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# EFFECT OF CANAL PREPARATION METHODS ON THE APICAL EXTRUSION OF DEBRIS

Ju-Myong Park, Sung-Kyo Kim
*Department of Conservative Dentistry, College of Dentistry, Kyungpook National University*

ABSTRACT

## 근관형성법이 근관잔▲사의 치근단 정출에 미치는 영향

박주명 · 김성교
경북대학교 치과대학 보존학교실

근관 형성중 잔사의 치근단 정출은 치근단 조직의 반응을 유발하여 동통과 부종을 일으키며 치유를 지연시킬 수 있다. 본 연구의 목적은 수종의 기구와 방법을 사용하여 근관을 형성하고 이에 따른 근관 잔사의 치근단 정출량을 비교함으로써 잔사의 정출을 최소화 할 수 있는 기구 조작법을 알아보고자 하는 것이다.

120개의 발거된 사람의 하악 절치에서 근관형성중 치근단으로 정출되는 잔사의 양을 비교하였다. 첫 번째 실험에서는 40개의 치아를 10개씩 4군으로 나누어 2.52% 차아염소산나트륨용액으로 근관을 세척하면서 다음의 4방법 중 하나를 이용하여 근관을 형성하였다. 수동 스테인레스 스틸 K-화일을 이용하여 step-back technique, crown-down pressureless technique으로 근관을 형성하였고 전동 니켈 티타늄 기구로는 Quantec SC series 2000과 Profile .04 taper series 29를 이용하여 근관을 형성하였다. 두 번째 실험에서는 80개의 치아를 16개씩 5군으로 나누고 근관 세척에 의한 잔사의 치근단 정출 영향을 배제하고자 근관 세척을 시행하지 않고 근관을 형성하였다. 이 때에는 첫 번째 실험의 방법중 Quantec SC series 2000 대신에 Quantec SC 및 Quantec LX를 이용하여 근관을 형성하였고 나머지는 첫 번째 실험과 동일하게 시행하였다. 각 치아로부터 정출되는 잔사를 용기에 모아 24시간동안 건조시킨 후 전자 저울로 무게를 측정, 비교하여 다음과 같은 결과를 얻었다.

근관 세척을 시행한 경우와 시행하지 않은 경우 공히 step-back technique을 사용한 군에서는 다른 군에 비해 현저히 많은 량의 치근단 정출 잔사가 나타났다. 그러나, crown-down technique을 이용하여 근관 형성한 군과 수종의 Ni-Ti 파일을 이용하여 전동으로 근관 형성한 군들 사이에는 정출 잔사량에 유의한 차이가 나타나지 않았다.

따라서, 본 실험에 사용된 수동 및 전동 기구의 종류는 근관 잔사의 치근단 정출에 영향을 미치지 않는 것으로 생각되며, 근관잔사의 치근단 정출을 최소화하기 위해서는 수동 및 전동 기구 공히 step-back 방법에 의한 filing 동작보다는 crown-down technique의 reaming 동작을 사용하여 근관을 형성하는 것이 바람직하다고 사료된다.

**주요어** : 근관잔사, 치근단정출, 근관형성, 전동화일, crown-down technique, step-back technique

## I. INTRODUCTION

Root canal systems should be cleaned, shaped and obturated in three dimensions for successful endodontic treatment[1]. In fact, most obturation problems are connected with cleaning and shaping, and chemomechanical debridement of the root canal system is considered as an essential part in endodontic therapy.

Despite strict length control of endodontic instrument during root canal preparation, extrusion of canal contents including dentin filings, pulp tissue fragment, necrotic tissue, microorganisms and intracanal irrigant may occur[2,3]. This is of concern to the endodontist since material extruded from the apical foramen may be related to postinstrumentation pain or flare-ups and delayed healing.

Studies showed that pushing the necrotic tissue through the apical foramen could produce interappointment discomfort[4] or postinstrumentation pain[5]. It was explained how bacteria and necrotic dentin in the root canal could initiate antigen-antibody reaction that could trigger the complement cascade and inflammatory reaction[6]. During root canal instrumentation, files were likely to force materials from the apical third of canal into the surrounding tissue[7] and root canal instrument acted as a plunger in the canal[2]. Instrument have a tendency to force the canal contents toward the apex and this is evident when the size of the instrument approximates that of the canal[8]. Some investigators suggested that canals with necrotic pulp should not be instrumented through their entire length in order to avoid forcing the debris through the apical foramen[9] but, others demonstrated that even instrumentation short of the apex would set up an inflammatory response in the periapical area[10].

Thus, instrumentation should be performed in a manner that minimizes the amount of debris extruded into the periapical tissue in order to minimize postoperative reactions. Early canal flaring of the canal provides a coronal escapeway, which reduces this "piston-in-cylinder" effect and would lessen the potential for a positive apically directed hydrostatic pressure[8]. In the step-down technique, radicular access is made by opening and flaring the coronal half to two thirds of canal with Hedstroem files or Gates Glidden burs. The bulk of pulp tissue, microorganisms and debris which could be extruded periapically and cause periapical inflammation are removed before apical instrumentation[11]. The crown-down pressureless technique also involves early canal flaring, followed by the incremental removal of canal contents proceeding from the canal orifice to the working length[12]. Studies demonstrated that step-back technique without cervical preflaring produced more apical debris than any other techniques using hand files[13-15].

Recent advance in technology has permitted the manufacture of endodontic files from Nitinol which is a nickel titanium alloy with a very low modulus of elasticity. The #15 Nitinol files have been proved to be two or three times flexible than the stainless-steel ones of the same size[16]. In many studies, Ni-Ti files caused less transportation of root canal and resulted in more centered canal than stainless-steel ones did[17,18]. Some investigators revealed that engine-driven Ni-Ti Lightspeed removed less dentin and produced rounder canal preparation than K-Flex files [17].

The rotary Ni-Ti systems such as Lightspeed, McXim and Profile .04 systems may produce less apical debris than step-back filing using stainless steel hand file[19]. The amounts of extruded debris with Lightspeed, Profile .04 taper series 29, McXim instrument and Flex-R file using balanced force technique were compared and revealed that there was no difference among the four groups, and the amounts of extruded debris were positively correlated with those of extruded irrigant[20].

Quantec files with different design in comparison with Profile .04 taper series 29, Lightspeed and McXim have been introduced and manufactures suggest that the compression of debris be removed from the canal wall is the most frequent cause of instrument failure. The flute design affects the removal of debris out of the canal. Quantec files have a flute space with larger distal space which was very effective in channeling debris through the spiral of the flute[21]. But, there has been no study about the effect of these files on the apical extrusion of canal debris.

It is well known that mechanical debridement of the root canal is not sufficient to achieve the thorough debridement and endodontic irrigating solutions are used to facilitate it. It is evident that removal of debris out of the canal is dependent on canal size[22,23], dimension of irrigation needle and its depth of penetration into the canal[22,24]. Some authors reported that canal instrumentation without irrigation did not produce collectable amount of debris[25]. The extrusion of irrigation solution was also affected by the penetration depth of the needle into the canal[26]. The amount of extruded debris was positively correlated with that of irrigant extruded[20].

The purposes of this study were to evaluate the influence of canal preparation methods on the extrusion of debris through the apical foramen using different file types and techniques with and without irrigation, and to investigate the most appropriate instrumentation technique for minimizing the amount of debris extrusion.

## II. MATERIALS AND METHODS

### Preparation of the specimens

One hundred twenty extracted human mandibular incisors with mature apex and without any external root resorption were selected. The teeth were radiographed mesiodistally and single canaled teeth were used. The teeth were divided into 2 groups. The first group contains forty teeth and subdivided into four subgroups of ten each. In the second group, eighty teeth were contained and subdivided into five subgroups of sixteen each. All the teeth were stored in 5.25% sodium hypochlorite to remove the organic debris attached to the root surface and cleaned with ultrasonic scalers and currettes. Routine access openings were made and the canal patency was established with placing #10 K-file into canal until it could just be seen flush with the external root surface at the apical foramen. Then, the file was withdrawn by 1mm and this length was recorded as working length for each tooth. Each tooth was positioned in a rubber top by forcing its root in the hole made in the center of the top and secured with self curing clear resin. An empty microcentrifuge tube was attached to the rubber top as a collecting container. The rubber top with the tooth and the collecting container was positioned at the top of glass bottle. A 22-G needle was placed through the rubber top to equalize between the inside and outside of the microcentrifuge tube. The operating field was shielded from the operator by surrounding the bottle with aluminum foil to simulate the clinical situation(Fig. 1).

In the first experiment, the root canals were instrumented and irrigated with 2.52% sodium hypochlorite. The amount of irrigant used in the root canal was carefully controlled and its total volume was 10 ml for each canal. Root canal irrigation was done with a syringe and the needle tip placed as far into the canal as possible without binding.

In the second experiment, root canals were instrumented without irrigation. The collecting container was filled with distilled water to the level of the root apex to facilitate debris collection.

All the preparation and weighing procedures were done by a single investigator.

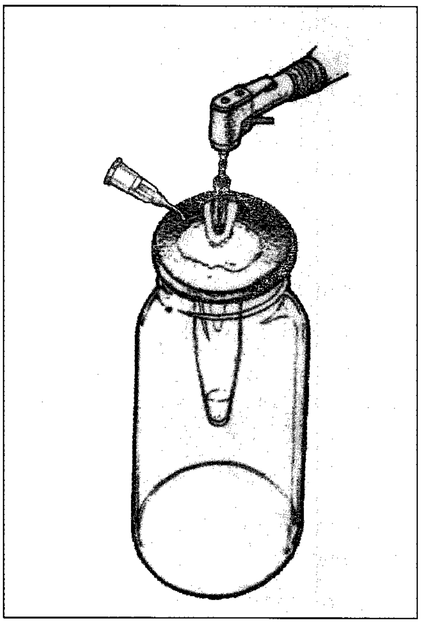

**Fig. 1.** The diagram of experimental unit for the root canal instrumentation and collection of debris

### Root Canal Instrumentation

1) Step-back technique using stainless steel K-files

Root canals were instrumented with precurved stainless steel K-files. The apical preparation was begun with the first file binding at working length. The apical canal was enlarged to three larger file sizes from the initial apical one. Each of three successively larger files were used in a step-back fashion. The coronal flaring was performed with #2, #3, #4 Gates Glidden drills consecutively. The patency was confirmed with #10 K-file in each procedure. All files were used in push and pull motion only.

2) Crown-down pressureless technique using stainless steel K-files

Root canals were instrumented with non curved stainless steel K-files.

A size 35 K-file was placed in the canal to the point of the first resistance without apical force. The depth was 16mm or more, this was the radicular access length. If this was less than 16mm, the canal was enlarged until the #35 file penetrated into the canal by 16mm. The #2, #3 and #4 Gates Glidden drills were used for completion of the radicular access. The #35 K-file was inserted into the canal passively, then rotated twice, and removed. Consecutively smaller files were used until a file reached the working length. Next sequence was started with an instrument one size larger than the previous one until the apex was prepared to three larger file size than the initial one. The patency was confirmed in each sequence.

3) Engine-driven instrumentation using Quantec LX series 2000™

Quantec LX series 2000™(NT Company, Savannah. USA) was used in a 1/16 reduction gear handpiece(Aseptico Inc., USA) powered by an electric motor(Aseptico Inc. USA) at a constant speed of 300 rpm. These files have non-cutting tip. The teeth were instrumented according to the manufacturer' s directions. The #1 file was used as an orifice opener. The #2 to #8 files were used in turn to the working length. The #9 file was used to the depth 1 mm short of the working length. If an obstruction prevented the file, recapitulation was performed with #1. In each step, canal patency was confirmed.

4) Engine-driven instrumentation using Quantec SC series 2000™

These files have the same design as non-cutting types except the tips with cutting blade. The instrumentation procedures were same as the LX types.

5) Engine-driven instrumentation using Profile .04 taper series 29

Profile .04 taper series 29(Maillefer, Swiss) was used at a constant speed of 300 rpm. These files have U-file design and non cutting tip. The #4 and #5 Profiles were first used to the depth of 1/2 of the working length followed by #3 to the 3/4 of the working length. The #2, #3 and #4 Gates Glidden drills were used for coronal flaring. #2 to #6 Profiles were used in turn to the working length. #7 and #8 Profiles were used in a step-back fashion.

### Debris collection and Quantification

At the completion of canal instrumentation, the end of the root surface was flushed with 0.5ml of 95% alcohol to collect the adhering debris and the collecting container was separated from the tooth. The containers were placed in a desiccator (Daerim, Korea) at 120℃ for 24 hours. An electronic balance (A&D company, Japan) was used to weigh the container and collected debris. The amount of debris in each tooth was calculated by subtracting the weight of the container from the total weight of the container and debris. The weight of each container and debris was recorded to 1/100 of a milligram. The weights were measured three times respectively and the mean values were recorded as the weight.

### Statistical Analysis

The mean weights of extruded debris for every groups were compared using one-way ANOVA. Dunkan' s Multiple Range Test was used to determine significant differences in extruded debris.

## III. RESULTS

### Debris extrusion during root canal instrumentation with irrigation

Root canal instrumentation was done with irrigation using 2.52% sodium hypochlorite solution. The mean weight of apically extruded debris for each group is outlined in Table 1. The greatest mean weight was found with step-back group ($7.78\pm1.61$ mg). The amount of apically extruded debris was $3.75\pm2.21$mg for the crown-down group, $3.34\pm1.88$ mg for the Profile group and $2.82\pm1.89$ mg for the Quantec SC group. Step-back technique produced significantly more debris than the other three instrumentation methods ($p<0.05$). However, there was no significant difference among crown-down, Profile and Quantec SC groups ($p<0.05$) (Fig. 2).

### Debris extrusion during root canal instrumentation without irrigation

Root canal instrumentation was done without irrigation. The amount of apically extruded debris for each group is outlined in Table. 2. The greatest mean

**Table 1.** The amount of apical debris during root canal instrumentation with irrigation (mg)

| Preparation method | n | Mean | SD | Range |
|---|---|---|---|---|
| Step-back | 10 | 7.78 * | 1.61 | 5.10-9.89 |
| Crown-down | 10 | 3.75 | 2.21 | 0.79-8.14 |
| Quantec SC | 10 | 2.82 | 1.89 | 1.10-6.33 |
| Profile | 10 | 3.34 | 1.88 | 0.50-5.99 |

* Significantly different from the other groups (p〈0.05).

**Table 2.** The amount of apical debris during root canal instrumentation without irrigation (mg)

| Preparation method | η | Mean | SD | Range |
|---|---|---|---|---|
| Step-back | 16 | 0.20 * | 0.19 | 0.05-0.80 |
| Crown-down | 16 | 0.09 | 0.05 | 0.03-0.25 |
| Quantec LX | 16 | 0.06 | 0.03 | 0.01-0.12 |
| Quantec SC | 16 | 0.10 | 0.06 | 0.01-0.25 |
| Profile | 16 | 0.07 | 0.03 | 0.02-0.12 |

* Significantly different from the other groups (p〈0.05).

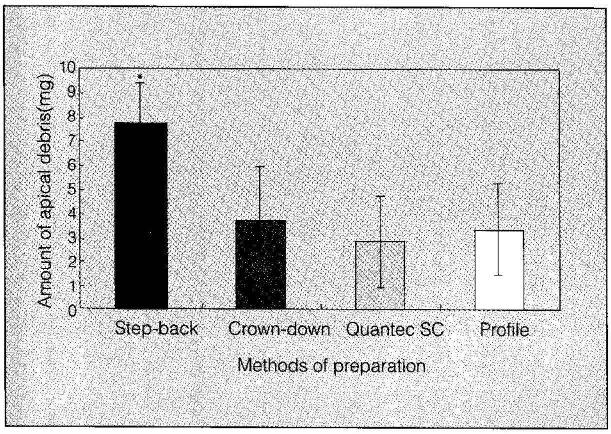


**Fig. 2.** The amount of apical debris presented as mean ± SD. Significant difference from the other groups are noted (*) at a p〈0.05 level.

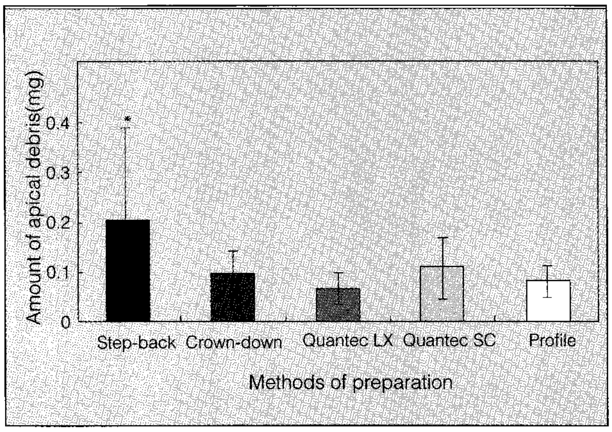


**Fig. 3.** The amount of apical debris presented as mean ± SD. Significant difference from the other groups are noted (*) at a p〈0.05 level.

weight was found with step-back technique with stainless steel K-file (0.20±0.19mg). There was a significant difference between step-back group and the other four groups(p〈0.05).

The amounts of extruded debri were 0.09±0.05mg for crown-down group, 0.06±0.03mg for Quantec LX group, 0.10±0.06mg for Quantec SC group, and 0.07 ±0.03mg for Profile group. However, there was no significant difference among the groups except the step-back group(Fig. 3).

## Ⅳ. DISCUSSION

The development of pain and swelling (flare-up) during or after endodontic therapy is a very vexing problem for the endodontists. In the case of teeth with pulpal or periapical pathosis, dentists open the pulp chamber and instrumentate and irrigate the canal to remove irritants and to obturate it three dimensionally. But, this procedure also presses the irritant of necrotic debris, dentin particles, fragments of tissue, microorganism and their toxic products into the periapical area. It is well-documented in the literature that contaminate dentin and pulp tissue as well as noncontaminated one could trigger an inflammatory reaction when they are forced periapically during root canal instrumentation[10]. The root canal irrigants and intracanal medicaments may also produce the same response.

There are several factors that possibly trigger the flare-up process. When root canal therapy is initiated and introduces infective debris into the lesion, a chronic inflammatory periapical lesion reacts violently and immunological phenomena, either cell mediated or humoral, occurs to the debris in the area[10]. To initiate these types of responses, it is postulated that a certain minimal amount of inoculum is needed[6]. Therefore, for the successful endodontic therapy, thorough cleaning and shaping should be performed and the amount of extruded debris should be minimized.

This study was performed to evaluate the influence of canal preparation methods on the extrusion of debris through the apical foramen using different file types and techniques, and to investigate the most appropriate instrumentation technique in minimizing the extrusion of debris. This investigation also evaluated the effect of canal instrumentation in the absence of root canal irrigation to avoid the variation by irrigation procedure.

Since Walia et al.[16] introduced the nickel-titanium files in the endodontic field, many investigations stated that it had superior mechanical properties than the stainless steel ones[18,27-35]. Because of its high flexibility, the load on the cutting blade in a curved canal is greatly reduced, which reduces stress on the instrument and the possibility of fracture. Recently, Engine-driven Ni-Ti instruments have been used in endodontics due to their convenience and time saving effect. Studies showed that engine-driven nickel titanium files produced less procedural errors such as zip, elbow, apical transportation and the extrusion of root canal debris during root canal preparation than hand instrumentation with stainless steel ones[27,29,30,34,36]. But, Huh and Kim[36] demonstrated that crown-down pressureless technique with stainless steel K-file did not produce more procedural errors and extrusion of debris than the engine-driven Ni-Ti instrumentation. They concluded that hand instrumentation with reaming motion of stainless steel files were as effective as engine-driven Ni-Ti methods in maintaining the canal curvature without procedural errors. Their conclusion was coincided with this study in respect of debris extrusion. However, even though they didn' t find any apical debris with crown-down pressureless technique, all instrumentation techniques produced certain amount of debris extrusion in this study. Researchers have found that no technique was totally effective in preventing debris extrusion, and in this study there was no technique producing no debris at all. Results of this study reinforced the fact that the linear filing motion produced more apical debris. When the engine-driven Ni-Ti instrument are used, the systems are combined with a crown-down or cervical flaring type preparation and these techniques have previously been found to affect favorably debris extrusion[37,38]. In this study, step-back group produced more debris than crown-down, Quantec or Profile groups. Engine-driven instrumentation produced less apical debris than step-back instrumentation however, in comparison with crown-down preparation, there was no significant difference. The result of this study agrees with McKendry[14] and Al-Omari and Dummer[37]. They showed that step-back instrumentation produced more extruded debris than rotary instrumentation and hand instrumentation using reaming motion. The hypothesis that engine-driven Ni-Ti instrumentation would produce less debris than hand instrumentation was only partially supported. A common finding in many studies is that push-pull instrumentation produces more debris than instrumentation techniques that incorporate a rotation force.

Instrumentation with irrigation produced significantly more apical debris than that without irrigation[25] and in the cases using deep delivery of irrigation needle into the canal, the significantly more sodium hypochlorites were extruded apically than that using irrigation needle placed in the coronal access cavity[26]. There was no significant correlation between the volume of extruded irrigant and the final mean dry weights[15]. However, others revealed positive correlation between the amount of extruded debris and extruded irrigant[20,39]. In vivo, the effect of the amount of irrigation on its ability to penetrate periapical tissues is unknown. In the first experiment of this research, 10ml of irrigant was used for each canal, and passive injection method of irrigant was used to minimize the extrusion force. In the second experiment, the root canals were instrumented without any irrigation procedures in order to completely eliminate the influence of the irrigation procedure and the results were coincided with the first experiment. Step-back group produced significantly more extrusion of debris. Root canal irrigation may press the canal debris periapically, but this investigation shows that if same amount of irrigant is used and passive irrigation is conducted, this was not the main factor that influence the total extruded volume difference between groups. The mean amount of debris was more in the first experiment than in the second one, and the increased amounts may be form sodium hypochlorite crystals.

Some authors investigated relationship between instrumentation length and apical debris, and concluded that less material was extruded when the canal was prepared to a distance just inside the apical foramen[40]. Others revealed that the group instrumented short of the foramen had significantly less apical debris than that instrumented to the entire canal length[15]. Profile used 1 mm short of the apex produced less apical debris than that used to the apical foramen, and significantly more irrigant was extruded when filing was done to the apical foramen[39]. Thus, in this experiment, all canals were instrumented to the length of 1 mm short of the apical foramen to reduce the influence caused by instrumentation length.

Factors such as canal length, curvature, and foramen size did not affect on the amount of apical debris[15,20,41]. There was no correlation between the weight of apically extruded debris and the canal diameter at various point and distance of curve form orifice[37]. In our study, with the exception of using teeth with the same apical canal size and same working length, there was no trial to standardize the anatomical factors of root canal.

In this study, the design of instrument did not affect the amount of the apical debris. Hinrichs et al[20] compared several types of engine-driven : Ni-Ti instrument, Lightspeed, Profile .04 taper series 29, NT McXIM instrument. They showed no statistically significant difference among the groups with respect to total extruded debris. In this study, 3 types of engine-driven Ni-Ti files were used. Profile .04 taper series 29 (Maillefer, Swiss) have a novel range of sizes which, unlike the ISO standard, increases in diameter by a consistent 29% and have the flute design same as the U-file42). Quantec Series 2000™(Tycom, California, USA) consist of ten size files and have a flute space that becomes progressively larger distal to the blade to avoid any compression of debris[21]. This is divided into SC type of safety cutting tips and LX type of non cutting tips. Non cutting safe tips, bat tips or piloted tips help prevent canal transportation by deflecting the instrument around a curvature before the blade becomes engaged, and by no cutting the dentin but burnishing only. For preparing small curved calcified canal, the safe cutting tip is more useful. There was no significant difference in the result from groups using different file types. The files used in our studies have completely different type of flute design and we expected the difference in the amount of extruded debris. Files were originally designed for filing motion, but when used with reaming motion, they produced more efficient outcome to the respect of root canal preparation and prevention of debris extrusion than filing motion.

Huh and Kim[36] supposed that engine-driven Ni-Ti instruments were used in a slow push and pull motion and they affected the extrusion of debris. However, Martin and Cunningham[40] have shown that more debris is extruded apically in hand instrumentation than in endosonic instrumentation. They stated that endosonic instrumentation produced little apical pressure and the instrument was smaller than hand files, which resulted in less binding into the canal. The ultrasonic instrument produced less extrusion of debris than conventional filing technique[41]. The ultrasonic and sonic instrumentation made the debris being suspended in the irrigant and removed with the continuous irrigation before it became packed at the apical foramen. Thus, if used without apical pressure, the push-pull motion of engine-driven instrument will not affect the extrusion of canal debris.

The correlation of the amount of extruded debris with the clinical problem are not revealed clearly. It could be argued that the greater the weight of debris, the more severe the tissue reaction. This research was done in vitro. In vivo, the apical area is not empty and the vital tissue may prevent the extrusion or spread of extruded debris, and the real amount of extruded debris may be less than that in vitro. Not only the mass of debris but also the type and virulence of bacteria in the debris and the resistance of host tissues may have an influence on the periapical reaction. And in the teeth of children with immature apex, the amount of extruded root canal debris was not studied. In this study, all the instrumented teeth were kept intact apical foramen, and the apical stops were preserved. But clinically, there may be many teeth with apical perforation. In that circumstance, more extrusion of debris may be produced than in the teeth with intact apical foramen. There are needs for further studies about these factors. The clinical significance of such factors is only possible to deduce but, it would be wise to use certain technique that minimizes the extrusion of debris to prevent the occurrence of unwanted complication during endodontic treatment.

In summary, step-back technique seems to produce more apical debris than crown-down pressureless technique or engine-driven Ni-Ti instrumentation methods using Profile or Quantec files. In addition, to minimize the amount of apical debris, all instrumentation should be done with rotational motion, and when instrumentation or irrigation is applied, neither of them must produce apical force. The avoidance of binding of files into the canal could also reduce the unnecessary apical force.

## V. SUMMARY

Apical extrusion of canal debris is occurred inadvertently during root canal preparation and this could produce interappointment discomfort or postinstrumentation pain.

The purpose of this study was to investigate the influence of canal preparation methods on the apical extrusion of canal debris by means of comparing the amounts of apically extruded debris with several kinds of instrumentation methods. In the first experiment, 40 incisors were divided into four groups of 10 each. They were instrumented using one of the four techniques: Step-back, crown-down pressureless technique with stainless steel K-files, engine-driven instrumentation with Quantec series 2000, and Profile .04 taper series 29. Root canal irrigation was done with 2.52% sodium hypochlorite solution. In the second experiment, 80 incisors were divided into five groups of 16 each and instrumented using step-back, crown-down pressureless technique with stainless steel K-files, engine-driven instrumentation such as Quantec SC, Quantec LX, and Profile .04 taper series 29. No irrigation procedure was performed in this second experiment. Extruded debris from each tooth was collected in a container and weighed by the use of an electronic balance after desiccation.

With or without canal irrigation, step-back technique produced significantly more amount of apical debris than the other groups ($p<0.05$). However, there was no significant difference among crown-down pressureless technique, engine-driven instrumentation with Quantec LX, Quantec SC, or Profile. Therefore, either by hand or engine-driven instrumentation, it is concluded that to minimize apical debris, techniques using reaming motion of files should be applied rather than filing motion.

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