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Research Article

Problems with a Cordless Endodontic Hand Piece when Preparing Severely Curved Root Canals

Abstract

The aim of this study was to describe the shaping ability of a rotary nickel-titanium instrument in combination with different torque-controlled endodontic devices in severely curved root canals of extracted human teeth.

Sixty human molars with curvatures ranging from 25° to 69° were embedded in a muffle system and portioned into five horizontal sections (thickness 1.2 mm), starting from the apex. Canals were divided into three groups ($n = 20$ for each) and were prepared with either a cordless endodontic handpiece (SiroNiti) or two conventional devices (E-Master™ and Endo IT control) using FlexMaster® instruments and a crown-down preparation technique. We evaluated the frequency of instrument failure, preparation time, loss of working length and differences between pre- and postoperative instrumentation of root canal cross-sections. The root canal area before and after the intervention was determined using area-measuring software. The data were analyzed statistically using a one-way ANOVA followed by a Kruskal-Wallis multiple-comparison Z-test.

Significantly higher values for preparation time and instrument failures were observed when using the cordless endodontic handpiece, while using the Endo IT control device resulted in significantly higher values for loss of working length (0.6 mm). Specimens treated with the SiroNiti device showed the greatest significant change from preoperative cross-sections.

Preparing root canals using the described devices lead to various problems. The cordless endodontic handpiece produced unsatisfactory results for three of the four parameters analyzed. Thus within the limitations of our study, the SiroNiti device can only partially be recommended for treating curved canals.

Introduction

Successful endodontic treatment mainly relies on preserving the original anatomy of the root canal while avoiding instrument fractures and iatrogenic preparation errors, such as loss of working length, zipping, or ledging [1,2]. In most cases, rotary instrumentation has proved a valuable advancement for meeting these parameters. Unlike stainless steel files, nickel-titanium instruments have sufficient cleaning ability and can preserve root canal anatomy. To minimize the risk of instrument fracture, nickel-titanium rotary instruments with torque-controlled motors not exceeding the recommended speed for the specific system should be used [3]. Some torque-controlled motors, despite being recommended for several years, increase operational safety and the risk of instrument fracture. These can be categorized as first-generation motors without torque control, fully electronically controlled second-generation motors with sensitive torque limiters, third-generation motors with a simple torque control, and fourth-generation motors with built-in apex locator and torque control [4]. They also can be classified into electric or mechanical high-torque control motors. The electronic torque is generally limited via a power speed curve that determines the mechanical variance with the help of the slip or magnetic drive. The latest development in torque control is to incorporate gear systems within the cordless endodontic handpiece that regulates torque depending on the size of the rotary instrument. This eliminates the need for conventional torque-controlled motors.

In addition, the cordless nature of the instruments offers complete portability [4].

It should be noted that there is a lack of systematic comparative studies between different endodontic motors [5]. In addition, to our knowledge, no studies comparing cordless endodontic handpieces with conventional motors using FlexMaster® instruments in natural teeth have been published. Therefore, this *in vitro* study in extracted human molars aims to compare the performance of a mechanical high-torque-controlled endodontic handpiece (study group with the SiroNiti device) with that of two conventional electric torque-controlled motors (control group 1 with E-Master™ device and control group 2 with Endo-IT control device) using FlexMaster® instruments to prepare severely curved root canals under conditions as close as possible to clinical ones. Our null hypothesis is that the three different torque-controlled devices will show no difference in terms of frequency of instrument failure, preparation time, loss of working length, or cross-section of root canals.

Materials and Methods

Sample preparation

This study involved $n = 60$ severely curved root canals of upper (mesiobuccal) and lower (mesial) human molars. The curvature angles were measured and root canal curvature subsequently classified based on the criteria described by Schneider [6].



The study included only severely curved ($\geq 25^\circ$) root canals. In order to maximize uniformity of conditions, the root canals were randomly stratified and divided into three subgroups, each consisting of 20 root canals (10 large, 5 medium, 5 narrow canals). To determine the classification in large, medium or narrow canals, friction of the first FlexMaster® file (VDW, München, Germany) after canal enlargement was tested manually in the region above the canal curvature. If file .06/20 already clamped above the canal curvature, the canal was grouped as “narrow”, if file .06/25 clamped above the canal curvature, canal was classified as “medium” and if it was file .06/30 that clamped in the same region, the canal was graded as “large”.

The mean angles of curvature were 41° for each group. We used a modified Bramante technique to prepare the samples [7]. The molars were trepanned with an ISO 14 diamond bur (Gebr. Brassler, Lemgo, Germany). Each tooth was fixed separately on a 2 x 2 x 4 cm aluminum cuvette using a metal wire to avoid the tooth sinking during embedding in a fast-hardening, cold-polymerizing resin (Technovit 4004, Heraeus Kulzer GmbH, Wertheim, Germany). After hardening, the resin block was removed from the cuvette and marked with a diagonal groove on one side to facilitate the subsequent determination of the cutting plane. To achieve a uniform surface, a 9 mm layer of the embedded tooth was trimmed off coronally to the apex. Starting from the apex, the tooth resin blocks were sectioned into a minimum of five horizontal slices (each 1.5 mm thick) using a saw microtome (SP 1600, Leica, Wetzlar, Germany). The final slice thickness was 1.2 mm, owing to the saw blade thickness of 280 μm and modest vertical unevenness of approximately $\pm 50 \mu\text{m}$.

Before and after preparing the root canals, the mesial parts of the root cross-sections were digitized from their top and bottom sides at a magnification of 1.25 x 6.3 x 2.0 using a CCD camera (CF11/2, Kappa, Gleichen, Germany) on a macroscope (M410, Wild, Heerbrugg, Switzerland). An angular specimen holder attached to the object stage ensured a reproducible position for taking images of the section planes under the macroscope.

Root canal preparation

After canal enlargement with an IntroFile (VDW, Munich, Germany), the canals in the three groups were prepared using the crown-down technique with FlexMaster® instruments (constant rotation of 300 rpm) in combination with the different torque-controlled motors (E-Master™ and Endo IT control, both with a pre-programmed torque value depending on the files used, in accordance to the manufacturers' specifications) or an endodontic handpiece (SiroNiti, at the recommended torque level 3 for FlexMaster® file .06/30, level 2 for files .06/25, .04/30, .02/35, .02/40 and level 1 for all the other files used, read out from the torque CARD for FlexMaster®). Instrument sequencing was standardized in dependence to manufacturers' instructions according to the width of the canal as follows:

- A. Large canals: .06/30, .06/25, .06/20, .04/30, .02/30, .02/35, .02/40
- B. Medium canals: .06/25, .06/20, .04/30, .04/25, .02/25, .02/30, .02/35, .02/40
- C. Narrow canals: .06/20, .04/30, .04/25, .04/20, .02/20, .02/25, .02/30, .02/35, .02/40.

Notwithstanding the manufacturers' instructions, final preparation size for all teeth was .02/40.

Before being used, all instruments were loaded using FileCare® EDTA (VDW, München, Germany). After each preparation step, each canal was rinsed with 2.5% sodium hypochlorite solution (1 ml). Individual FlexMaster® files were applied a maximum of five times for each canal.

Instrument failure

The instrument failures are only related to instrument fractures. In case of fracture, endodontic device as well as the number of usages and size of fractured instrument were documented.

Preparation time

Preparation time was recorded in seconds by microchronometer (Casio Europe GmbH, Norderstedt, Germany). Any instrument changes and rinsing processes were considered.

Measuring the differences in working length

X-ray images (Heliodent DS, Sirona, Bensheim, Germany) were taken after sample blocks were sawn. Saw cuts could be precisely repositioned at any time in their prepared form. Optical control was achieved via a cut curve on test samples. To determine the working length, the fact that the ISO 15 K-reamers (VDW, München, Germany) were clamped and the end of the furthest apex could be reached was taken into account. This was verified by observing the lower side with the help of a head-mounted magnifying glass G3 (Carl Zeiss, Oberkochen, Germany). After preparation using the apical master file (for all canals: FlexMaster® file .02/40), another X-ray image was taken to determine the loss of working length.

Initially X-ray images were used to determine the curvature angle as well as the beginning of the curve. Both factors were determined using the AxioVision suite (Carl Zeiss, Oberkochen, Germany). AxioVision is a software suite for digital and modularly integrated image processing and analysis used for microscopy that shows intersection data in μm^2 .

Measuring the root canal intersections

To measure the root canal-intersections by AxioVision, the scaling was calibrated using a stage micrometer (x - and y -scaling for each 2.21 micrometer). After enlarging the images, the surface edges of the canal were moved and marked with a mouse before converting values from μm^2 into mm^2 . The differences in canal surfaces before and after preparation were determined during this process.

Statistical analysis

The study variables (frequency of instrument failure, preparation time, loss of working length and differences between pre- and postoperative instrumentation of root canal cross-sections) were statistically analyzed using a one-way analysis of variance (NCSS 2000, Statistical Systems, Kaysville, Utah, USA). Significant differences were determined using the nonparametric Kruskal-Wallis multiple-comparison Z-value test according to Bonferroni. Means and standard deviations (SD) were also evaluated.

Results

There was no instrument failure during preparation when using either the E-Master™ or Endo IT control motors. However, for the study group (SiroNiti), 2 of the 32 instruments fractured. Both were fractured during their fifth use. The canal curvature was 60° for the fractured .02/35 instrument and 62° for the fractured .02/40 instrument.

Table 1 shows the results for parameter preparation time, loss of working length, and changes in cross-section.

Discussion

Instrument failure rate

A total of 96 files were used, 32 per motor system. Two of the 96 instruments were fractured, both while using the SiroNiti angle piece, a fracture ratio of 2.08%. According to Shen et al. [8], NiTi instruments fracture for complex reasons based on a variety of factors [5,9-16]. When endodontic instruments are rotated, they are subjected to cyclic stresses in curved canals [17]. The intensity of these stresses is also related to arc length and instrument size [18]. To Lopes et al. [18], the radius and the position of the canal curvature are the most critical parameters that determined the stress in the instrument, with higher stress levels being produced by decreasing the radius and moving from the apical to the mid root position [19]. Cumulative microstructural changes eventually cause the instrument to fracture [17]. In the current study, minimal changes in the cutting process were observed in the fractured instruments. It is assumed that severe curvatures of root canals in both teeth were contributing factors for the fractures [20,21,6].

However, the curvature characteristics of the canals were distributed evenly across study groups, so when searching for the etiology of these fractures, the focus is on the characteristics of the motors used. Thus excessive motor torque relative to the chosen filing system may have been responsible for deformation of the file ends [22]. Therefore, the torque values of each system were compared. The SiroNiti angle handpiece was preset to level 2 for both fractured files, in accordance with the manufacturer's specifications. Sirona provided no torque values, so it was not possible to make an exact comparison. However, outside of manufacturers' specifications, references to torque average values for the SiroNiTi angle handpiece can be found in the literature. They describe an amount of 17.6 mNm [23]. For the E-Master™ and Endo IT control devices, the average torque value for the files was 7.9 mNm (manufacturer's specifications).

Other authors have taken into account instrument size as another factor in fracture risk [24]. For example, Peters et al. proved that larger instruments fracture sooner [25]. It is also known from

existing literature that the risk of fracture increases as the canal radius decreases [26]. The current study did not measure the curvature radius of the prepared canals, which limits the interpretation of the results.

Preparation time

When comparing an Endo IT and SiroNiti angle handpiece, Schäfer et al. determined a significantly shorter preparation time when using the Endo IT device [27]. The torque control for triggering the magnetic coupling of the SiroNiti handpiece is mechanical. Conversely, E-Master™ and Endo IT instruments are operated via software-supported electronic torque control. During preparation, total instrument locking occurred more frequently when using the SiroNiti handpiece. The instrument could only be unlocked by reversing the motor. This was the main reason for the longer preparation time compared to the other two systems, because the process was consistently delayed by instrument gripping and blockage. In many cases, minor reverse rotation was not enough to release the instrument from a root canal.

When exceeding the torque with the E-Master™ and Endo IT control instruments, the devices briefly stop before reverse rotation begins, which is halted by releasing a foot pedal. Because the operator can determine the duration of reverse rotation, instrument blockage can be avoided. The almost identical averages for the E-Master™ and Endo IT control systems are understandable given that they apply same operating principles and torque values.

Loss of working length

Losses in working length are critical, because they can lead to straightening or splinting of dentin. In this study, working length was measured between the plateau of reduced cusp and the last apical section.

When using the Endo IT control system, loss of working length occurred in 9 out of 20 teeth (45 %) with a mean of 0.6 mm. This result is very different from the mean of 0.17 mm determined by Schäfer et al. [27].

An explanation for this deviation probably has to be searched in the characteristics of the Endo IT control motor, since both preparation technique and apical preparation size were the same for all teeth. In consideration of the fact that loss of working length did not occur using the other two devices, especially the E-Master™, which has supposedly identical torque values to the Endo IT control and works with the same functional principle, we hypothesize that possibly the actual torque values of Endo IT control may have differed from the torque values specified by the manufacturer. Yared et Kulkarni [28] determined the torque output and examined the accuracy of five identical DTC Torque control motors. They found that for the different torque settings, the actual torque values were significantly higher than the torque set on the motor and claimed by the manufacturer. It is imaginable, that similar results could be reached while investigating the accuracy of Endo IT control.

Changes in cross-section

The E-Master™ and Endo IT control systems are operated using software-supported electronic control, which resulted in a subjectively quieter treatment flow than the SiroNiTi device. During

Table 1: Comparison of analysis results (mean values and standard deviations) acquired in the study. The values same marked are statistically significant.

| | SiroNiti | E-Master | Endo IT control |
|---|-----------------------------|----------------------------|----------------------------|
| Criterion | | | |
| Preparation time (Sec) | 380.45± 60.93 ^{ab} | 325.80± 33.06 ^b | 330.70± 45.49 ^a |
| Loss of working length (mm) | 0.10± 0.31 ^a | 0.10± 0.31 ^a | 0.60± 0.75 ^{a,b} |
| Difference pre/post in cross-section (mm ²) | 0.10± 0.06 ^{ab} | 0.09± 0.07 ^a | 0.09± 0.06 ^b |

preparation with the SiroNiti handpiece, after mechanical coupling out due to excess torque, a slight “after-rotation” was observed at each subsequent motor rotation. Considering the complete file blockages that often occurred along with proportional “after-rotations,” this could have led to increased material removal in the area of canal curvature.

After considering all determined values, increased material removal in different layers was observed when using the SiroNiti instrument compared to the E-Master™ and Endo IT control systems. No significant differences were observed between the E-Master™ and Endo IT control devices. Therefore, it seems the software-supported electronic control of the E-Master™ and Endo IT control systems leads to reduced and more uniform root canal dentin removal. This advantage seems to be due to the behavior of these systems when exceeding torque. The “reverse after-rotation” which occurs when using the SiroNiti device was not observed when using E-Master™ and Endo IT control systems, where exceeding the torque value led resulted in an immediate stop and subsequent reverse rotation.

However, it is difficult to satisfactorily clarify why there was a frequent number of working length losses, especially when using the Endo IT control compared to the E-Master™ system. In several publications, Yared et al. (2004), pointed out that actual torque strongly deviated from preset torque for these motors (Novvag Motor; TCM Endo III; Endo-DTC Motor, which is identical to Endo IT control) [28-30].

This may explain the differences relating to the deviations in the studied parameters (instrument failure rate, preparation time, loss of working length, root canal cross-sections).

Our null hypothesis can finally be rejected due to significant differences between the devices examined.

Conclusion

Root canal preparation with the three systems described in this study created different problems. The tested cordless endodontic handpiece produced unsatisfactory results for three of the four parameters studied. Thus, we conclude that, within the limitations of our study, the SiroNiti handpiece can only be partially recommended for treating curved root canals.

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