A Comparison of Three Stainless Steel Instruments in the Preparation of Curved Root Canals in vitro

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국문초록

세 종류의 Stainless Steel File을 이용한 만곡근관 형성 후 근관형태 변화에 관한 비교 연구

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통상적인 근관형성 과정에서 근관형태의 직선화 경향을 발견할 수 있으며, 그 결과 만곡이 심한 근관에서 이상적인 근관형태를 얻기가 어렵다. 이를 극복하기 위한 많은 기구들과 근관 성형법들이 개선되고 소개되었다. 본 연구에서는 최근에 개발된 직사각형의 단면을 가지는 stainless steel file인 RT file과 Flex-R file, K-file을 이용하여 만곡근관 형성 후 최종 근관형태를 비교하여 각 file을 평가하고자 한다.

본 실험은 Bramante등의 방법을 변형하여 술 전의 근관형태와 술 후의 근관형태를 비교하였다. Schneider의 방법을 변형하여 3차원적 만곡을 계산하여 12도에서 36도 이내에 만곡도를 가진 근관을 선택하였다. 49개의 발거된 상악대구치 협측근관이나 하악대구치 근심근관을 3개의 군으로 나누고 레진과 플라스틱으로 제작된 mold에 투명한 교정용 레진으로 매몰하였다. 근첨에서 2.5, 5, 8mm 지점에서 절단하여 각 mold에서 재조립한 후 다음과 같이 근관형성을 시행하였다. 제 1군은 SS K-file을 이용하여 step-back 방법; 제 2군은 Flex-R file을 이용하여 balanced force 방법; 제 3군은 RT file을 이용하여 step-back 방법으로 근관 형성하였다. 술 전과 술 후에 각 시편들을 입체현미경으로 사진촬영하여 근관 중심 위치 이동률, 근관형성으로 삭제된 상아질양, 근관형성 후 모양을 Sigma scan/ image software program으로 계산하고 One way ANOVA로 통계적 유의성을 검증하여 다음과 같은 결론을 얻었다.

1. RT file이 치근단에서 K-file보다 유의성 있게 근관의 중심을 유지하는 것으로 보였다. 치아 중앙부에서는 RT file과 Flex-R file이 K-file에 대해 유의성 있게 우수한 것으로 나타났다.
2. 근관형성 후 삭제된 상아질양에서는 치근단에서 RT file이 적게 나왔으나 유의성은 없었다.
3. 근관형성 후 절단면 모양은 원형, 타원형, 불규칙한 형태들이 다양하게 나타났고 각 군간에 유의성 있는 차이는 없었다.

I. INTRODUCTION

Removal of microbial contaminants and organic substrates from the root canal system in conjunction with the total closure of that system is the primary biologic objective of root canal therapy. It is paramount that the shaping of the root canal space be defined in such a way that this objective can be achieved[1].

Whereas most of the criteria can be easily met in straight canals, 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[2].

In curved canals, there is a tendency for all preparatory techniques to transport the prepared

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canal away from the original axis. Weine[3] 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[4] referred to this inherent characteristic for endodontic files as the "restoring force" of the instrument.

In 1965, Luks[5] was the first who doubted the ability to create round preparation that could be adequately obturated with solid core materials. Schneider[6] 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[7].

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, 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 techniques was a step-back or flared technique[3]. Apical instrumentation is accomplishing using smaller diameter files, which are more flexible and thus are able to be advanced to the full working length and larger size files are sequentially stepped back from the apical terminus. In 1985, Roane et al.[4] introduced the "balanced force" concept. This method of canal preparation was based on instrument rotation, and a new type of instrument with a modified noncutting tip, Flex-R files (Union Broach, Emigsville, PA, USA). An instrument with a triangular cross-section was chosen because it provide cutting edges with identical rake and clearance angles. In addition, other techniques such as step-down technique, crown-down technique and anticurvature filing have also been developed to reduce transportation of the canal during instrumentation.

With the development of cleaning and shaping methods, improvement in the file tip design and changes in the cross-sectional area and shape are made. RT file (Mani, Inc., Tochigi-Ken, Japan), K-type file having a rectangular cross section, is recently developed new endodontic file. Katsuumi[8] reported that files having rectangular cross section were found to have higher filing performances due to increase of blade slope and excellent mechanical properties. He reported that RT file showed flexibility, small bending torques, and torsional torque almost equal to that of the square file. Although the angle of torsional fracture varied according to instrument size, RT files were not easily fractured by torsion

The purpose of this study was to compare the effects of endodontic files on the preparation of curved root canals and to evaluate the final shapes of curved root canals.

Ⅱ. MATERIALS and METHODS

1. Specimen selection

Extracted human mandibular and maxillary molars 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 was determined by placing a #10 stainless steel(SS) K-file into each canal until it just disappeared at the apical foramen and then the teeth were radiographed from the mesial-distal aspect and bucco-lingual aspect respectively.

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. The angles of curvature were determined using Schneider's method[9]. Canals with curvature between 12 degrees and 36 degrees were selected. The following formula was used for each canal to determine the true angle of curvature (TAC) from clinical and proximal radiographic view[12]:

TAC = Arctan[Tan(clinical angle)^2 + Tan(proximal angle)^2]$^{1/2}$.

Forty-nine canals were finally selected, using the following criteria: 1) Canals which were separated from the orifice to the apical foramen, 2) Canals which exceeded 15mm from the occlusal reference point to the apical foramen, and 3) Canal which had a snug fit with either #10 or #15 K-file.

2. Specimen Preparation

The model system used for instrumentation was a modification of the method presented by Bramante et al.[13]. The model system consisted of fabricating muffles of acrylic resin and acrylic plate to prepare the acrylic resin-tooth block. The roots were embedded in a clear casting resin (Dura Ortho-resin, Dental Mfg, Co., Worth, Ill, USA). For the purpose of fixing the sections after cutting, grooves were made at the muffles. After the resin had set, the block was removed from the mold and sectioned with a cutting system (Exakt, Kulzer, Germany).

The cuts were made at 2.5, 5, and 8mm from the apex. Care was taken to make the cuts perpendicular to the canal to avoid angled cuts. Each section was encoded and marked to identify the coronal side. Each section was photographed with a stereomicroscope (SI-PT - Olympus, Japan) set at×2.6 magnification. Outlines of root canals were then carefully drawn.

3. Canal instrumentation

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

Group 1: 16 canals were instrumented with stainless steel K-files (Mani, Inc., Tochigi-Ken, Japan) using a step back method[14]. The canals were enlarged at working length to size #35 followed by a sequential 0.5mm step back preparation. Recapitulation was performed with the master apical file.

Group 2: 17 canals were prepared using balanced-force technique of instrumentation described by Southard et al.[15] using Flex-R file. Gates Glidden drills were not used. This ensured that only the effect of the Flex-R files would be evaluated after instrumentation. A standardized apical preparation of #45 was used as described by Sabala et al.[16].

Group 3: 16 canals were instrumented with the same technique as Group 1 with RT files.

Each canal was irrigated with 1ml of 3.5% NaOCl after each instrumentation. 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 were photographed exactly as previously described. The preinstrumentation tracings were aligned with the postinstrumentation tracings. This allowed direct comparison of the pre- and postinstrumentation. The following dimensions were determined for each section: a) Mean centering ratio, b) Mean area of dentin removed, c) Postinstrumentation canal shape.

4. Statistical Analysis

Data have been obtained by Sigma scan/ image software program, ver 1.20 (Jandel Scientific, Corp., San Rafael, Ca, USA). The mean centering ratio is a measure of the ability of the instrument to stay centered in the canal; the smaller is the ratio, the better centered the instrument in the canal. The ratio, as reported by Calhoun and Montgomery[10], was calculated for each instrumented section using the following formula: (X1 - X2)/Y. X1 represented the maximum extent of canal movement in one direction, X2 is the movement in the opposite direction, and Y is the largest diameter of the canal preparation. The area of dentin removed was calculated by subtracting the area of the uninstrumented canal from the area of the instrumented canal[11]. One way analysis of variance (ANOVA) was used for evaluating the data of this study.

Ⅲ. RESULTS

Forty-nine canals were used in this study. Centering ratio data are presented in Table 1. At the apical level, RT file had the smallest centering ratio, that is, it transported the canal less than other groups. There was significant difference between RT file and K-file($p<0.05$), but there was no significant difference between RT file and Flex-R file. At the middle level, RT file and Flex-R file showed significantly smaller centering ratio than K-file($p<0.05$). At the coronal level, there were no significant differences. Table 2 shows the mean area of the dentin removed. RT file showed smaller removal of dentin at the apical level, but ANOVA did not show statistical differences at any of the levels between groups. The incidences and percentages of canal shapes at different levels are given in Table 3. There were not significant differences

There was significant difference between RT file and K-file($p<0.05$) at the apical level. At the middle level, RT file and Flex-R file showed significantly smaller centering ratio than K-file($p<0.05$). n=16 in K-file and RT file. n=17 in Flex-R file.

Ⅳ. DISCUSSION

Many techniques are used for in vitro analysis of endodontic instrumentation of root canals, including radiographic analysis[17-20], histological

Table 1. Centering Ratio at each level of the root canals

Experimental Group	Apical Mean ± SD	Middle Mean ± SD	Coronal Mean ± SD
SS K - file	0.365 ± 0.147	0.406 ± 0.194	0.277 ± 0.150
Flex - R file	0.293 ± 0.190	0.236 ± 0.163	0.259 ± 0.201
RT file	0.243 ± 0.146	0.231 ± 0.158	0.225 ± 0.078

Table 2. Mean area of dentin removed at each level of the root canals

Experimental Group	Apical Mean ± SD	Middle Mean ± SD	Coronal Mean ± SD
SS K - file	0.149 ± 0.095	0.138 ± 0.083	0.170 ± 0.088
Flex - R file	0.125 ± 0.060	0.128 ± 0.066	0.176 ± 0.137
RT file	0.114 ± 0.062	0.188 ± 0.213	0.200 ± 0.171

Measurements in mm^2. There were not statistical differences between groups.($p>0.05$)

Table 3. Post-instrumentation canal shapes (%)

Experimental	Apical			Middle			Coronal		
Group	Round	Oval	Irregular	Round	Oval	Irregular	Round	Oval	Irregular
SS K-file	2(12)	8(50)	6(38)	1(6)	4(25)	11(69)	3(19)	7(44)	6(38)
Flex - R file	6(35)	6(35)	5(29)	3(18)	8(47)	6(35)	3(18)	3(18)	11(65)
RT file	4(25)	6(38)	6(38)	3(19)	8(50)	5(31)	-	4(25)	12(75)

Measurements in percentage. There were not statistical differences between groups($p>0.05$).

images obtained with the light microscope[21,22] or the scanning electron microscope[23], injectable silicone[24], and others. These techniques do not permit observation of the canal anatomy before and after instrumentation, and it is important to know with precision which areas of dentin have been properly instrumented and cleaned by endodontic instrumentation.

The present study was based on the cross-sectional assessment of root canal shape proposed by Bramante et al.[13] and modified by Mongotmery and Calhoun[10]. By sectioning and comparing the photograph of the preinstrumented teeth to the postinstrumented teeth, it is possible to evaluate the effects of instrumentation accurately and to allow direct viewing of canal shape. But this evaluation method has shortcomings, loss of dentin during root cutting does not permit a perfect assembly of root fragments. A higher number of cuts would dramatically decrease the length and continuity, and this can affect the curvature of the canal. Three horizontal cuts were used in this study. The first cut was made at 2.5mm from the 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 occurs 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 8 mm 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 in analyzing the effect of instrumentation.

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 increased 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.

In 1999, Katsuumi examined the mechanical properties and cutting efficiency of the K-type file having a rectangular cross section. Sample files of sizes #15 to #40 having side ratios 1 : 2, 1 : 3, and 1 : 4 were produced, and four tests were performed. Cutting test : the filed distance of an acrylic plate was measured after 300 strokes. Bending test : the maximum torque was measured for a file which was bent 45 degrees, torsion test: the maximum torque was measured for a file which was twisted until fracture, and the angle of rotation at fracture were measured. K-type files having square and triangular cross sections were used as a control. The results were that the rectangular file of side 1 : 3 showed the greatest filing distance. The rectangular files of side ratios 1 : 4 and 1 : 3 were found to be flexible and had small bending torques. The rectangular file of side ratios 1 : 3 was found to have a torsional torque almost equal to that of the square file. Although the angle of torsional fracture varied according to instrument size, files having a rectangular cross section were not easily fractured by torsion. So according to the study of Katsuumi, files having rectangular cross sections, especially the rectangular file of side ratio 1 : 3, were found to have higher filing performances due to increase of blade slope, and excellent mechanical properties.

RT file, the rectangular file of side ratio 1 : 3, has two rake angles of -72 degree and -18 degree, whereas K-file and flex-R file have identical rake angle of -45 degree and -30 degree respectively. A negative rake angle has the blade turned in the opposite direction of the force applied to cut the dentin. A blade with a negative rake angle is less efficient and requires more energy to cut dentin than a blade with a neutral or positive rake angle. Because -18 is near neutral, RT file seems to be more effective in removing dentin.

According to the results of this study, RT file can predictably enlarge curved canals, while maintaining the original path. The results presented in Table 1 revealed statistical difference in centering ratio at the apical level and middle level between the RT file group and K-file group.

The mean area of the instrumented canals (Table 2) prepared with RT file at the apical level was smaller than those of the other two groups. This meant that RT file remained more centered than K-file and worked more uniformly on the walls of the original canal. And at the coronal third, RT file showed more preparation than other groups. This meant that RT file can remain in the center at the apical level and remove dentin easily at the coronal. However, there was no significant difference in 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.

As presented in Table 3, the postinstrumentation canal shapes of the experimental groups varied among round, oval, and irregular shapes, but there were not significant differences among groups.

No separation of instrument occurred. This may be explained by the frequent changes into new instruments throughout the experiment.

Although it was not an objective of the study, the impression was that the time required to instrument the canals differed between groups. So, further studies about canal preparation, including preparation time, canal center movement, loss of working distance, canal aberrations, and direction of transportation, are needed for evaluating RT file.

In summary, it seems to be appropriate to regard the RT file, characterized by its rectangular cross sectional area, as a development toward a universal root canal instrument.

Ⅴ. CONCLUSIONS

In this study the modification of Bramante technique was used. This method enabled to examine the canal before and after instrumentation at any level within the same canal. The effects of hand instrumentation using K-file, Flex-R file, and RT file to maintain the original canal location, the amounts of dentin removed, and the final shape of the instrumented canals were observed.

The conclusions are as follows:

1. RT file remained more centered in the canals than K-file group at the apical level($p<0.05$). And at the middle level, RT file and Flex-R file showed significantly smaller centering ratio than K-file($p<0.05$).
2. The mean areas of dentin removed in the instrumented canals prepared with RT file were smaller than other two groups at apical level. But, there were not statistical differences($p>0.05$).
3. The shapes of the canals after instrumentation varied among round, oval and irregular shapes. There were no significant differences($p>0.05$).

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