A Comparative Study of the Efficiency of FlexMaster® NiTi Rotary and K-Flexofile® Stainless Steel Hand Instruments

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(Received August 31, 2005; Accepted for publication October 12, 2005)

Abstract: The aims of this study were to compare the effectiveness of FlexMaster® nickel-titanium rotary and K-Flexofile® hand instruments with regard to straightening of curved root canals and preparation time, and to evaluate the morphological aspects of instrumented root canal walls in extracted human teeth. A total of 60 root canals in molar teeth, with curvatures ranging between 0 and 35°, were divided into three groups of 20 root canals each, based on the degree of curvature. Half of each group was prepared using FlexMaster® instruments by a crown-down preparation technique and the other half using K-Flexofile® by a conventional technique. After each instrumentation, the root canals were flushed with 3 ml of 5.25% sodium hypochlorite and 3% hydrogen peroxide, alternatively, and 1 ml of 14% EDTA. Using radiographs taken before and after root canal preparation, the angles of root canal curvature of all specimens were determined. The preparation time was also recorded. All roots were bisected longitudinally and the canal walls were examined by scanning electron microscopy for morphological aspects. The use of FlexMaster® instruments resulted in significantly less straightening of root canal curvatures and a shorter preparation time compared to K-Flexofiles® (p <0.01). They resulted in less debris, but left a thicker smear layer at the apical third of root canal than the K-Flexofile®. These results showed that rapid preparation of curved root canals with minimal canal straightening was possible using FlexMaster® instruments, and the use of FlexMaster® resulted in less debris, but a thicker smear layer than that of K-Flexofile®.

Key words: FlexMaster®, morphology, preparation time, root canal curvature, root canal straightening.

Cleaning and shaping of root canal space are the primary objectives of root canal therapy.1,2) Several techniques and devices have been introduced in the last few years to achieve an optimum chemomechanical condition of the root canal system required for a perfect seal. Previous studies have reported that none of the instruments or techniques was capable of completely cleaning root canals, especially when curved.3–5) Procedural complications such as formation of zip, elbow or ledge, hourglass deformity, and perforation of root or canal transportation may arise in case of curved root canal preparation and straightening of curved root canals would compromise the success of root canal therapy.

To prevent the occurrence of these undesirable outcomes during root canal preparation and to make the whole treatment procedure a successful one, FlexMaster® nickel-titanium (NiTi) rotary instruments were introduced recently. However, it has been observed that different NiTi rotary instruments showed inconsistent results.6) The new NiTi
instruments may represent a new approach to obtain a rapid endodontic preparation. The type of smear layer produced by NiTi instruments, the removal of dentin and pulpal debris and the quality of endodontic preparation still needs to be assessed. In fact, the effect of several NiTi instruments on dentin of root canal walls is not completely known.

The aim of this investigation was to compare the effectiveness of FlexMaster® NiTi rotary files (VDW, Munich, Germany) and K-Flexofile® stainless steel hand instruments (Dentsply Maillefer, Ballaigues, Switzerland) with regard to straightening of curved root canals and preparation time in extracted human teeth. In addition, we evaluated the ultra-structural morphology of the apical, middle and coronal thirds of root canal walls after instrumentation by two methods.

Materials and Methods

Selection of teeth
A total of 60 extracted human teeth, including both maxillary and mandibular molar teeth, with at least one curved root and curved root canal were selected for this study. All teeth were extracted due to periodontal disease. Only teeth whose clinical crowns were largely intact, root canals were freely accessible with a root canal instrument size 10 up to the intact root tip, and root canal width near the apex was approximately compatible with size 15 were included. This was checked with silver points sizes 15 and 20 (Antaeos, Munich, Germany). Before preparation, all teeth were kept in normal saline. Teeth with open apices or fillings, and third molar teeth were excluded.

Root canal instrumentation
Access opening was prepared with diamond burs in the conventional method and standardized radiographs were taken prior to instrumentation. A size 15 K-type file was introduced into each curved root canal until it appeared at the apical foramen. The tooth was attached to a film (ultra-speed film, Kodak, NY, USA) and aligned so that the long axis of root canal was parallel and as near as possible to the surface of film. The X-ray tube and thus the central X-ray beam were positioned perpendicularly to the root canal. All radiographs were taken at an exposure time of 0.12 s at 70 kV and 7 mA with a distance of 15 cm from film. The degree of root canal curvature before and after instrumentation was determined using the method described by Schneider (Figure 1). On the basis of degree of root canal curvature, the teeth were divided into three groups of 20 root canals each; group A: 0–15°, group B: 16–30°, group C: 31–35°, and then each group was randomly subdivided into two groups of 10. There was no significant difference in root canal curvature between the subgroups in each group. The working length was determined by measuring the length of initial instrument (size 15) at the apical foramen minus 1 mm for all groups. After each instrumentation, the root canal was flushed with 3 ml of 5.25% sodium hypochlorite (NaOCl) and 3% hydrogen peroxide (H₂O₂), alternatively, and 1 ml of 14% EDTA.

The following instrumentation sequences were used for the two instruments:

Instrumentation with FlexMaster®
A total of 30 root canals, 10 from each group, were prepared with FlexMaster® instruments, according to the manufacturer's instructions. The instruments were run by a torque controlled motor (E-Master, individual programmed torque value for every FlexMaster® file, VDW, Munich, Germany) and a contra-angle hand piece (W & H, Burmose GmbH, Austria) with a gear reduction of 1:1, and were maintained at constant rotation between 150 and 300 rpm from insertion of the file into root canal until removal. Instrumentation was completed using a crown-down pressureless technique according to the manufacturer's instructions, using a gentle in and out motion. Every instrument was withdrawn when resistance was felt and replaced by the next smaller instrument in the
A lubricant including EDTA (RC Prep, Premier Dental, PA, USA) was used as a chelating agent in the narrow curved root canals. The instrumentation sequence was as follows:

1. A 0.06 taper size 20 instrument was used to one half of the working length.
2. A 0.04 taper size 30 instrument was used from one half to two thirds of the working length.
3. A 0.04 taper size 25 instrument was used to two thirds of the working length.
4. A 0.04 taper size 20 instrument was used to the full working length.
5. A 0.02 taper size 20 instrument was used to the full working length.
6. A 0.02 taper size 25 instrument was used to the full working length.
7. A 0.02 taper size 30 instrument was used to the full working length.
8. A 0.02 taper size 35 instrument was used to the full working length.

**Instrumentation with K-Flexofile®**

A total of 30 root canals, 10 from each group, were prepared using hand instruments and traditional techniques. It was performed with stainless steel K-Flexofile® using both reaming and filing working motion. All root canals were sequentially prepared from size 15 to 35 without pre-bending the instruments, which were used to the full working length of root canals.

**Evaluation**

All root canal preparations were completed by one operator, whereas the assessment of root canal curvatures before and after instrumentation and the scanning electron microscopic (SEM) evaluation were carried out by another person who was blind to this experiment.

**Assessment of degree of root canal straightening and preparation time**

After root canal instrumentation was completed, a standardized radiograph was taken with the final instrument inserted in the root canal as described previously for all root canal preparations in each group. The degree of straightening of root canal was defined as the difference in angles found between before and after instrumentation (Figure 1). The time required for root canal preparation was also recorded including the total active instrumentation, instrument changes within the sequence and irrigation.

The degree of straightening of curved root canals and root canal preparation time after two methods were statistically compared using Mann-Whitney U-test and among three groups using Kruskal-Wallis test with a significance level of p < 0.01.

**Morphological assessment of root canal wall by SEM**

After preparation, the root canals were flushed with 5.25% NaOCl and dried with absorbent paper points. All root canals were split longitudinally with diamond fissure burs and the specimens were prepared for SEM investigation, after polishing. An SEM (JSM-T220A, JEOL, Tokyo, Japan) with a 15-kV acceleration voltage, was employed to examine and to take micrographs of every specimen at ×25–1,500 magnifications at standard positions.

Each root canal was evaluated at three areas (apical, middle and coronal thirds) and was analyzed for the morphological aspects of dentin of root canal wall. The following points were evaluated; smear layer: flat layer of dentin particles, remnant of necrotic pulp tissue and bacterial components, debris: dentin chips, pulp remnants and particles loosely attached to canal wall, surface profile: grooves, pits, orifices of dentinal tubules, ledge formation, zipping, hourglass deformities.

**Results**

**Straightening of root canals**

The mean values on straightening of curved root canals are shown in Table 1. The use of FlexMaster® instruments resulted in significantly less straightening compared to that of the K-Flexofile® in all groups. In case of the FlexMaster® instrumentation technique, the mean degree of straightening of root canal curvature was 2.12° in all groups, whereas with K-Flexofile®, the root canal straightening occurred more frequently and the mean was 7.48° in all groups.Straightening of root canal curvature occurred significantly in group C in both instrumentation techniques compared to other groups.

**Root canal preparation time**

The mean time taken to prepare root canals with FlexMaster® system or stainless steel hand K-Flexofile® is shown in Table 2. The method using FlexMaster® instruments was significantly faster than that using hand instruments.

**Instrument failure**

During the preparation of all 60 root canals,
only one instrument was separated. None of the FlexMaster® instruments was separated, but one stainless steel K-Flexofile® size 30 was fractured in the apical region of a root canal in group C.

**Morphology of root canal wall**

**Smear layer**

In both instrumentation techniques, a greater amount of smear layer was found at the apical third of root canal than coronal or middle third, but there was no clear difference between coronal and middle thirds in group C. The FlexMaster® instruments produced greater amount of smear layer at the apical third than K-Flexofile® and the amount of smear layer gradually increased from coronal to apical third in case of K-Flexofile® in group C. There was no clear difference in the smear layer between the two techniques in groups A and B. Both instrumentation techniques produced a smear layer that partially occluded the dentinal tubules where the deposit was less or a smear layer that completely filled the dentinal tubules where the deposit was more in some areas. The FlexMaster® instrument produced a markedly thicker and homogenous smear layer, whereas the smear layer produced by K-Flexofile® instruments was fine and multi-layered (Figures 2 and 3).

**Debris**

The apical third of root canal wall showed a greater amount of debris than the coronal or middle third in both instrumentation techniques in group C (Figures 4 and 5), and the debris deposition was more in group B than A, which suggested that the debris deposition was related to the degree of root canal curvature. FlexMaster® produced less debris on the whole root canal wall (Figure 5) in comparison to K-Flexofile® in all groups. The presence of pulpal debris was very rare and little was observed at the apical third of root canal wall with irregularities such as grooves, depressions or large pits in group C for K-Flexofile® instruments (Figure 4).

**Surface profile**

The FlexMaster® instrumentation technique maintained the original conical shape and the curvature of root canal wall with minimal surface
profile irregularities, better than K-Flexofile® in all groups (Figures 6 and 7). At the apical third in both instrumentation techniques, the surface profile of root canal wall was affected by the presence of grooves and uninstrumented areas compared to those at middle and coronal thirds in all groups. No clear difference was found between the coronal and middle thirds of root canal wall. The surface profile showed more irregularities, grooves, pits, zipping, ledge formation and unprepared areas on root canal walls when using K-Flexofile® than when using FlexMaster® instrumentation technique especially in group C.

Discussion

For this investigation, a total of 60 intact, extracted human teeth were selected. To ensure standardization, the teeth in both subgroups of each group were balanced with respect to the apical diameter of root canal and angle of canal curvature, judging from the initial radiographs. The homogeneity of two subgroups was statistically examined before the experiment.

The angle at which the radiographs were taken, and the exposure time of X-ray beam were same for all radiographs with a constant source to film distance of 15 cm. All these helped to standardize the total radiographic evaluation procedure. However, the curvature measured by this technique may
not always be effective in root canal preparation, because it has been pointed out that this is not a three dimensional measurement. In future, more effective three dimensional measurement techniques need to be developed.

For the subgroups using FlexMaster® instruments, the root canals were prepared using a crown-down pressureless technique. Among the several root canal preparation techniques, the crown-down pressureless technique was selected for FlexMaster® subgroups to prevent ledge formation and fracture of the instruments. Though the step back technique is also useful for curved root canal preparation, it is not suitable for rotary systems because of the risk of destruction of the apical third of root canal. In the present study, none of the FlexMaster® instruments was separated, but one stainless steel K-Flexofile® size 30 was separated in the apical region of a root canal in group C. A reported complication of the use of NiTi rotary instruments is their tendency to separate in root canals. As NiTi rotary instruments are stressed when used in curved root canals with smaller radius, the instruments exceed their elastic limit and separation may occur. In case of K-Flexofiles®, fracture may occur when they undergo excessive stress. The FlexMaster® instruments were used with slight pumping movement maintaining a constant torque controlled force with constant rotation. The crown-down pressureless technique was followed, and little contact of the file with root canal wall was maintained. However, FlexMaster® instruments have high flexibility and elasticity, which is why they do not deform but break without warning. Further studies might be helpful to invent an index or device which could determine the possibility of fracture of the FlexMaster® files before clinical use for better treatment results.

According to the present study, the original root canal curvature was maintained better with FlexMaster® rotary instrumentation than with stainless steel K-Flexofile® instrumentation. This may be attributed to the high elastic flexibility in bending and torsion of the FlexMaster® files. The flexibility of endodontic files is an important characteristic, as more flexible files tend to negotiate curved canals better and reduce the tendency of straightening, zipping, ledging or perforation of curved root canals. The result of the present study also supported the findings of previous studies in which root canals in extracted teeth were prepared with FlexMaster® instruments. Hand instrumentation may have left the possibility of canal space being inadequately debrided of vital or necrotic pulp tissue, which might result in inadequate obturation of root canal space, as some researchers have suggested.

Regarding working time, the FlexMaster® instruments took almost half the time in comparison to hand instruments to prepare root canals. These findings were also in good agreement with the previous results where root canals were prepared with FlexMaster® instruments. From the present study, we demonstrated that the FlexMaster® technique would be able to simplify root canal preparation by making it less time consuming, efficient and reducing fatigue for the operator as well as the patients.

For morphological changes of root canal dentin wall, each specimen was evaluated and analyzed considering three points: smear layer, debris and surface profile. The smear layer is a surface film of approximately 1–2 μm thickness which remains on root canal wall after instrumentation. No smear layer is found on areas which are not instrumented. The smear layer contains dentin particles, residual vital or necrotic pulp tissue, bacterial components as well as retained irrigants and it blocks the openings of the dentinal tubules. In the present study, the FlexMaster® instrumentation produced a markedly thicker and homogenous smear layer, whereas the smear layer produced by the K-Flexofile® was fine and multi-layered, the so called "tree bark" smear layer as previously described. As this study supported the hypothesis that NiTi rotary instruments create different ultra-structural aspects on dentin walls compared with manual stainless steel K-Flexofile®, we presumed that the morphology and the amount of deposition of smear layer may be influenced by the design and the structure of instrument used such as its segmental shape and size, cutting efficiency, elasticity of the metal used, method of application and also the type of irrigant used. As very little is known about how to remove the smear layer from root canal walls, further research is needed to introduce an instrumentation technique that would produce no smear layer or a minimum amount of smear layer, and for an effective irrigant to remove smear layer from
root canal dentin wall during preparation. The debris is defined as dentin chips and residual vital or necrotic pulp tissue attached to root canal wall, which in most cases, is infected.\textsuperscript{5)\textsuperscript{,}}\textsuperscript{5)} Findings similar to the results of the present study have also been described by other authors.\textsuperscript{3,\textsuperscript{5,\textsuperscript{6,\textsuperscript{22,\textsuperscript{29}}}\textsuperscript{21}}} In this investigation, it was confirmed that apical third of root canal contained more debris according to the SEM inspection in all groups. This observation was in agreement with other studies.\textsuperscript{5,\textsuperscript{6,\textsuperscript{22,\textsuperscript{29}}}\textsuperscript{21}} This debris may be removed by effective and adequate root canal preparation along with vigorous use of irrigation.\textsuperscript{23-\textsuperscript{26}}} Regarding surface profile, some studies demonstrated that all instruments are unable to completely create a homogenous surface profile in the apical third compared to the middle and coronal thirds of root canal.\textsuperscript{11,\textsuperscript{27}}} The present study showed some areas of unprepared dentin and grooves in the middle and apical thirds of root canal walls in all groups. These findings also supported other previous studies.\textsuperscript{3,\textsuperscript{5,\textsuperscript{6,\textsuperscript{22,\textsuperscript{29}}}\textsuperscript{21}}} The present study suggested that neither of the instrumentation techniques achieved total debridement of the root canal system with debris and smear layer remaining on dentin wall and were also unable to create a homogenous surface profile of root canal wall. The apical third of root canal was the critical area where greater amount of debris was located in all groups. From the results of the present study, we have shown that the FlexMaster\textsuperscript{\textregistered} instrumentation technique was better than stainless steel K-Flexofile\textsuperscript{\textregistered} as it maintained the original root canal shape and curvature with more uniform and regular dentin surface, rapid preparation technique and created less debris during instrumentation, although the smear layer produced was thicker.

The FlexMaster\textsuperscript{\textregistered} NiTi instrumentation technique enabled rapid preparation of curved root canals with a minimal canal straightening effect. The use of FlexMaster\textsuperscript{\textregistered} instruments resulted in less debris but thicker smear layer than that of stainless steel hand instrumentation, and maintained the original canal shape and curvature with a uniform and regular dentin surface. The apical third of root canal was the anatomical area with greater amount of smear layer, debris and surface irregularities in all experimental groups.

**Acknowledgements** This study was supported in part by Grants-in-Aid for Scientific Research (C) (16591922) from the Japan Society for the Promotion of Science (JSPS), and also supported by MEXT. HAITEKU (2005–2009).

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