeatedly used in five canals, an irregular pattern was observed (Fig. 11). However this tendency could not be discerned through a SEM analysis, but we may assume that according to the progressive use of a file, at least up to its fifth use, a kind of wear was evident and might decrease the cutting efficiency.

The technique employed when using a file may also exert an influence on the efficiency of the instrument. In the past, there have been a lot of efforts in trying to reduce the sequence of the file by employing a continuous rotation method. But now, we have reached a point where a reciprocating motion is employed. With the reciprocating motion

during the instrumentation, only a one file may be able to achieve a complete root canal preparation, reduce the discomfort when one might have to use several series of files. Therefore this method has presented a more efficient and safe result, as suggested by previous researches (13-17).

The anatomy of root canal in which the instrument was used is one of the most clinically inconsistent factors. This is the reason why the differences in the shaping efficiency of files are tested in standardized resin blocks, not in actual teeth (5, 6, 10). However, as it has been pointed out in several recent studies (18-20), there is a big difference between a file for cutting the resin block, and a file for preparing the tooth structure. Thus, considering this clinical situation, the natural teeth were incorporated in this study to produce more accurate clinical results. Any research using natural teeth is quite meaningful. Because the entire root canal preparation is actually achieved with single-file, which was used in the research, without any help from other series of files. And the comparison from this study might have clinical implications.

In the present study, the preparation of the canals was investigated according to the working length and curvature of the canal. Although the result of this study according to these two variables poses a definite limit, there was a strong negative correlation between the efficiency and these factors. As the working length increased, and as the canal curvature increased, the working time required for canal preparation with RECIPROC R25 or WaveOne Primary also increased. It is presumed that this difference of working time did not significantly affect the length of clinical session where each file is used. However, in overall, reducing the number of rotation cycle of each NiTi file and reducing the contact time with root canal wall, is beneficial. It ultimately minimizes the risk of file

fracture by reducing the flexural and torsional fatigue stress. The decrease in the number of rotation cycle and shortened contact time within a curved canal eventually leads to an increase in fatigue life. Then the results should be noted as that even when we use these reciprocating systems in more severely curved canal and longer canal, we may have a higher chance of instrument fracture than in a straight and short canal. Also this result is similar to that of You et al. (13) who confirmed the extended lifespan of NiTi rotary file when it was used with reciprocating motion.

Recently, the results of comparative research on cyclic fatigue and torsional resistance between WaveOne and RECIPROC were reported with significant differences (21). However, in the clinical situation when the reciprocating motion was applied, the two types of fatigue resistances were involved with each other simultaneously. In this respect, it is interesting to find out that there were no significant differences between the two file systems under the SEM observation in this study. SEM analysis also revealed that no visible signs of deformation including such as crack initiation and propagation had been observed in both types of files until they were used up to 5 canals which were similar to those shown in SEM results of recent studies (22, 23). This indicates that, although the manufacturers recommend discarding the files after single use, they might be re-used more than once (one canal). It is presumed that this metallurgical superior fatigue resistance compared with those made of regular super-elastic NiTi files is due to the M-wire properties of the WaveOne and RECIPROC files (11, 24-6). In consideration of reusability of reciprocating files, a further research is required to verify the fatigue resistance after re-use, since SEM analysis alone cannot differentiate the reduction of cyclic fatigue resistance of these files.

In conclusion, within the limits of this study, WaveOne took a shorter time to shape a root canal than RECIPROC regardless of canal anatomy. As the number of file use increased, its efficiency decreased. But, few or no microcracks were detected until the files were used more than 5 times or less. Therefore, these reciprocating files might be re-used up to 5 canals with no critical changes in metallurgical properties even though the manufacturers recommend discarding the files after single use.

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Tables and Figures

Table 1. Correlation between working time and 3 variables (working length, canal curvature, number of file re-use) in each group.

Variables	Regression coefficient	*p*-value
Working length	0.3134	0.0015
Canal curvature	0.2690	0.0068
File re-use	0.2705	0.0065

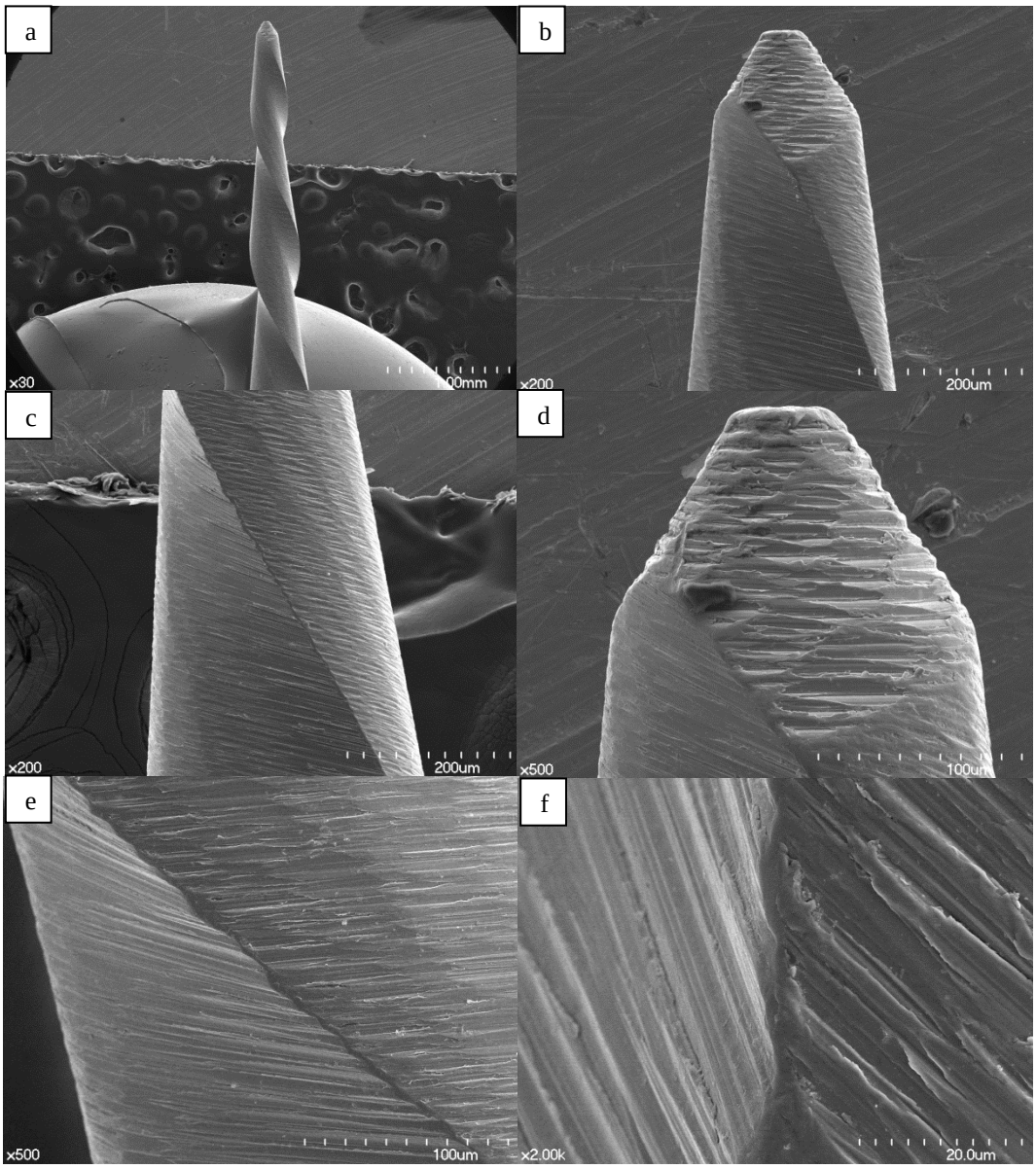

Figure 1. The longitudinal SEM views of RECIPROC R25, control group. a. X30, b. X200 at tip portion, c. X200 at middle of blade area, d. X500 at tip portion, e. X500 at middle of blade area, f. X2,000 at middle of blade area.

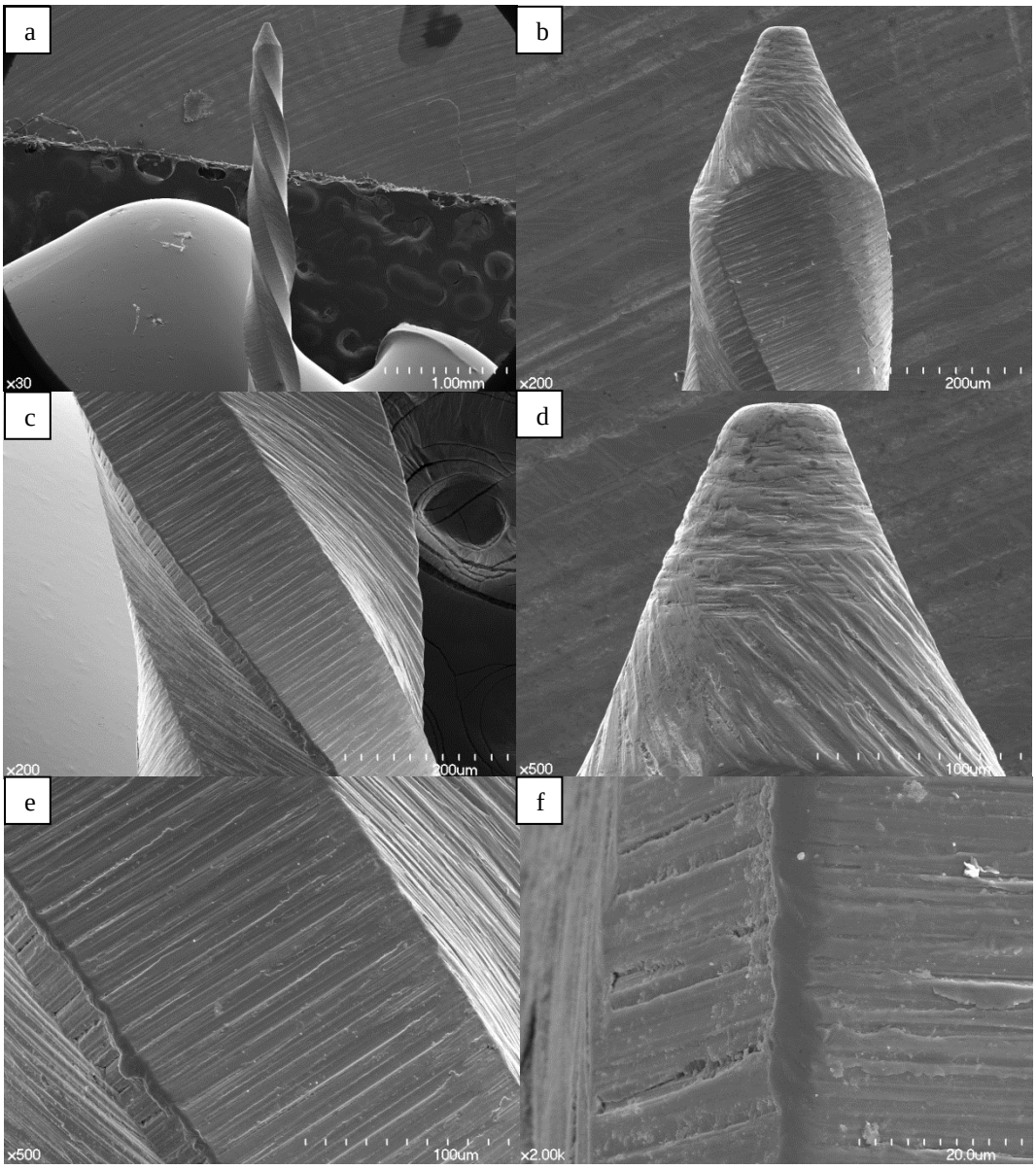

Figure 2. The longitudinal SEM views of WaveOne Primary, control group. a. X30, b. X200 at tip portion, c. X200 at middle of blade area, d. X500 at tip portion, e. X500 at middle of blade area, f. X2,000 at middle of blade area.

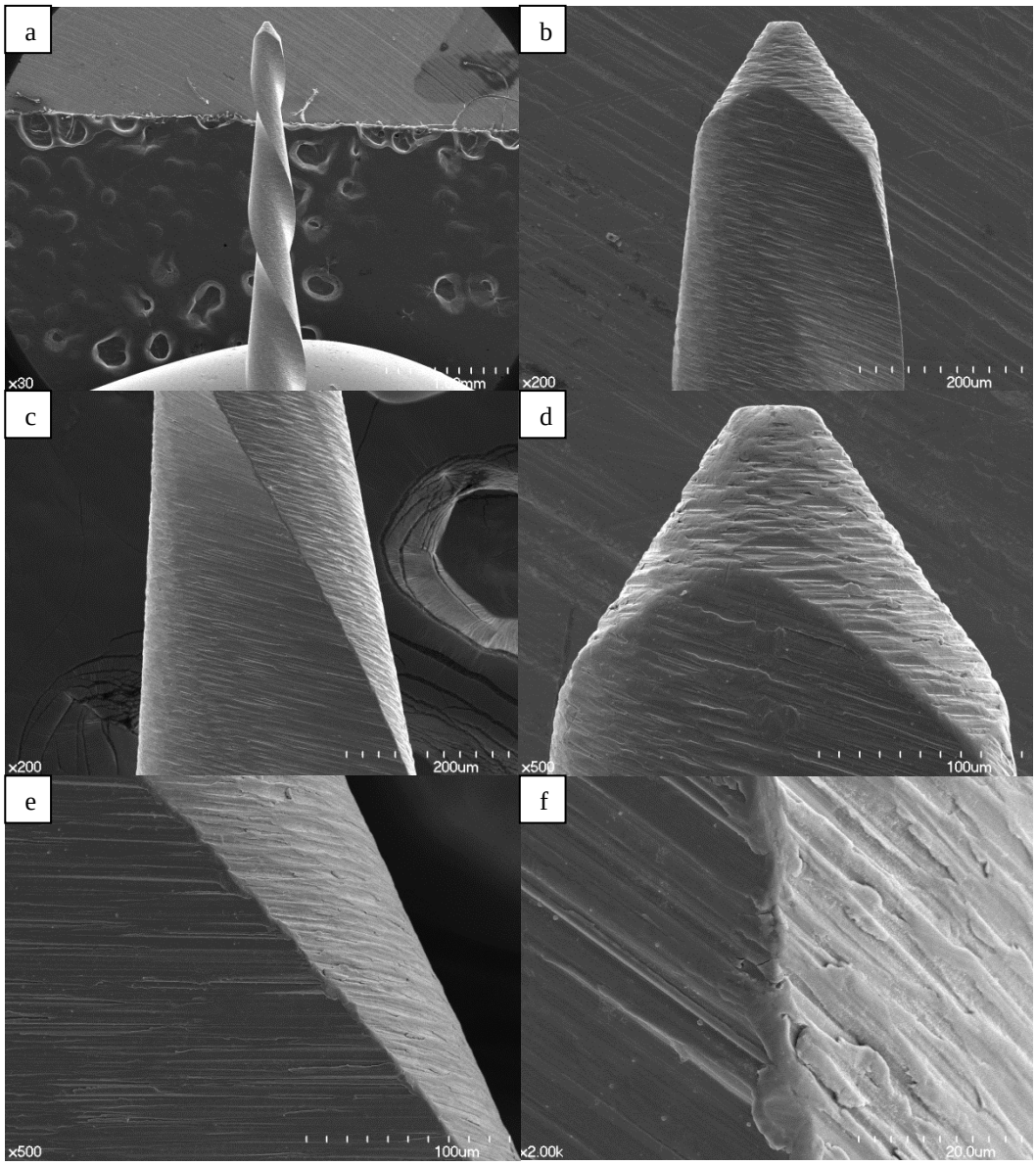

Figure 3. The longitudinal SEM views of RECIPROC R25 used in 1 canal. a. X30, b. X200 at tip portion, c. X200 at middle of blade area, d. X500 at tip portion, e. X500 at middle of blade area, f. X2,000 at middle of blade area. There is no significant difference.

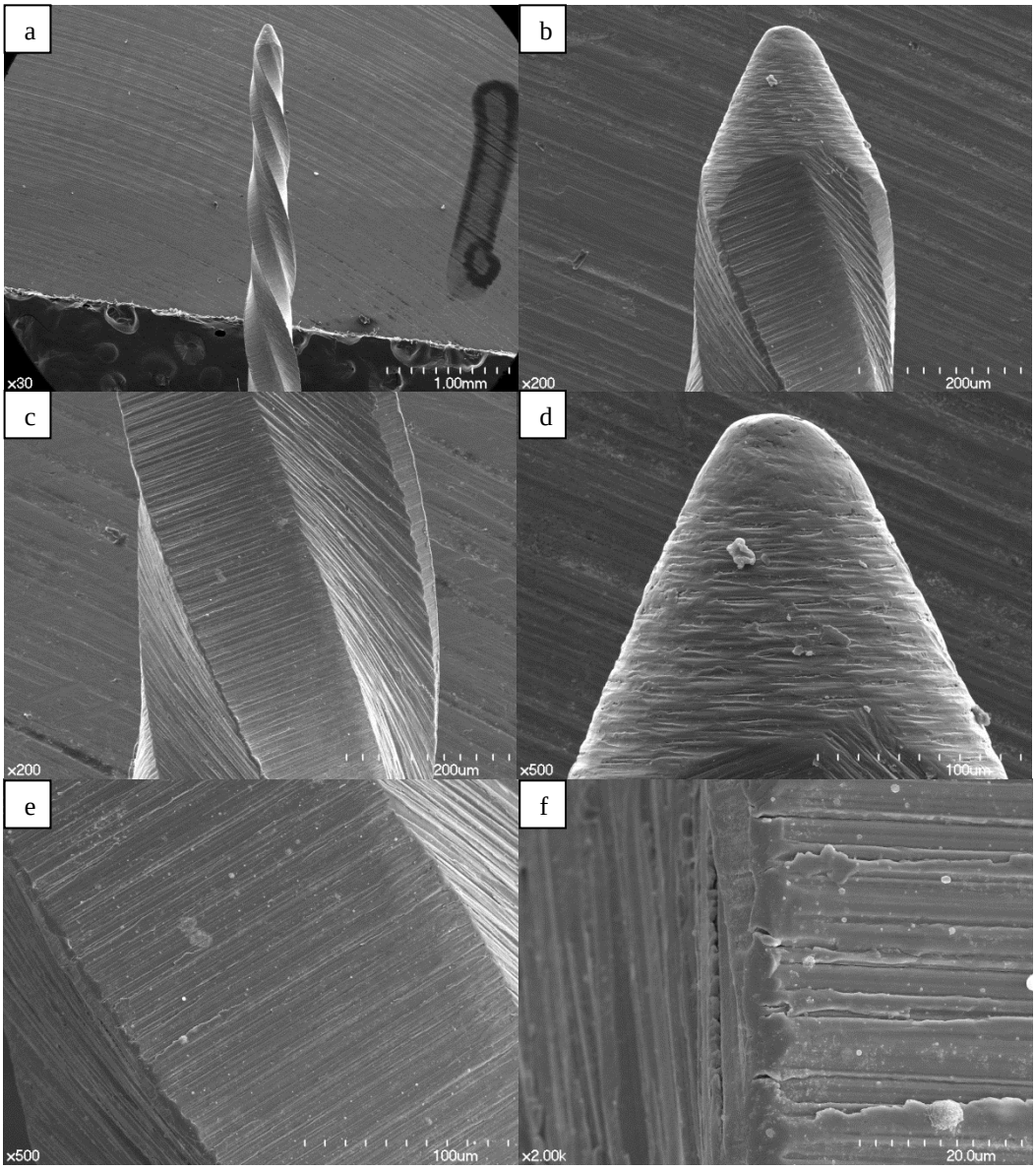

Figure 4. The longitudinal SEM views of WaveOne Primary used in 1 canal. a. X30, b. X200 at tip portion, c. X200 at middle of blade area, d. X500 at tip portion, e. X500 at middle of blade area, f. X2,000 at middle of blade area. There is no significant difference.

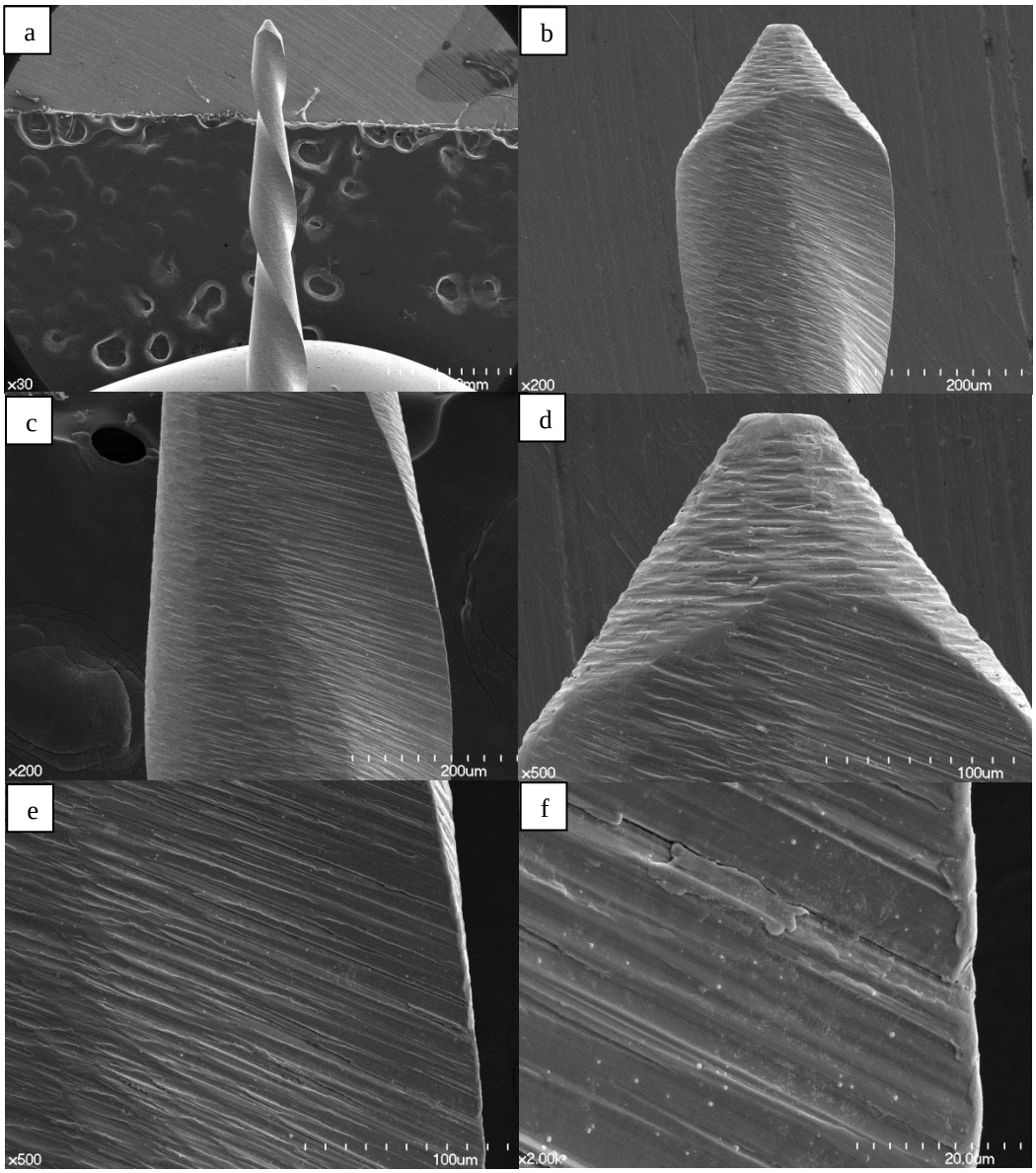

Figure 5. The longitudinal SEM views of RECIPROC R25 used in 5 canals. a. X30, b. X200 at tip portion, c. X200 at middle of blade area, d. X500 at tip portion, e. X500 at middle of blade area, f. X2,000 at middle of blade area. There is no significant change.

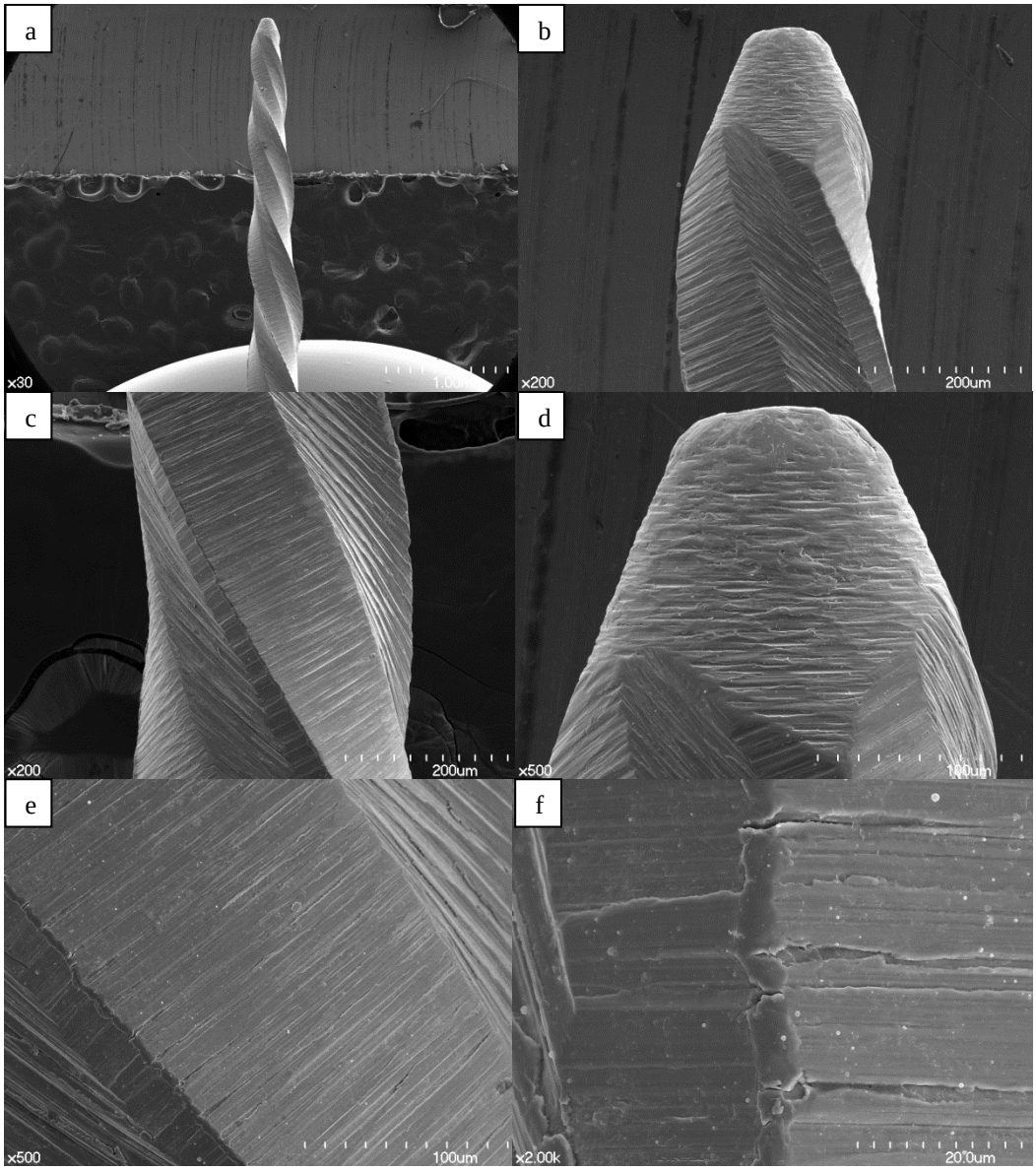

Figure 6. The longitudinal SEM views of WaveOne Primary used in 5 canals. a. X30, b. X200 at tip portion, c. X200 at middle of blade area, d. X500 at tip portion, e. X500 at middle of blade area, f. X2,000 at middle of blade area. There is no significant change.

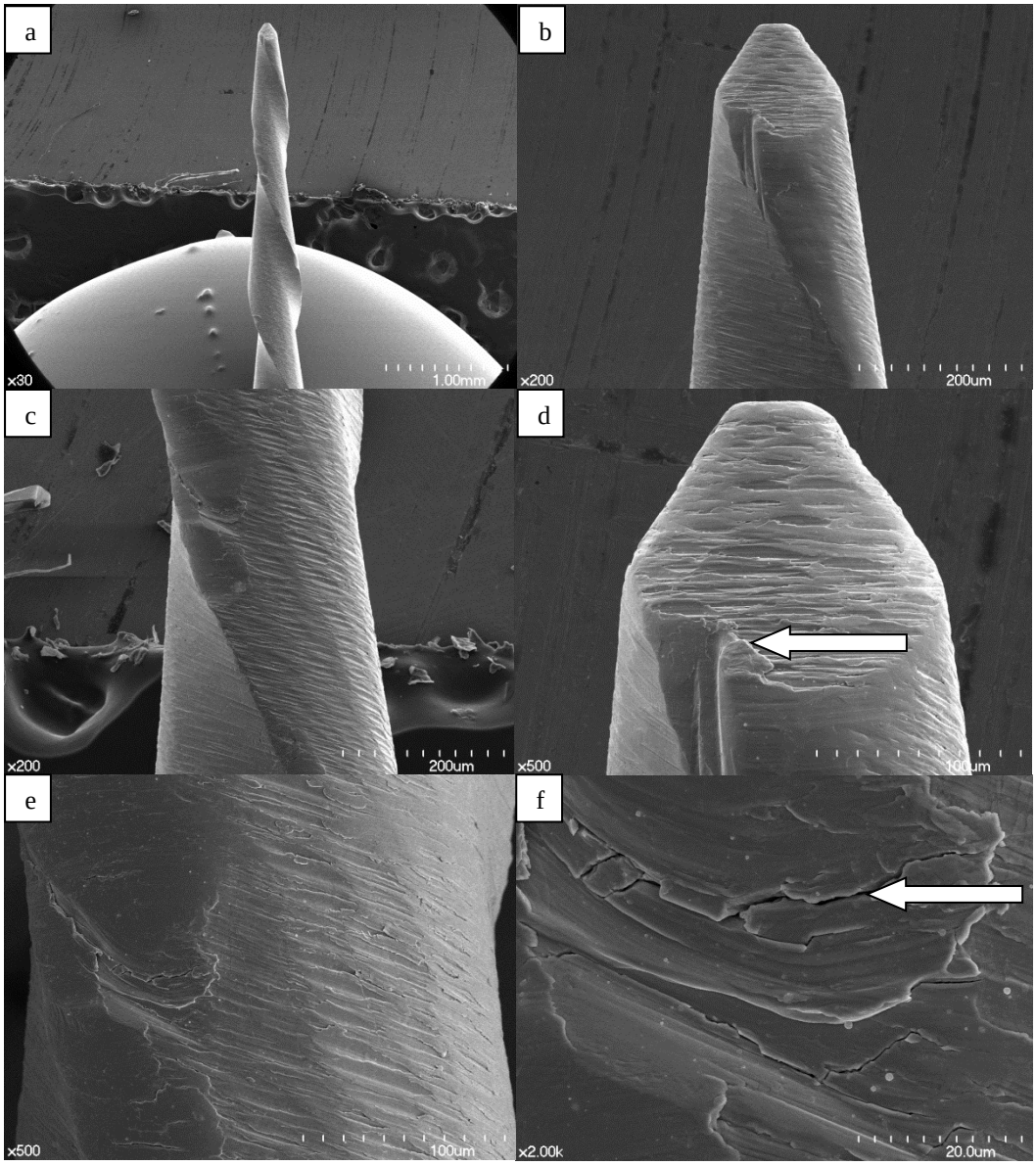

Figure 7. The longitudinal SEM views of RECIPROC R25 used in 10 canals. a. X30, b. X200 at tip portion, c. X200 at middle of blade area, d. X500 at tip portion, e. X500 at middle of blade area, f. X2,000 at middle of blade area. The blunt tip of file and crack lines are observed. (The arrows indicate microcracks.)

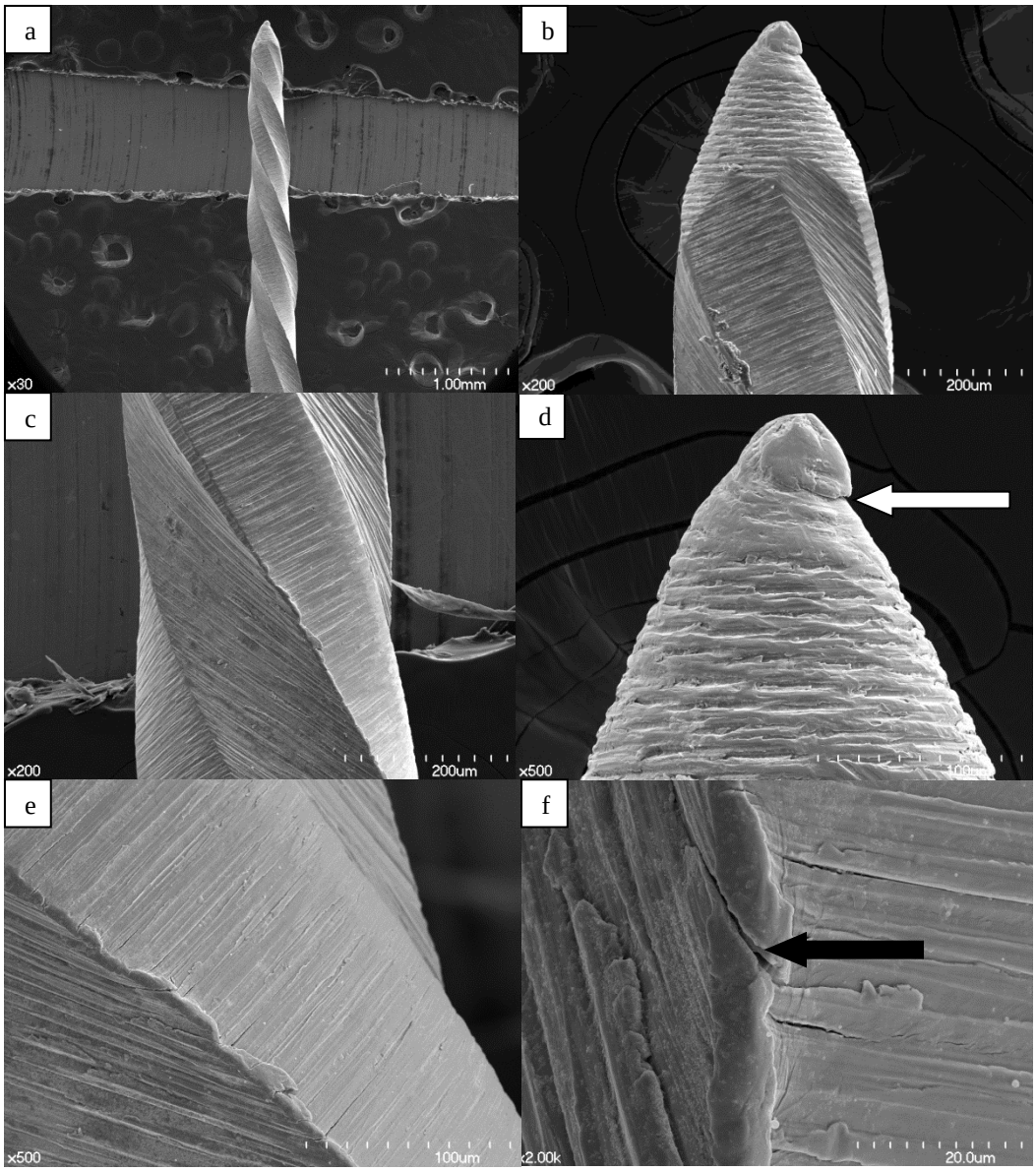

Figure 8. The longitudinal SEM views of WaveOne Primary used in 10 canals. a. X30, b. X200 at tip portion, c. X200 at middle of blade area, d. X500 at tip portion, e. X500 at middle of blade area, f. X2,000 at middle of blade area. The blunt tip of file (white arrow) and crack lines (black arrow) are observed.

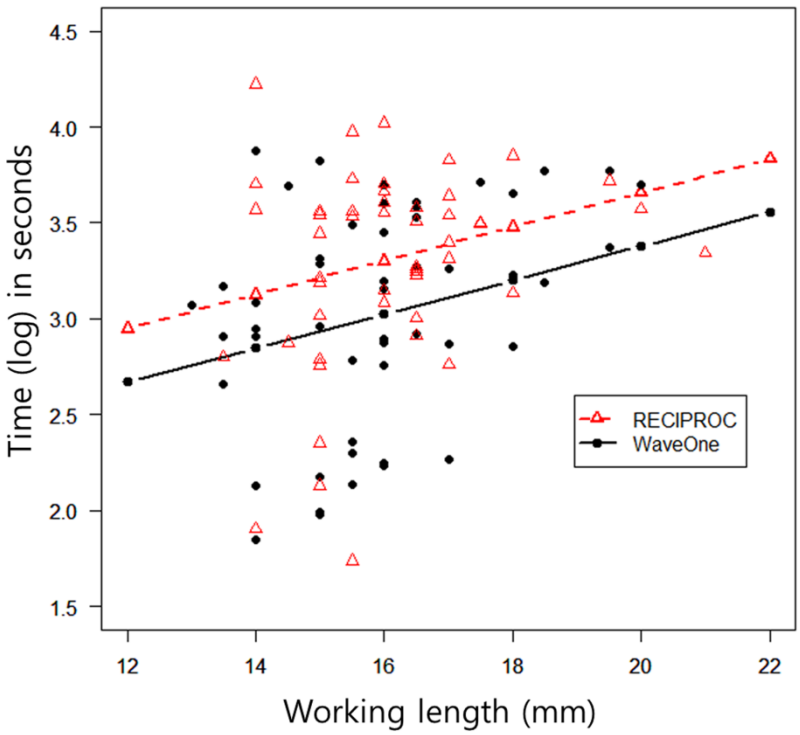

Figure 9. Scatter plot for the total preparation time (working time) according to the working length. As the working length increased, the working time for shaping the canal also increased in both file. However, WaveOne Primary files were faster than RECIPROC R25 files ($p < .05$).

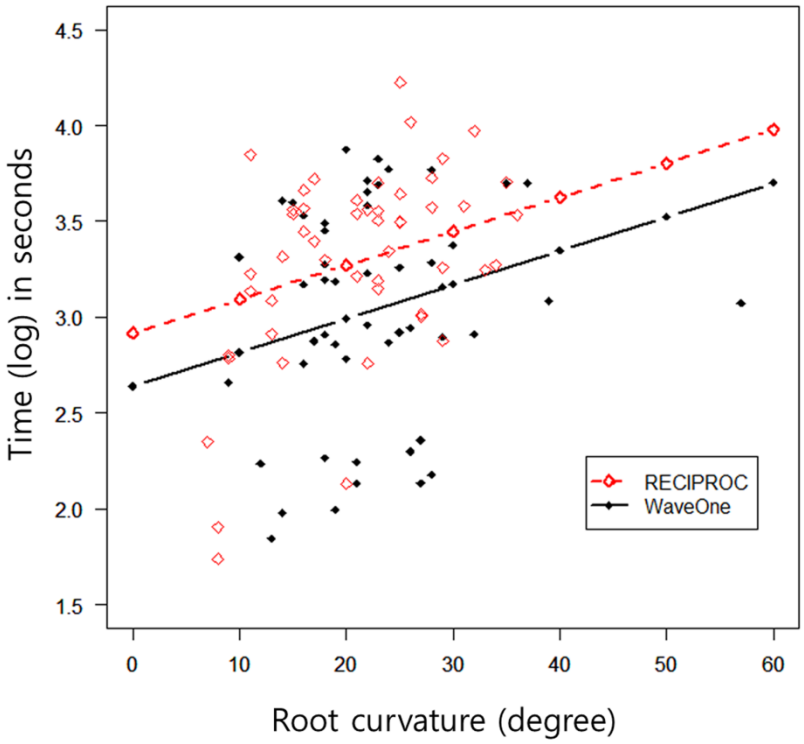

Figure 10. Scatter plot for the working time according to the curvature of canal. As the curvature of the canal increased, the working time taken to complete the canal preparation increased in both file. However, WaveOne Primary files were faster than RECIPROC R25 files ($p < .05$).

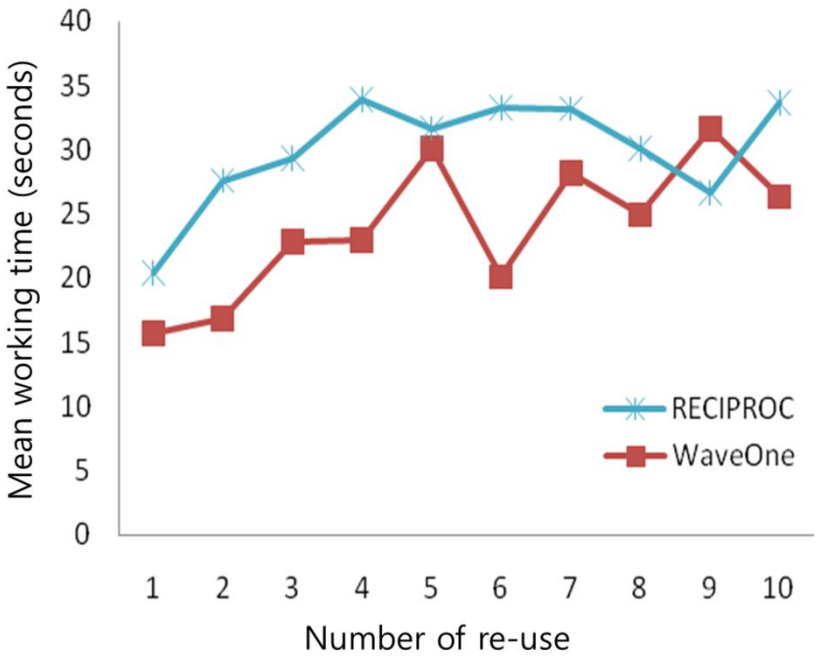

Figure 11. Scatter plot for the working time according to the number of re-use. With the number of file use was increased, in the beginning, the working time needed to complete the preparation of each canal was increased. But an irregular pattern was observed at the later part.

국문초록

근관형태에 따른 reciprocating Nickel-Titanium instruments의 임상적 효율에 관한 연구

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목적

본 연구의 목적은 최근 사용되고 있는 reciprocation 방법을 이용한 single-file system의 임상효율을 자연치의 근관에서 근관의 만곡도 및 근관의 길이와 연관하여 비교 분석하고, 또한 이 파일의 반복 사용의 가능성을 SEM 관찰을 통하여 평가하는 것이다.

재료 및 방법

발치된 50개의 대구치의 상악 협측 근관과 하악 근심 근관을 이용하여 총 100개의 근관을 사용하였다. 근관와동 형성 후, #10 K-file을 이용하여 근첨공에서 1mm 뺀 거리를 근관장으로 정하였다. 근관장 결정 후, #15 K-file을 이용하여 glide path를 형성하였다.

100개의 근관 중 50개는 RECIPROC R25 file (n=50)로 형성하였고, 나머지 50개는 WaveOne Primary file (n=50)로 형성하였다. 각 치아는 근관의 길이, 근관의 만곡도, 근관성형 하는데 걸리는 시간을 각각 측정하여 기록하였으며, 파일을 재사용하는 횟수에 따른 작업시간의 변화도 총 10회까지 관찰하였다. 파일의 재사용에 따른 표면변화를 SEM으로 관찰하였다.

결과

실험 결과, RECIPROC group 의 평균 작업장은 16.1 ± 1.5 mm 였고, 평균 만곡도는 21.0 ± 7.8°였으며 WaveOne group 은 평균 15.9 ± 1.7 mm 와 22.6 ± 8.2°로 서로 큰 차이가 없었다. 근관 형성 시간을 비교하면 WaveOne group (23.9 ± 12.0 초)이 RECIPROC group (30.0 ± 12.5 초)보다 빠른 편이었다 ($p < .05$).

두 group 모두에서 근관장이 길어질수록, 근관만곡도가 증가할수록 작업시간은 증가하였다 ($p < .05$). 또한 파일의 사용 횟수가 증가할수록 작업시간은 증가하였다. SEM 관찰에서는 두 파일 모두 5회 사용까지는 어떠한 변화나 crack도 관찰되지 않았다.

결론

본 연구에서는 근관의 형태와 관계없이 WaveOne Primary가 RECIPROC R25 보다 빠르게 근관 형성을 할 수 있었다. 두 파일 모두에서 근관 형성 효율이 파일을 재사용할수록 떨어졌으며, 5회까지는 microcrack이 거의 관찰되지 않았다. 따라서 대구치 기준으로 파일의 미세 구조 변화없이 한번 이상 재사용 할 수 있을 것으로 사료된다.

주요어: preparation time, reciprocating motion, working length, canal curvature, clinical file efficiency, reusability

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감사의 글

대학을 졸업하고, 수련을 하고, 대학원을 또 다니면서, 그리고 그 모든 과정을 마치고서, 이제 다시 그 과정을 돌아보면서 많은 길을 잘해낼 수 있도록 도와주신 수많은 분들께 저절로 고개 숙여 감사를 드리게 됩니다.

대학원 과정 전체에서 많은 가르침을 주신 서울대 보존과 교수님들께 감사드리고, 특히 끝까지 박사 과정을 할 수 있도록 지지해 주신 지도교수이신 이우철 교수님께 무한한 존경과 감사의 마음을 전합니다. 또한 임성삼 명예교수님은 제 석사 졸업 때도 이끌어 주셨으며, 논문의 완성도를 드높여 주신 백승호 교수님은 수련의 때도 무수한 임상의 깨우침으로 이끌어 주셨습니다.

심사 과정에서 많은 가르침을 주신 김영재 교수님과 백상혁 교수님께도 감사드립니다. 또한 박사논문의 연구와 실험을 가능하게 해주신 유성엽 선생님은 진정한 저의 은인이라고 생각하고 있습니다.

제가 모든 연구 과정이 힘들 때마다 마음 속에서 응원해 주신 정성창 서울대 명예 교수님께도 진심으로 이 자리를 빌어 고개 숙여 감사 올립니다.

그리고 마지막으로 저의 학위를 가장 자랑스러워 하실 아버지, 어머니와 장인, 장모님, 지난한 과정을 말없이 지켜보고 응원해준 아내와 서진이, 서우에게 '사랑합니다' 라고 말하고 싶습니다.