A Comparison of Stainless Steel K-file, Profile .04, and Quantec LX Instruments to Shape Curved Root Canals in vitro

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국문초록

Stainless Steel K-file, Profile .04와 Quantec LX를 이용한 만곡 근관 형성후의 근관형태의 변화에 관한 비교연구

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목 적

통상적인 근관성형 과정에서 근관형태의 직선화 경향을 발견할수 있으며 그 결과 만곡이 심한 근관에서 이상적인 근관 형태를 얻기가 어려움으로 인해 이를 극복하기 위한 많은 기구들과 근관 성형법들이 개선되었고 소개되었다. 본 연구에서는 수동형 *Stainless Steel K-file, NiTi* 엔진 구동형 *Profile .04* 와 *Quantec LX file*를 이용하여 만곡 근관의 성형 후 최종 근관 형태를 비교하고 평가하고자 한다.

방 법

본 실험은 *Bramante*등의 방법을 변형하여 술 전의 근관 형태와 술 후의 근관 형태를 비교하였다. Schneider의 방법에 따라 12°에서 68°이내에 만곡도를 가진 45개의 발거된 상하악 대구치의 근심근관들을 선택하여 15개씩 3개의 군으로 나누고 알루미늄으로 제작된 mold에 투명한 교정용 레진으로 매몰하였다. 근첨에서 2.5, 5, 8mm 지점에서 절단하고 각 mold에 재조립한 후 다음과 같이 근관 성형을 시행하였다. 제 1 군은 SS K-file를 이용하여 Step-back 방법; 제 2 군은 NiTi 엔진 구동형인 Profile .04 ; 제 3 군은 NiTi 엔진 구동형인 Quantec LX file로 근관 성형하였다. 술 전과 술 후에, 각 시편들을 입체 현미경으로 사진 촬영하여 근관 중심 위치 이동률, 근관성형 후 면적과 모양, 잔존 상아질의 최소 두께를 Sigma scan / image software program으로 계산하고 One way ANOVA로 통계적 유의성을 검증하였다.

결 론

1. Profile .04와 Quantec LX는 SS K-file보다 근관성형시 근관의 본 형태를 유지하는 경향이 있었으나 통계적으로 유의성이 없었다(p>0.05).
2. 근관 성형 후 면적은 Profile .04 엔진 구동형 NiTi file를 이용한 군이 다른 군과 비해 가장 적었으나 통계적으로 유의성이 없었다(p>0.05).
2. 모든 방법들은 같은 부위에서 같은 방향으로 전이되는 양상을 보였다. 즉, 근단부에서는 바깥쪽으로, 중앙부에서는 안쪽으로 전이하려는 경향이 있었다. 그러나, 치관부에는 그러한 법칙이 적용되지 않아 전이되는 양상이 안쪽이나 바깥쪽으로 구별되지 않게 일어났다.
3. 술 후에 근관의 모양은 원형, 타원형, 불균일한 형태를이 다양하게 나타났지만, Profile .04 와 Quantec LX를 사용했을 때 주로 원형 형태의 근관을 보여주었으며 Stainless Steel K-file은 타원형이나 불균일한 근관 형태를 보였다.

주요어 : cross-sectional 방법, 근관 전이,centering ratio, NiTi 엔진 화일

I. Introduction

It is generally known that successful root canal treatment depends on removal of the pulpal tissue, bacteria and necrotic debris from the root canal system, combined with adequate canal shaping that facilitates the final obturation[18].

Whereas most of these criteria can be easily met in straight canal, fulfilling these goals can be very difficult in curved canals. The most difficult area to clean and to maintain canal shape is the apical area[12,18,20]. In curved canals, there is a tendency for all preparation technique to transport the prepared canal away from the original axis[22]. *Weine*[22] demonstrated that every file had a tendency to straighten curved canals, resulting in excessive removal of dentin on the outer wall of the apical curvature and the formation of teardrop-shaped foramen. *Roane*[14] referred this inherent characteristic for endodontic files as the "restoring force" of the instrument.

In 1965, *Luks*[10] was the first who doubted about the ability to create round preparation that could be adequately obturated with solid core materials. *Schneider*[17] demonstrated that as canal curvature increased, the ability to produce round shape decreased. For gutta-percha, the optimum shape is a continuously tapering and conical form, with the smallest diameter at the apical limit of instrumentation[2].

In curved canals, it is important to make sure that preparation does not result in hourglass shape, with canal transportation or irregularities such as zips and elbows, ledges and perforations that may compromise the long-term success of treatment by making cleaning less efficient and obturation more difficult.

A number of preparation techniques and instruments have been described to provide the optimum shape at the end of the preparation. One of the first technique was a Step-back or flared technique[22], apical instrumentation is accomplished using smaller diameter files, which are more flexible and thus are able to be advanced to the full working length, then larger size files are sequentially stepped back from the apical terminus. Flex-R files and the *Balanced force* technique were introduced by *Roane et al.*[14] In addition, other techniques such as *Step-down technique*[7], *Crown-down technique*[11], and *Anticurvature filing* have also been developed to reduce excessive movement of the canal during instrumentation. Furthermore, improvements in the file tip design, change in the cutting surface, and changes in the materials of the instruments are made. One of the most significant advances that might potentially alleviate the problem of straightening of curved canals was the replacement of stainless steel with a nickel-titanium alloy. Despite of these various modifications and improvements the ideal form of canal shape is not achieved consistently and instrumentation still remains a challenging, time-consuming and problematic area in endodontics.

The root canals may be prepared manually or with the aid of a mechanical device. Preparing the root canals manually is highly technique-sensitive as labor-intensive. This has led to the introduction of various machine driven instruments. New products and instruments are appearing to make endodontic treatment both faster and better than more conventional treatment.

Currently, there are many rotary instrument, such Profile .04 (Maillefer, Ballaigues Swiss), which is made of a nickel titanium alloy with a taper of 4% that is twice the taper used in conventional ISO instruments. According to the manufacturers, the U-shaped cross-sections and noncutting tip can be used over the full working length without causing any change in the initial position of the foramen.

Quantec LX was recently introduced by the manufacturer of Quantec Series 2000(NT Co., Chattanooga, TN, USA). A new line with the same design and same taper, except the tip geometry, was redesigned resulting in an instrument with noncutting tip. It is unknown what effect the new tip designs will have on canal preparation.

The purpose of this *in vitro* study was to compare the effect of Profile .04 and Quantec LX NiTi file rotary systems and Stainless Steel K-file hand instrument using Step back technique on the ability to maintain the original path and to evaluate the final shape resulted of curved root canals.

Ⅱ. Materials and Methods

Specimen selection

Extracted human mandibular and maxillary molar with fully formed apices were chosen for this study. The teeth were reserved in 100% humidity throughout the study. Conventional access openings were prepared. The distal roots of the mandibular molars and the palatal roots of the maxillary molars were removed with the respective crown. Canal length and canal patency of the mesial canal was determined by placing a #10 K-file into each canal until it was just visible at the apical foramen and then the teeth were radiographed from the mesial-distal aspect.

Both canals were used if they were separate through the entire length of the canal and exited from different apical foramen, otherwise one canal was used. Canal curvature was determined using Schneider's method and curvature of the canals in the mesio-distal plane was between 12° and 68°. Forty-five canals were finally selected, using the following criteria: 1) Canal which is separated from the orifice to the apical foramen, 2) Canal which exceeded 15mm from the occlusal reference point to the apical foramen, 3) Canal which had a snug fit with either a #10 or #15 (K-flex) file were included.

Specimen Preparation

The model system used for instrumentation was a modification of the method presented by ***Bramante et al.***[1] The model system consisted in fabricating muffles of aluminum instead of stone and using these as model for the preparation of the acrylic resin-tooth block. The roots were embedded in a clear casting resin (Dura Ortho-resin Dental Mfg. Co., Worth, Ill; USA), under the purpose of fixing the sections, once cutting, a screw was introduced with the roots into the resin.

After the resin had set, the block was removed from the aluminum muffles (mold) and sectioned with a diamond saw using the cutting system (Exakt, Kulzer, Germany).

The cuts were made at 2.5, 5 and 8mm from the apex. Care was taken of making the cuts perpendicular to the canal to avoid angled cuts. Each section was encoded and marked to identify the coronal side and the location of the mesial-distal, bucco-lingual direction. Each section was photographed with a stereomicroscope (SI-PT - Olympus, Japan) set at x 2.5 magnification. Root canals outline were then carefully drawn and the following dimensions determined for each section: a) Mean centering ratio, b) post instrumentation area, c) post instrumentation canal shape, d) minimum remaining of dentin thickness.

Canal instrumentation

Once the sections were photographed, they were reassembled in the respective molds and canal instrumentation was performed. The canals were randomly distributed into three experimental groups of 15 teeth each.

Groups A : the canals were instrumented with Stainless Steel K-files (MANI, Matsutani Seisakusho Co., Tochigi-ken; Japan) using a Step back method. The canals were enlarged at working length to size #30 and a combination of a filing and reaming action was used until it fit loosely in the canal. Gates Glidden drills (Maillefer, Swiss) #2 and #3 were used at the coronal third, followed by a sequential 0.5 to 1mm step back preparation[12]. Recapitulation was performed with the master apical file.

Group B : the canals were instrumented with Profile .04 (Maillefer, Ballaigues; Swiss), 0.04

Table 1. *Canal instrumentation*

Experimental Group	Instruments	Manufacturers	N	Methods
Hand instrumentation	K - file	Mani, Inc., Japan	15	Step-back technique[12]
Rotary instrumentation	Profile.04	Maillefer, Swiss	15	Manufacturer recommendation
Rotary instrumentation	Quantec LX	Nt Co., Chattanooga, TN, USA	14	Manufacturer recommendation

mm/mm taper nickel-titanium rotary system at 300 rpm in the NT-Matic II engine (Aseptico, USA) , in accordance with the technique recommended by the manufacturer.

Group C : the canals were instrumented with Quantec LX (NT Co, Chattanooga, TN, USA) rotary system at 300 rpm in the NT-Matic II engine (Aseptico, USA), in accordance with the technique recommended by the manufacturer.

Each canal was irrigated with 1ml of 3.5% of NaOCl after each instrument. Between each file for all groups #10 or #15 K-file was inserted to verify the patency of the canals. All instruments were discarded at the first visible indication of stress. All procedures were performed by the same operator. After completion of the canal preparation, the section was photographed as same as previously described. The pre-instrumentation tracings were aligned with the post-instrumentation tracings. This allowed direct measurement of the pre and post instrumentation.

Statistical Analysis

Data has been obtained by *Sigma scan/image software program, ver 1.20* (Jandel Scientific Corp., San Rafael Ca. USA). The mean centering ratio, as reported by *Calhoun and Montgomery*[3] was measured in millimeter and calculated using the following formula: $X1 - X2/Y$, where $X1$ represents the maximum extent of canal, $X2$ is the movement in the opposite direction, and Y is the diameter of the final canal preparation. The prepared area of the canal was calculated by subtracting the area of the preinstrumented canals from the area of the postinstrumented canals. The extension and direction of the canal transportation were determined by measuring the minimal remaining dentin thickness. *One way analysis of variance* (ANOVA) was used for evaluating the data of this study.

Ⅲ. Results

Forty-five canals were used in this study. One specimen of group C was discarded due to the difficulty in identifying and tracing the outline of the canal. Centering ratio data are presented in Table 2, the lower the value, the better the technique centered instrumentation. At the apical level, Quantec LX had the largest centering ratio, that is, it transported the canal more than other the groups, however, there were not statistically significant differences between the groups at either level as shown by ANOVA. Table 3 shows the average of post instrumentation canal area, the total area of dentin removed after instrumentation was less with Profile .04 than with the other groups at the three levels, not statistical differences were showed among three groups. Table 4 shows the means SE of the minimum remaining mesial and distal root structure outside the canal at three different levels. ANOVA did not show statistical difference at any of the levels between groups. The incidence and percentage of canal shape types at different levels are given in Table 5. At the apical level, the percentage of round shapes canals showed significant difference, between for SS K-file group (26.6%) and for Quantec LX group (71.4%). At the 5mm levels the Profile .04 and Quantec LX produced significantly more round canals, 80% and 92% respectively, than the 20% for SS K-file. At the 8mm level no significantly difference was observed, Profile had 46.6% and Quantec LX 64.2% round canals compared with 26.6% for SS K-file. In addition, at the 5 and 8mm SS K-file

Table 2. *Centering Ratio at each level of the root canals*

Experimental Group	Apical	Middle	Coronal
	Mean ± SD	Mean ± SD	Mean ± SD
SS K - file	0.209 ± 0.139	0.211 ± 0.125	0.236 ± 0.101
Profile .04	0.220 ± 0.112	0.206 ± 0.122	0.198 ± 0.130
Quantec LX	0.227 ± 0.113	0.221 ± 0.169	0.317· ± 0.161

There were not statistical differences among groups (p>0.05).

n = 15 in Group A,B and n=14 in Group C

Table 3. *Mean area at each level of the root canals*

Experimental Group	Apical Mean ± SD	Middle Mean ± SD	Coronal Mean ± SD
SS K - file	0.278 ± 0.109	0.403 ± 0.109	0.561 ± 0.215
Profile .04	0.152 ± 0.042	0.316 ± 0.117	0.420 ± 0.221
Quantec LX	0.252 ± 0.090	0.342 ± 0.095	0.480 ± 0.111

Measurement in mm. There were not statistical differences among groups (p>0.05).
n=15 in Group A,B and n=14 in Group C

Table 4. *Minimum remaining dentin thickness at each level of the canals (mm)*

Experimental Group	Apical Mean ± SD	Middle Mean ± SD	Coronal Mean ± SD
Inner curve			
SS K-file	0.019 ± 0.014	0.031 ± 0.020	0.033 ± 0.018
Profile .04	0.012 ± 0.09	0.027 ± 0.017	0.024 ± 0.016
Quantec LX	0.023 ± 0.012	0.028 ± 0.015	0.033 ± 0.022
Outer curve			
SS K-file	0.021 ± 0.09	0.020 ± 0.011	0.030 ± 0.025
Profile .04	0.017 ± 0.012	0.023 ± 0.014	0.028 ± 0.015
Quantec LX	0.020 ± 0.013	0.025 ± 0.015	0.031 ± 0.025

Measurement in mm. There were not statistical differences among groups (p>0.05).
n=15 in Group A,B and n=14 in Group C

Table 5. *Post-instrumentation canal shapes (%)*

Experimental group	Apical			Middle			Coronal		
	Round	Oval	Irregular	Round	Oval	Irregular	Round	Oval	Irregular
SS K-file	4(27)	8(53)	3(20)	3(20)	6(40)	6(40)	4(27)	5(33)	6(40)
Profile .04	7(47)	7(47)	1(7)	12(80)	2(13)	1(7)	8(53)	6(40)	1(6)
Quantec LX	10(71)	4(29)	-	13(93)	1(7)	-	9(64)	5(36)	-

Measurement in percentage. Significant differences on canal shapes between hand and rotary instrumentation. n=15 in Group A,B and n=14 in Group C

exhibited higher percentage of irregular canals (40%) than Profile .04 (6.6%) and Quantec LX (0%), at the apical level SS K-file group showed 20% and Profile .04 group showed 7%.

Ⅳ. Discussion

Many investigators have used different methods to evaluate the cleaning and shaping of root canals, such methods using microscopic, plastic blocks or pre and post instrumentation radiographic evaluations.

The present study was based on the cross-sectional assessment of root canal shape proposed by *Bramante et al.*[1] and modified by *Mongotmery and Calhoun*[3]. By sectioning and comparing the photographing of the pre instrumented teeth to the post instrumented teeth, it is possible to evaluate the effects of instrumentation accurately and to allow direct viewing of canal shape and position relative to the border of the root surface. But this evaluation method has shortcomings such limitation of sampling at a few sites along the length of the canal, a higher number of cuts would dramatically decrease the length, continuity and possible effect the curvature of the canal. Three horizontal cuts were used in this study. The first cut was made at 2.5mm from apex (i.e. a distance of 1.5mm from the apical terminus of the root canal preparation). Because many authors reported that canal transportation often occured at the apical few millimeters, measurement at this level was essential. The midroot level or height of curvature is another one in a curved canal that is prone to procedural error. Hence, this level was a logical choice for the second section, and the third cut that was made at 8mm from the apex. Despite of this limitation, this cross-sectional method for studying root canal instrumentation may be considered more clinically relevant than other methods to analysis the effect of instrumentation in canal transportation.

It is well known by clinicians that inadvertent procedural errors can occasionally arise during the instrumentation of narrow curved canals.

Sequential progression to large instruments during cleaning and shaping procedures results in decreased flexibility and increased rigidity of instruments with increases undesirable effects in the apical third[5,22]. An attempt to solve these problems has led to the development of various instrumentation techniques and instruments, one of the most important advanced was the introduction of instruments made with nickel-titanium. In 1988 ***Walia et al.***[21] reported that files made from Nitinol, a nickel-titanium alloy, had two to three times more elastic flexibility in bending and torsion than SS K-file, as well as superior resistance to fracture in clockwise and counterclockwise torsion.

There were many studies comparing the effects of the conventional SS K-file and NiTi file on canal shape[2]. ***Esposito and Cunningham***[6] reported that NiTi file was better in maintaining canal curvature and extension of canal transportation was less than SS K-file. However, other studies[9,16] showed no difference between two type of files on the final canal shape. According to the results of this study, hand instrumentation with SS K-file and rotary instrumentation with Profile .04 and Quantec LX NiTi instruments can predictably enlarge curved canals, while maintaining the original path.The results of this study presented in Table 2 revealed no statistical difference in centering ratio at the apical level between NiTi file and SS K-file, neither in the middle or coronal third. An interesting finding in this study was that centering ratio among the three groups at different levels was not predictable. It was not surprising that there was no difference between SS K-file and NiTi file at the two coronal third, but it was expected in apical third.

Because of many investigations have reported that the stiffness of files and corresponding negative effects (zipping and ledges) increase dramatically after #25 to #30 file, in this study the master apical file (MAF) of the groups was completed with #30 file at the apex, relatively a small size in comparing with other studies. The reason why the expected pattern did not occur cannot be determined with certainty, but it may be related to the use of small size of MAF file, the great variation of canal angulation of the sample in each group and the minimal size of the sample. Further investigation will be necessary to confirm these findings.

The mean area of the instrumented canals (Table 3) prepared with Profile .04 NiTi file was smaller than those of the other two groups. This meant that remained more centered than the other instruments and worked more uniformly on the walls of the original canal. The other instruments rasped more on certain walls. However, there was no significant difference in the final area of any groups ($p>0.05$). It is widely accepted that final shape of prepared root canal should be a gradual taper, with the narrowest portion at the apical constriction[2]. However, the thickness of dentin to be removed has never been defined.

Inspection of the pre and post instrumented canal tracings suggested that portions of the original canal wall were not instrumented in a majority of the root sections. This observation has also been made by ***Walton***[21], who reported the canal wall opposite the direction of center movement tended to be untouched and this often left a layer of debris and pulp tissue intact.

An ideal instrumentation outcome would have equal dentin removal from all canal walls, providing successful debridement, yet avoid excessive thinning of the root structure. Such an ideal preparation becomes even less possible when one considers complex canal anatomy containing fins or isthmuses.

Measurement of the minimum remaining mesial and distal root structure after canal instrumentation at different levels revealed no significant difference between any of the technique (Table 4). By comparing postinstrumentation remaining root thickness on either side of the canal, it can determine whether there was any canal transportation.

In previous studies[6,9,16,19], it was reported that both SS K-file and NiTi file tended to straighten the curved canals by transporting the apical terminus to the curve and removing dentin predominantly from the inner wall at the coronal two thirds of the canals. ***Roig Cayon***[15] explained this phenomenon by the tendency of the operator to remove the instrument by forcing it toward the distal. However, ***Kosa***[8] reported that transportation to the inner or outer curvature could not be producted regardless of level or instrument system. ***Calhour and Montgemery***[3] reported that all techniques tended to transport the canal in the same direction at the various levels examined. ***Pedicord***[13] reported that transportation was toward the furcation with no significant difference at any levels.

The results of this study confirm the findings of previous studies[3,4,15], in the majority of the specimen a tendency for the canal to be moved toward the outer curve at the apical third and inner curve at the middle was observed. In the apical and the middle third transportation followed the straightening force of the instruments, but in coronal level appears that no rule was followed and transportation occurred either inner or outer curve. This result could be due to the coronal third of the tooth is more susceptible to the direct manipulation of the operator and the specimens are not fixed like in clinical situation.

As presented in Table 5, the post instrumentation canal shapes of the experimental groups varied among round, oval and irregular shapes, there were significant differences between SS K-file and NiTi file groups. Rotary instrumentation produced significantly more round shapes than hand instrumentation. The results of the present study were consistent with previous research since instruments used in a rotary or reaming action performed better shapes (round) than instruments used in filing action.

At the 1.5mm level Profile .04 and Quantec LX rotary instrument had more round canals, 47% and 71% respectively than SS k-file group with 27%. However, when considering clinical relevance, the percentage of irregular shape canals may be most important due to the difficulty in obturation. SS K-file group had 20% of irregular canals at the 1.5mm level, as compared with 7% for Profile .04 and 0% for Quantec LX. However, another study[13] showed much higher percentages of irregular canals for SS K-file at the apical 54% and middle 42% position of the canals. The discrepancy could be due to differences between operator and evaluation, as well as the size of the master apical file and the type of the file.

Although the instrumentation time was not an principal objective in the present study, but it is conceivable that root canal preparation using the rotary systems would be considerably more faster than hand instrumentation, it took approximately 4 to 5 min. for rotary system, which Quantec LX system was faster than Profile .04, 7 to 9 min. for hand instrumentation. Results that coincided with other studies[4,9]. No separation of instrument occurred that may be explained by the frequent changes into new instruments throughout the experiment. The mechanical efficiency of the rotary system was superior than hand instrumentation. However, there were no significant differences between rotary systems. According to Kosa et al.[8] Profile .04 systems was better in maintain in canal centering and canal transportation at the apical level than Quantec 2000 systems. The difference may be due to the cutting tip of the Quantec 2000. In this study the new line with non-cutting tip Quantec LX systems was used. It could be the reason that there were no difference between both systems. Further research is needed to verify these results.

Ⅴ. Conclusion

In this study the modification of ***Bramante***[1] technique was used. This method enabled to examine the canal before and after instrumentation at any level within the same canal. The comparison of the effects of Profile .04, Quantec LX rotary systems and hand instrumentation using SS K-file to maintain the original canal location, the amounts of dentin removed, the direction of canal transportation and the final shape of the instrumented canals was observed.

The results were as follow:

1. There was a trend for Profile .04 and Quantec LX NiTi file to remain more centered in the canals than SS K-file group. However, the results were not statistically different from the other techniques (p>0.05).
2. The mean area of the instrumented canals prepared with Profile .04 NiTi file at the different level were smaller than the other two groups. But. there were not statistical different among any groups (p>0.05).
3. All techniques tended to transport the canal in the same direction at the various canal levels. They were moved to outer wall at the apical level, inner wall at the middle level. but at the coronal level transportation occurred either inner or outer curve.
4. The shapes of the canals after instrumentation varied among round, oval and irregular shapes. There were significant differences among Profile .04, Quantec LX and SS K-file. The majority of canals prepared by rotary systems were round while the canals with hand instrumentation were between oval and irregular shapes.

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사진부도 ①

Fig. 1. Pre instrumented canal of the apical third : Group A (SS K-file)

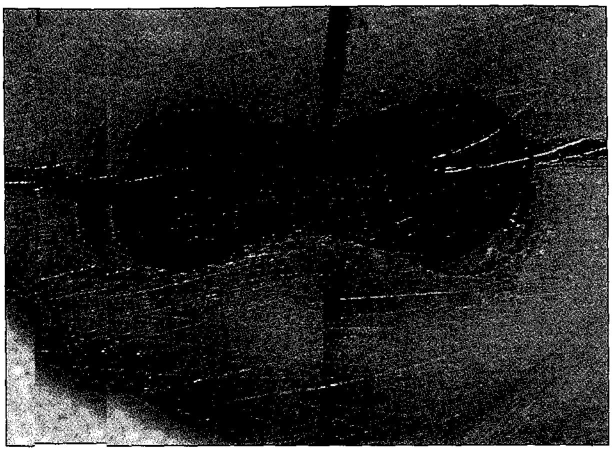

Fig. 2. Post instrumented canal of the apical third : Group A (SS K-file)

Fig. 3. Pre instrumented canal of the middle third : Group A (SS K-file)

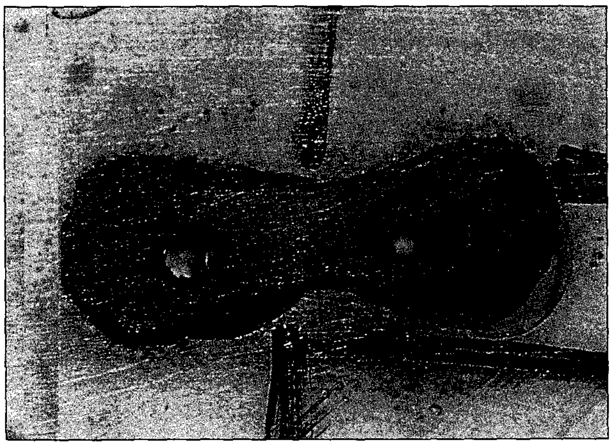

Fig. 4. Post instrumented canal of the middle third :Group A (SS K-file)

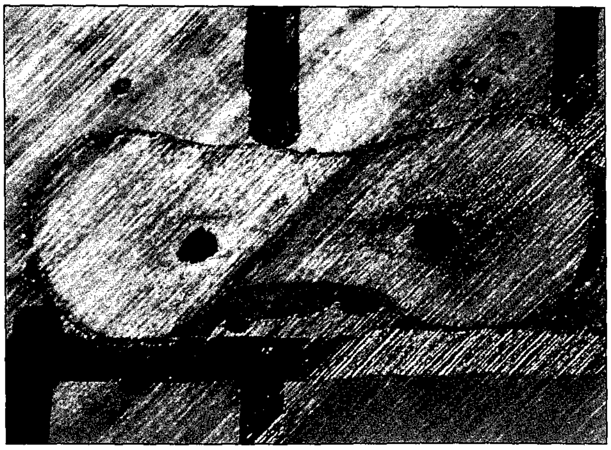

Fig. 5. Pre instrumented canal of the coronal third : Group A (SS K-file)

Fig. 6. Post instrumented canal of the coronal third : Group A (SS K-file)

사진부도 ②

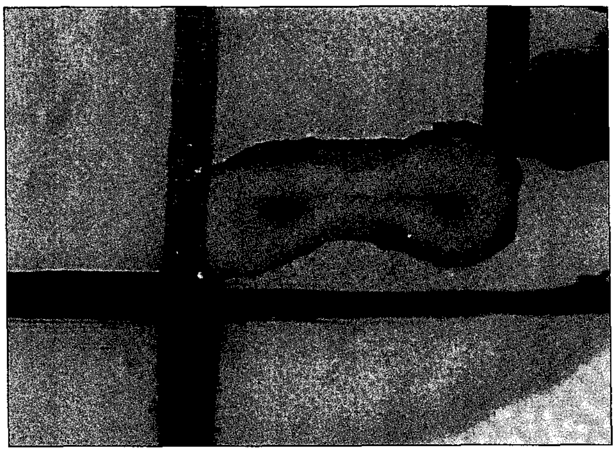

Fig. 7. Pre instrumented canal of the apical third : Group B (Profile .04)

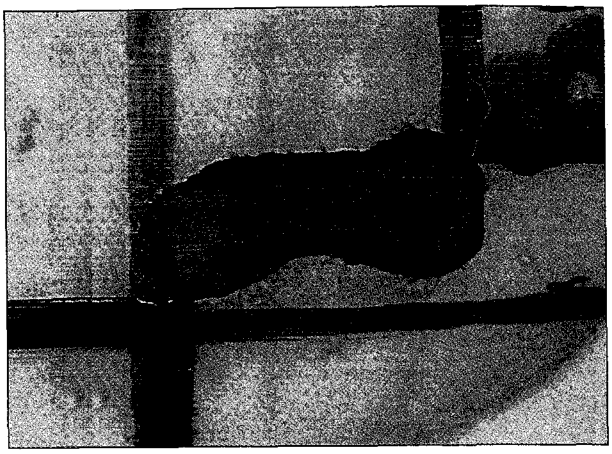

Fig. 8. Post instrumented canal of the apical third : Group B (Profile .04)

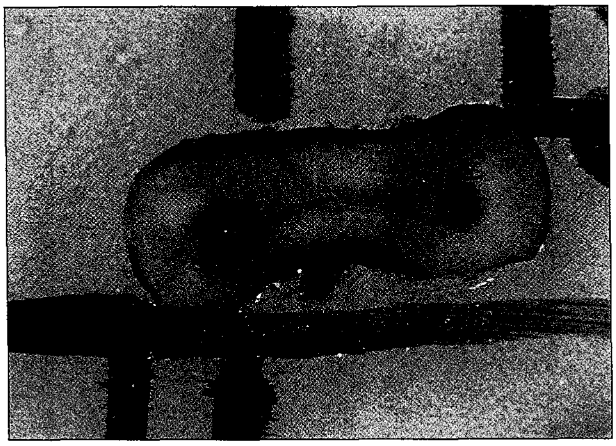

Fig. 9. Pre instrumented canal of the middle third : Group B (Profile .04)

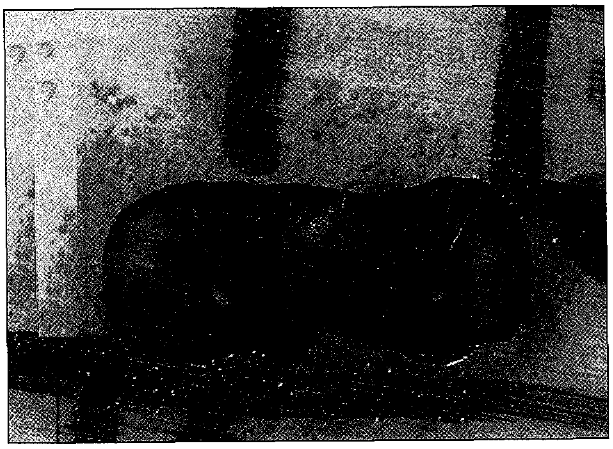

Fig. 10. Post instrumented canal of the middle third : Group B (Profile .04)

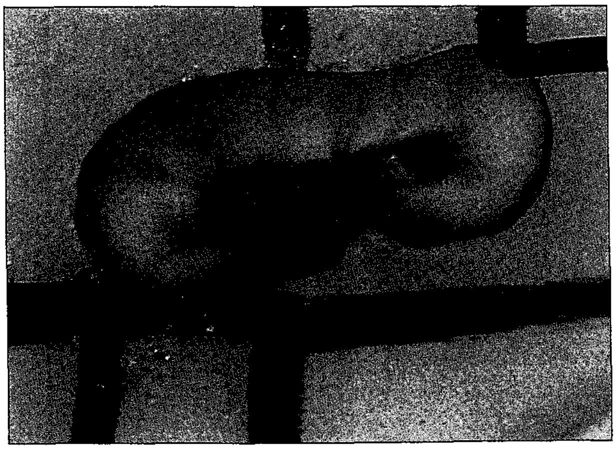

Fig. 11. Pre instrumented canal of the coronal third : Group B (Profile .04)

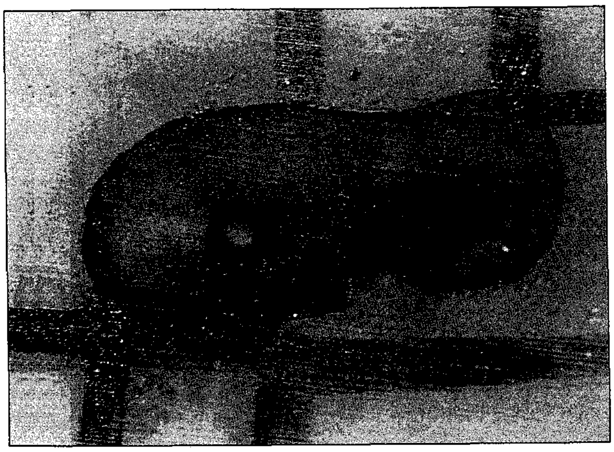

Fig. 12. Post instrumented canal of the coronal third : Group B (Profile .04)

사진부도 ③

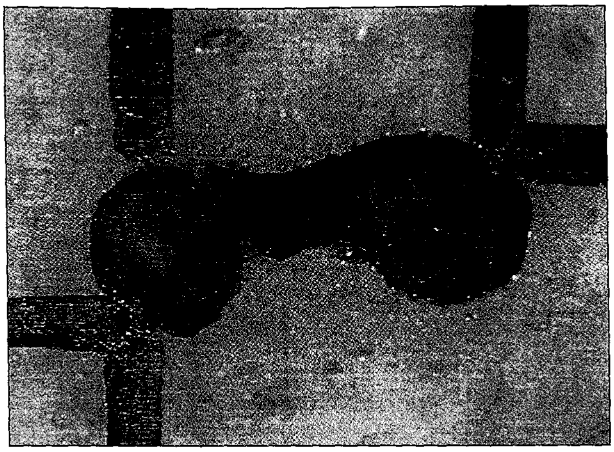

Fig. 13. Pre instrumented canal of the apical third : Group C (Quantec LX)

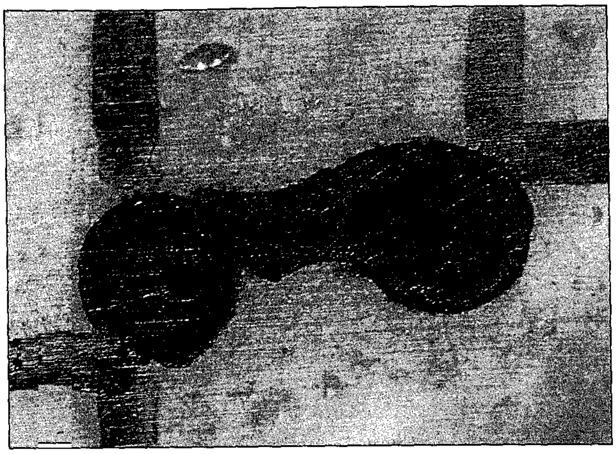

Fig. 14. Post instrumented canal of the apical third : Group C (Quantec LX)

Fig. 15. Pre instrumented canal of the middle third : Group C (Quantec LX)

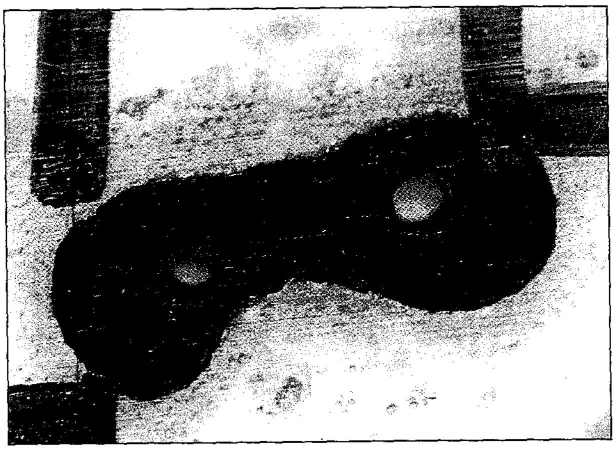

Fig. 16. Post instrumented canal of the middle third : Group C (Quantec LX)

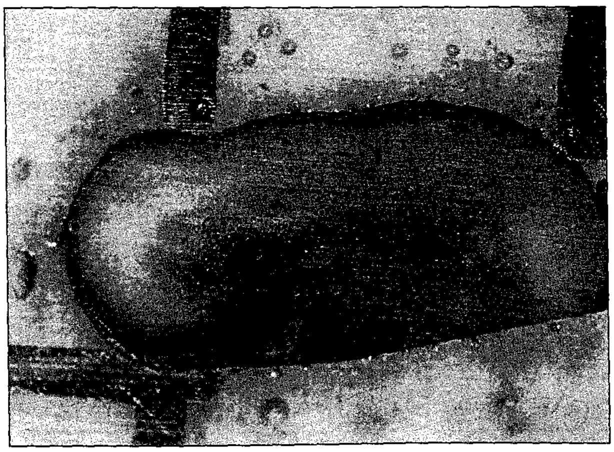

Fig. 17. Pre instrumented canal of the coronal third : Group C (Quantec LX)

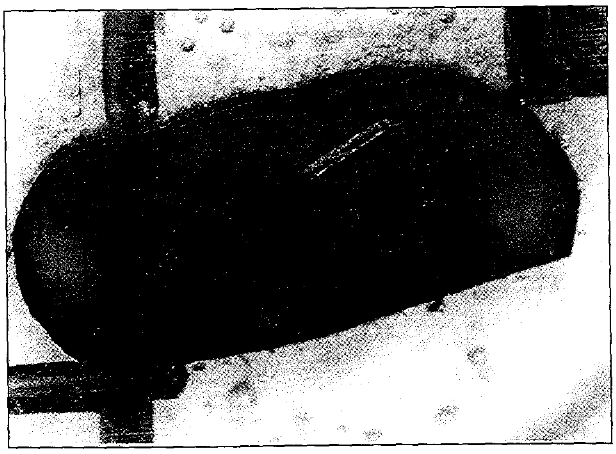

Fig. 18. Post instrumented canal of the coronal third : Group C (Quantec LX)