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Original

A comparative SEM investigation of the smear layer following preparation of root canals using nickel titanium rotary and hand instruments

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Abstract: The aim of this study was to compare the efficacy of NiTi flex K-file instruments and rotary FlexMaster and Race instruments (short for reamers with Alternating Cutting Edges) in root canal preparation. A total of 75 single rooted teeth with minimum curvature (< 5°) were selected and divided into three groups, each containing 25 teeth. Canals were prepared with NiTi flex K-file, FlexMaster and Race instruments using crown down preparation technique, up to size #40. After each instrument, the root canals were flushed with 5 ml of 0.5% NaOCl solution. The amount of debris and smear layer was quantified on the basis of Hulsmann method using a scanning electron microscope. Completely cleaned root canals were not found after instrumentation with any of the three instruments. In general, FlexMaster instruments left significantly less debris and smear layer than Race and NiTi flex K-file instruments ($P < 0.05$). NiTi flex K-files resulted in significantly more smear layer ($P < 0.05$) compared to Race and FlexMaster instruments only in the apical third of the canal. (J. Oral Sci. 49, 47-52, 2007)

Keywords: smear layer; debris; scanning electron microscope; rotary instruments.

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Introduction

For many years, dentists have been applying newly developed techniques and advanced technology for designing and manufacturing instruments to aid them in endodontic treatment. Despite progress in optimization of the design and properties of instruments, no instrument that has been introduced can ideally debride the root canal (1). Elimination of residual pulp tissue, removal of debris and maintenance of the original canal curvature during enlargement are the main objectives of root canal instrumentation (2). The smear layer is a combination of organic and inorganic particles on the canal walls after canal preparation, and appears as an amorphous irregular layer under scanning electron microscope (3). The smear layer is produced during root canal preparation by the manipulation of the surface elements of the dentinal walls of canals. Whether the smear layer needs to be removed or retained before canal obturation still remains a controversial topic. It is believed that, from a biologic point of view, the presence of a smear layer contributes to leakage and it is also a source of nutrients for microorganisms (3).

Most authors indicated that the cleaning ability of manual root canal instrumentation is superior to automatic devices (4). However, several recent investigations showed that automated devices using rotary NiTi instruments lead to good instrumentation results (5,6). The Race file (short for reamers with Alternating Cutting Edges) has a safety tip and triangular cross section. This file possesses an alternating spiral and has a cutting shank of 8 mm, giving variable helical angles and a variable pitch. This enhances

the file's 'antiscrewing-in' characteristic (7).

FlexMaster files have convex cutting edges, which produce three cutting edges with equal and discrete space, resembling K-files (8). These instruments lack radial land and have non-cutting tips (8). Unfortunately, little is known about the cleaning efficacy of these systems. The aim of this investigation was to compare the cleaning efficacy (residual debris and smear layer) after preparation with rotary NiTi FlexMaster, Race and NiTi flex K-files.

Materials and Methods

A total of 75 extracted human single-rooted teeth with mature apices and minimum curvature (< 5°) were selected for this investigation. The degree of canal curvature was determined using the Schneider method (9) and the teeth with curvatures of < 5° were chosen. The crowns of the teeth were sectioned with a diamond disk (D&Z, Diamant, Germany) and 14 mm of root structure was left. The remainder of the pulp tissue was removed with a barbed broach (Dentsply, Maillefer, Swiss). The size of the apical foramen was gauged with a #15 file (Dentsply, Maillefer, Swiss). The teeth were then randomly divided into 3 groups, each containing 25 teeth.

Working length was obtained by measuring the length of the initial file (size #10) at the apical foramen minus 1 mm in all the groups. The canals of all the teeth were prepared with instruments up to size #40. Each instrument was used only in three canals and then was replaced by a new one. During instrumentation, the root canals were flushed with 5 ml of 0.5% NaOCl solution (Pakshoma, Tehran, Iran). After instrumentation, 5 ml of normal saline (Samen, Mashad, Iran) was used with a plastic syringe as final rinse. The following instrumentation sequences were used in three groups.

Group A

FlexMaster (VDW, Munich, Germany) (8): These instruments were set into rotational speed (250 rpm) with an 8:1 reduction handpiece powered by a torque limited electric motor (TCM Motor 3000 Novage, Konstanz, Germany). Instrumentation was completed using the crown down technique, according to the manufacturer's instructions.

The preparation sequence:

1) 0.06 tapered size #40 instruments were used to one-half of the working length
2) 0.04 tapered size #30 instruments were used to two-thirds of the working length
3) 0.04 tapered size #25 instruments were used to full working length
4) 0.04 tapered size #20 instruments were used to full working length
5) 0.02 tapered size #25 instruments were used to full working length
6) 0.02 tapered size #30 instruments were used to full working length
7) 0.02 tapered size #35 instruments were used to full working length
8) 0.02 tapered size #40 instruments were used to full working length

Group B

Race (FKG Dentaire, La-Chaux-de-Fonds, Switzerland): These instruments were set into rotational speed (500 rpm) with an 8:1 reduction handpiece powered by a torque limited electric motor (TCM Motor 3000 Novage, Konstanz, Germany). Instrumentation was completed using the crown down technique, according to the manufacturer's instructions.

The preparation sequence:

1) 0.1 tapered size #40 instruments were used to one-third of the working length
2) 0.08 tapered size# 35 instruments were used to one-half of the working length
3) 0.06 tapered size# 25 instruments were used to two-thirds of the working length
4) 0.04 tapered size# 25 instruments were used to full working length
5) 0.02 tapered size# 25 instruments were used to full working length
6) 0.02 tapered size #30 instruments were used to full working length
7) 0.02 tapered size #35 instruments were used to full working length
8) 0.02 tapered size #40 instruments were used to full working length

Group C

NiTi flex K-file (Dentsply, Maillefer, Swiss): Hand instrumentation with these instruments was completed using the crown down technique.

All canals were sequentially prepared to the apical size of #40.

First sequence: sequential use of file #45 in coronal parts to #15 in full working length

Second sequence: sequential use of file #50 in coronal parts to #20 in full working length

Third sequence: sequential use of file #55 in coronal parts to #25 in full working length

Forth sequence: sequential use of file #60 in coronal part to #30 in full working length

Fifth sequence: sequential use of file #70 in coronal parts

to #35 in full working length
Sixth sequence: sequential use of file #80 in coronal parts to #40 in full working length

Evaluation

All root canal preparations were completed by one operator, while the scanning electron microscope (SEM) evaluations were carried out by a second examiner who was blind to the experimental groups.

Canal cleanliness

After preparation, all root canals were flushed with normal saline and dried with absorbent paper points.

Using a No.1 diamond disk (D&Z, Diamant, Germany), two longitudinal grooves were prepared on the buccal and lingual aspects of the teeth. The grooves were not deep enough to enter the canals. A plastic instrument was then used to separate the teeth into two halves and both halves were prepared for SEM evaluation, and examined under the Leo 360. SEM (Leo Electron Microscopy, Cambridge, UK) at ×500 and ×1500 magnifications. Separate evaluations were recorded for debris and smear layer. The cleanliness of each root canal was evaluated in three areas (apical, middle and coronal third of the roots) by means of a numerical evaluation scale (4).

The following scheme was used (8):
Debris (dentin chips, pulp remnants and particles loosely attached to the canal walls):
Score 1: clean canal wall, few debris particles
Score 2: few small conglomerations
Score 3: many conglomerations, less than 50% of canal wall covered
Score 4: more than 50% of the canal wall covered
Score 5: complete or nearly complete covering of the canal wall by debris

Smear layer (dentin particle, remnants of vital or necrotic pulp tissue, bacterial components, and retained irrigants):
Score 1: no smear layer, orifice of dentinal tubules patent
Score 2: small amount of smear layer, some open dentinal tubules
Score 3: homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules
Score 4: the entire root canal wall covered with a homogenous smear layer, no open dentinal tubules
Score 5: a thick, homogenous smear layer covering the entire root canal wall

Scores 1 and 2 were considered suitable scores (10). The debris and the smear layer were separately debrided and statistically analyzed with Kruskall Wallis test at a significance level of $P < 0.05$. Since this study has involved extracted teeth, there are no ethical considerations whatsoever.

Results

Completely cleaned root canals were not found after instrumentation with any of the three instruments.

The use of FlexMaster instruments resulted in

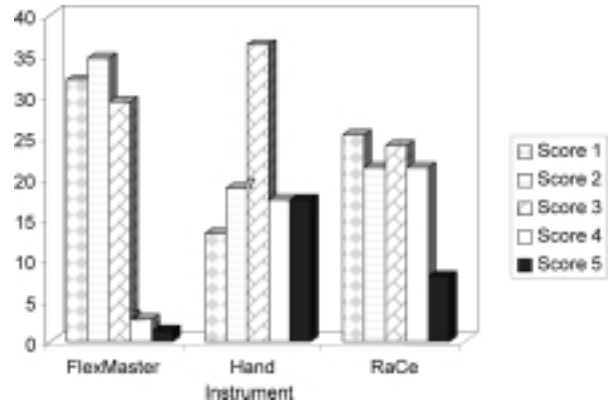

Fig. 1 Comparison of debris throughout the root canals between the three groups.

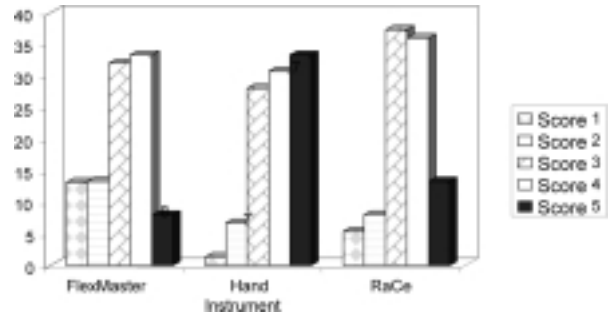

Fig. 2 Comparison of smear layer throughout the root canals between the three groups.

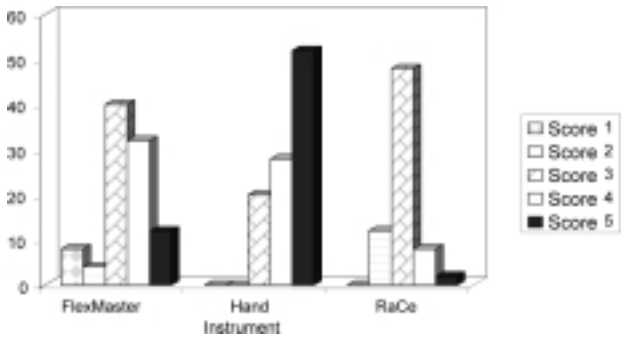

Fig. 3 Comparison of smear layer in the apical third of the canals between the three groups.

significantly less debris ($P < 0.05$) compared to the canal preparation with Race and NiTi flex K- files throughout the canal walls (Figs. 1, 4-6). In the coronal, middle and apical third of canal walls, FlexMaster instruments resulted in significantly less debris compared to the Race and NiTi flex K-files ($P < 0.05$). Use of NiTi flex K-files resulted in significantly more smear layer throughout the canal walls ($P < 0.05$) compared to the Race and Flex Master files (Figs. 2, 4-6). On evaluating the three sections (coronal, middle and apical) of the canal walls, it was demonstrated that NiTi flex K-files resulted in significantly more smear layer ($P < 0.05$) only in the apical third of the canal, compared to Race and FlexMaster instruments (Figs. 3, 4c, 5b, 6c).

Discussion

One of the most important aims of root canal preparation is the removal of vital pulp tissue, remaining necrotic debris and infected dentin, so that the bulk of microorganisms present in the canal will be eliminated (8).

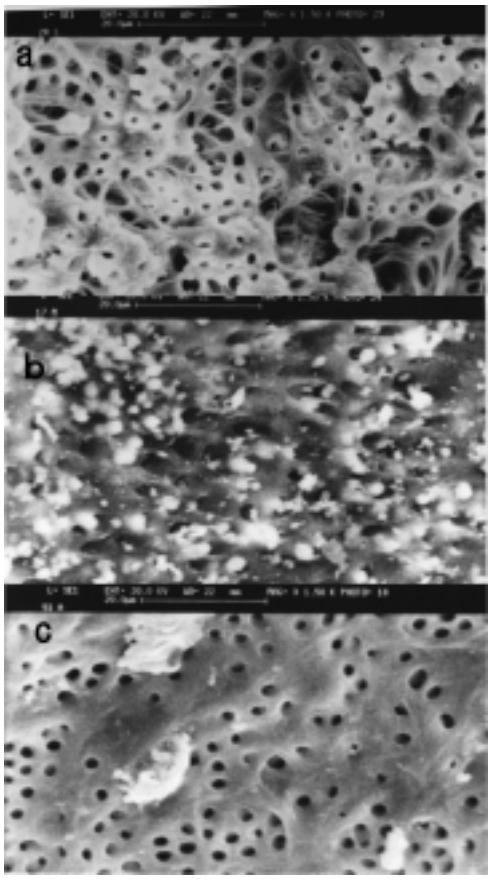

Fig. 4 Canal wall after preparation with FlexMaster rotary nickel titanium instruments. a) Clean canal wall in the coronal portion of the prepared canal (score 1); b) very small debris particles in the middle portion of the canal; c) large debris particles in the apical portion of the canal.

The ability to achieve this goal was investigated in the present study using rotary FlexMaster, Race and NiTi flex K-files.

During the past few years, Ni-Ti rotary instruments with advanced blade designs have been developed to improve the cleaning efficacy during root canal preparation. Various morphologic designs affect the cleaning property of rotary instruments. Rake angle of the cutting blade may be one of the factors that affect the cutting and cleaning efficacy of endodontic instruments (11). Positive rake angles will cut more efficiently than neutral or negative rake angles, which scrape the inside of the root canal (11). FlexMaster instruments have a negative rake angle (12) and Race instruments have two different cutting edges on one file. The first cutting edge alternates with the second that has been placed at a different angle (7). This is probably one reason for the difference in cleaning properties of these files. Further studies are required for evaluation of this matter.

Variable helix angles and pitch are other features that can improve the removal of the debris formed by instrumentation. Once the instrument has cut the dentin, the debris needs to be removed. Compression occurs when debris is caught between the canal wall and the instrument flutes. If the instrument becomes clogged, there will be no space left for debris to be transported out of the root canal. Instruments with consistent helix angle and pitch

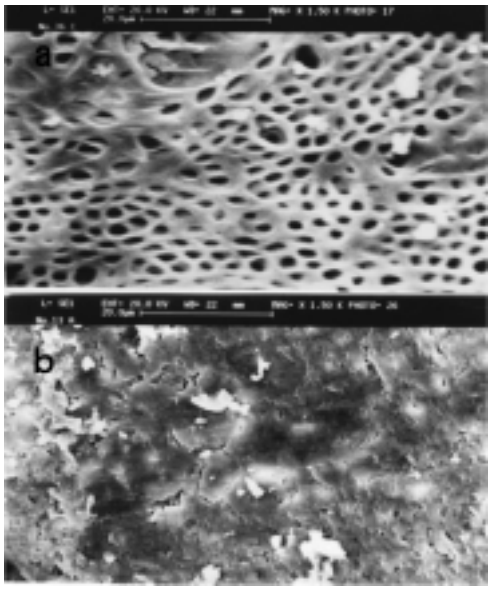

Fig. 5 Canal wall after preparation with Race rotary nickel titanium instruments. a) Clean canal wall in the coronal portion of the prepared canal (debris and smear layer score 1); b) complete covering of the canal wall with smear layer in the apical portion of the canal (smear layer score 5).

may allow debris to accumulate, particularly in the coronal part of the file, blocking the escape way of the debris (11). Race instruments have a very large chip space facilitating the utilization of the cutting efficacy of the sharp cutting edges; since the dentin debris can be absorbed in large quantities and rapidly transported away (13). The debris might prevent efficient removal of microorganisms from the root canal system. A thick and heterogeneous smear layer can prevent efficient elimination of intracanal microorganisms and compromise complete sealing of the root canal (3).

The SEM technique produces images of high resolution and magnification. The ×500 magnification was employed since it offered a wider view and also a detailed image of the surface. The micrographs at ×1500 magnification covered too small a surface and gave accurate information in the present study. The cutting and cleaning efficacy of three instrumentation methods was examined on the basis of a separate numerical evaluation scheme for debris and smear layer by means of SEM evaluation of the coronal, middle and apical portions of the canals after the three instrumentation techniques (1,14).

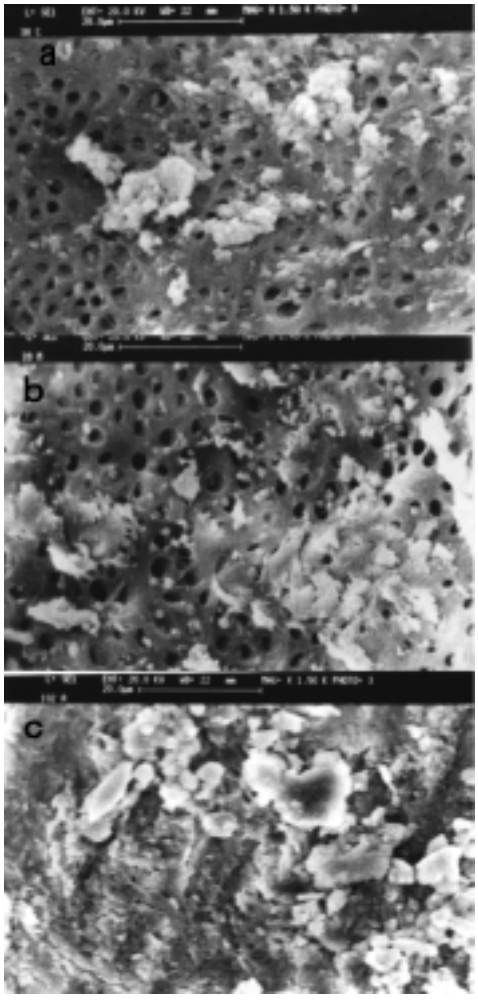

Fig. 6 Canal wall after preparation with hand instruments. a) Canal wall with only some debris particles in the coronal portion of the canal (score 2); b) middle portion of the canal: small pieces of debris covering the canal wall (score 3); c) complete covering of the canal wall with debris and smear layer in the apical portion of the canal (smear layer score 5, debris score 3)

In this study, sodium hypochlorite (0.5%) was used as the irrigation solution because high concentration of NaOCl may be too toxic for routine use and 0.5% NaOCl has sufficient antibacterial property and is considerably less toxic for cells than other concentrations (15,16).

One source of bias in this kind of study is the selection of teeth. It is essential to use natural teeth with similar curves. Furthermore, based on the initial radiographs, the teeth were balanced with respect to the degree of canal curvature. To this end, the Schneider method was used to determine canal curvature (9). The teeth in all experimental groups were also balanced with respect to the apical diameter of the root canal (8).

Another important consideration is the examiner evaluating the specimens. The examiner should be blind to the methods in which the instruments were used and the specimens were prepared. The person should have no knowledge about the codes so that the evaluations can be carried out without any prejudgment .To this end, the specimens in the present study were coded and randomly examined under SEM and the examiner had no knowledge about the codes and the methods employed in preparation procedures.

Partially uninstrumented areas with remaining debris were found in all canal parts. Similar findings have been reported by other authors (1,4). In general, the use of hand NiTi flex K-files resulted in significantly more remaining debris and smear layer compared to the rotary Race and FlexMaster instruments. These results are consistent with a previous report; in which Profile instruments proved to be superior to hand instrumentation as far as cleaning efficacy was concerned (17).

In this study, the use of FlexMaster rotary instruments resulted in significantly less debris and smear layer compared to hand Ni-Ti flex K file instruments, but it was similar to Race rotary instruments. Clinically, this finding may be more important than the significant difference between the three instruments in the amount of the smear layer remaining in the coronal and middle portions of the canals because the microorganisms which remain in the apical portion of the root canal have been considered the main cause of failure (8). It may be concluded that rotary instrumentation using FlexMaster and Race may be better for canal preparation than hand

Ni-Ti flex K-file instrument, since FlexMaster and Race instruments left significantly less smear layer in the apical third of the root canal.

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