



**Maria Giraki<sup>1\*</sup>, Edith Harapetian<sup>2</sup>,  
Stefan Rüttermann<sup>1</sup> and Susanne  
Gerhardt-Szep<sup>1</sup>**

<sup>1</sup>Department of Operative Dentistry, Center for  
Dentistry and Oral Medicine (Carolinum), Goethe  
University Frankfurt, Frankfurt am Main, Germany

<sup>2</sup>Dental office, Heppenheim, Germany

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**\*Corresponding author:** Dr. Maria Giraki, Department of  
Operative Dentistry, Center for Dentistry and Oral Medi-  
cine (Carolinum), Goethe University, Theodor-Stern-  
Kai 7, Frankfurt am Main 60596, Germany, Tel: +49-  
69-6301-84495; E-mail: [Giraki@med.uni-frankfurt.de](mailto:Giraki@med.uni-frankfurt.de);  
[mgiraki@hotmail.com](mailto:mgiraki@hotmail.com)

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## Research Article

# Hand-operated and rotary mity instruments in combination with an endodontic handpiece and endodontic motor preparation: A comparison of shaping ability in simulated curved root canals

## Abstract

The aim of this in vitro pilot study was to describe the shaping ability of a rotary nickel-titanium (NiTi) instrument in combination with different torque-controlled endodontic devices and to compare them with NiTi files in combination with a conventional preparation by hand in severely curved root canals of plastic blocks. Thirty blocks simulating a severely curved root canal were divided into three groups (n=10 for each). All canals were prepared with NiTi files to an ISO size of 40 using an apical-coronal preparation technique. Mity Roto 360° files (Loser, Leverkusen, Germany) were used for the automatic systems, while Mity K-Files (Loser, Leverkusen, Germany) were used for the preparation by hand. We evaluated the frequency of instrument failure, the preparation time, loss of working length, loss of weight, elbow-clip effects, and changes in root canal anatomy. The data were analyzed statistically using one-way ANOVA followed by a post hoc Bonferroni test ( $p < 0.05$ ). A total of three instrument failures were observed: one for Mtwo direct and two for Endo IT. Preparation time was significantly longer when preparing by hand (16.64 min) than for both automatic systems, which did not differ significantly. Critical loss of working length could be detected for all systems (1.3–2.81 mm). Irrespective of the torque-controlled motor, the shape of the canal anatomy was retained better with Mity Roto files than hand preparation. In summary, the two automatic systems did not differ significantly. Within the limitations of this study and especially due to the long working length losses, neither the MTwo direct handpiece nor the Endo IT professional motor can be recommended in combination with Mity Roto 360° files when an apical-coronal preparation method is used in severely curved root canals.

## Introduction

In the last years, the technical possibilities for the preparation of curved root canals have been greatly optimized through the development of special file systems and the use of torque-controlled endo motors. Factors such as 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 account for the success of endodontic treatments [1,2]. Unlike stainless-steel files, nickel-titanium (NiTi) 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].

The latest development in torque control is the incorporation of 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]. The clinical practicability, local flexibility, and simple adjustment options of endodontic handpieces can simplify the application of automatic systems in endodontic treatment. This supports the need for cordless automated preparation systems for endodontic therapy. An example of a cordless torque-controlled motor is the SiroNiTi endodontic handpiece. Based on own study results, its use cannot be recommended due to several disadvantages, such as longer preparation time and instrument failure, as well as changes to the preoperative cross-sections [5]. The aim of the

present study was, therefore, to test another cordless handpiece possessing the following advantages: No reading of set values on a card –which simplifies and quickens the setting of the torque limitation directly at the contra-angle –and its use in the conventional apical to coronal preparation technique.

Therefore, this in vitro pilot study aimed to describe the shaping ability of a NiTi instrument (Mity Roto 360°, Loser, Leverkusen, Germany) in combination with a mechanical high-torque-controlled endodontic handpiece (study group with the MTwo direct device, Sirona Dental Systems, Bensheim, Germany), and to compare it with the same rotary NiTi instrument in combination with a conventional electric torque-controlled motor (control group 1 with Endo IT professional device, VDW, München, Germany), and with conventional NiTi files (Mity K-File, Loser, Leverkusen, Germany) used in the hand preparation technique (control group 2). The parameters that were compared include the frequency of instrument failure, the preparation time, loss of working length, loss of weight, elbow-zip effects, and changes in root canal anatomy. For reasons of standardization, the preparation was performed on curved root canal equivalents in transparent plastic blocks (VDW, Munich, Germany).

Our first hypothesis was that there is a difference between the two torque-controlled devices in terms of frequency of instrument failure, preparation time, loss of working length, loss of weight, elbow-zip effects, or changes in root canal anatomy. Our second hypothesis was that there is no difference between the endodontic handpiece and the preparation by hand with NiTi K-Files in terms of frequency of instrument failure, preparation time, loss of working length, loss of weight, elbow-zip effects, or changes in root canal anatomy.

## Materials and Methods

### Sample preparation

This study involved  $n = 30$  simulation blocks of a root canal (VDW GmbH, Munich, Germany) that were equivalent to severely curved root canals. The blocks were made of acrylic. The canals of the blocks were standardized, pre-formed, and all were 19 mm in length. Measured from the coronal part of the translucent simulation block, the curve began at 10 mm. The simulation blocks were numbered and randomly divided into three groups:  $n = 10$  for the study group (SG) with handpiece preparation (Mity Roto 360° files with MTwo direct),  $n = 10$  for the control group 1 (CG1) with endodontic motor preparation (Mity Roto 360° files with Endo IT), and  $n = 10$  for a second control group (CG2) with preparation by hand (Mity K-Files). We evaluated the following parameters: instrument failure, loss of working length, preparation time, loss of weight, the presence of elbow-zip effects, and changes in canal anatomy. Figure 1 is a schematic diagram of the experimental setup.

### Root canal preparation

All canals were prepared by one person with an apical to coronal preparation technique using NiTi files to an ISO size of 40. For automatic preparation with the two torque-controlled endodontic devices (MTwo direct handpiece and Endo IT motor in combination with a contra angle E-Type handpiece 4:1), Mity Roto 360° instruments were used. The preparation by hand

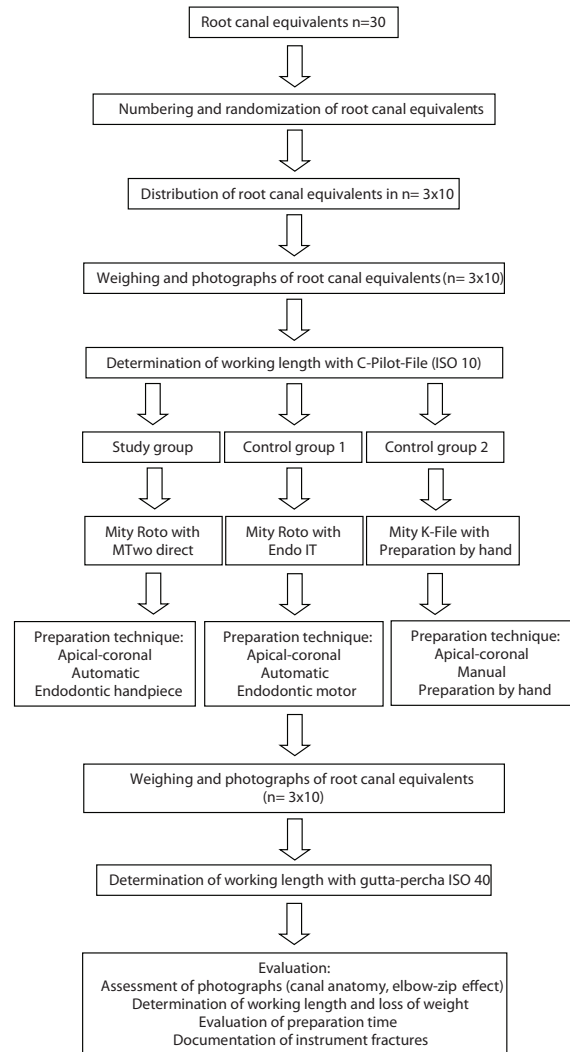


Figure 1: Flow chart of the study.

was done with Mity K-Files. Rotation speed of Endo IT and MTwo direct was set at a constant rotation of 300 rpm. For the automatic systems torque values were set manually depending on the files used, in accordance to the manufacturers' specifications.

The mechanized preparation was performed in a dynamic model. Instrument sequencing was standardized for both systems (manual and automatic) as follows: 15/02, 20/02, 25/02, 30/02, 35/02, and 40/02. The working length that was achieved was verified with a Gutta-percha of ISO size 40 (ROEKO, Langenau, Germany).

Before being used, all instruments were loaded using FileCare® EDTA (VDW, München, Germany). After each preparation step, each canal was rinsed with 2 ml Aqua dest. (Phönix GmbH, Sundern, Germany). Mity files were applied a maximum of two times per canal. Room temperature was constantly 21°C.

### Instrument failure

Instrument failures are related only to instrument fractures. In the case of a fracture, the endodontic device and

the simulation block number, as well as the type and the size of the fractured instrument, were documented.

### Preparation time

Preparation time including rinsing processes and instrument changes was recorded in minutes and seconds by a microchronometer (Siemens, Munich, Germany).

### Measuring the loss in working length

Loss of working length was measured by calculating the difference between the working length before and after preparation (in millimeter). Therefore, the canal length before the preparation was measured using a C-Pilot ISO 010 file (VDW, Munich, Germany), and after the preparation the working length of the prepared canal was measured by Gutta-percha ISO 40 (Roeko, Langenau, Germany). The working length was defined as the canal length of the unprepared canal minus 1 mm.

### Measuring the loss of weight

Simulation blocks were stored for 48 hours in a drying cabinet (Memmert GmbH, Schwalbach, Germany) at 37°C and were weighed using an analytical balance (Sartorius GmbH, Göttingen, Germany) before and after preparation to compare the removal by the different instruments.

### Elbow-clip effects

Elbow-clip effects were assessed using the tenfold enlarged projections of the root canals on a DIN A4 paper. The effects were recorded as no effect (=0), a weak effect (=1), or a strong effect (=2) (Figure 2).

### Canal anatomy

Root canals were photographed with a digital camera (Leica Microsystems Distribution GmbH, DFC 480, Wetzlar, Germany) before and after preparation with an integrated millimeter scale from the same side in order to determine the changes in canal anatomy. The slides of the root canals were projected onto a DIN A4 paper with a slide projector (Zeiss IKON GmbH, Perkeo R1500 AFS, Jena, Germany) prior to preparation. The projection was adjusted so that one millimeter of the millimeter paper was enlarged to one centimeter (10x magnification). The contours projected on the wall were color coded. Then, with the aid of orientation crosses, the comparison slide (identical root canal

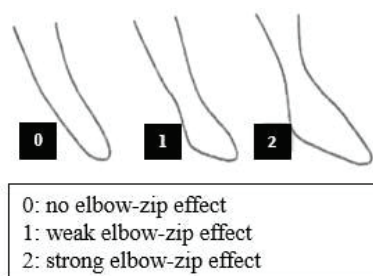


Figure 2: Gradiation of elbow-clip effects.

after preparation) was projected over the same picture and contours of the prepared root canals were drawn in a different color. Differences or changes in canal anatomy were verified using seven measurement points. These measurement points were determined by using the apex of the unprepared root canal as the center of a circle. From this, circular arcs were hit with the help of circles with radii of one, two, four, five, six, nine, and thirteen centimeters. The two points of intersection of each arc with the inner and outer curvature of the unprepared root canal were connected with a straight line and extended to the outer contour of the prepared canal. At each measurement section, the distance (at 90° angle) of the unprepared to the prepared canal was measured on the outside and on the inner side of the curvature. For simplicity, we distinguished only the apical region (measuring point 1 and 2) from the middle (measuring point 3, 4, and 5) and coronal (measuring point 6 and 7) regions.

### Statistical analysis

The study variables (frequency of instrument failure, preparation time, loss of working length, loss of weight, elbow-clip effect, changes in canal anatomy) were statistically analyzed using one-way analysis of variance (SPSS Statistics, Version 2.0, IBM, Ehningen, Germany).

Significant differences were determined using the post hoc Bonferroni test. Means and standard deviations (SD) were also evaluated.

## Results

### Instrument failure rate

Three instrument failures were recorded during preparation: two instrument failures when using the Endo IT control motor (one at ISO-size 35 and one at ISO-size 40) and one failure when using the MTtwo direct handpiece (at ISO-size 30). All fractures affected the apical root third. During hand preparation, there was no instrument failure.

### Preparation time, loss of working length, loss of weight, and elbow-clip effect

Table 1 shows the results for the parameters of preparation time, loss of working length, loss of weight, and elbow-clip effect. Significant differences among the three groups exist only for the parameter of preparation time, which was significantly longer for the control group 2 than for the study group and control group 1.

### Canal anatomy

Table 2 and Figures 3–5 show the results for the comparison of material removal from the inner side and the outside of the root canal curvature. The most important results are described as follows:

### Outside curvature

Overall, a larger change in canal anatomy was observed in the apical region of the root canal for the manual preparation

with the Mity K-File (3.42–5.27 mm) than in the middle area (0.25–2.70 mm). Independent of the type of endodontic motor, at measurement point 2, the Mity Roto 360° system showed significantly less material removal (ST: 2.58 mm; CG1: 1.96 mm) than with the Mity K instruments (CG2: 5.27 mm). The smallest material removal with all systems was in the middle area of the outer curvature (measuring point 3: 1.91–2.70 mm; measuring point 4: 1.2–1.62mm; measuring point 5: 0.25–1.15 mm). Only for measurement point 5 was significantly lower material removal observed with the Mity K group (0.25 mm) than the two Mity Roto 360° groups (SG: 0.91 mm; CG1: 1.15 mm). In the coronal area, significantly higher material removal was found for measurement point 7 in the Mity K group (CG2: 3.7 mm) than with the two mechanical systems, which did not differ significantly from one another (SG: 1.19 mm; CG1: 1.53 mm).

### Inner side curvature

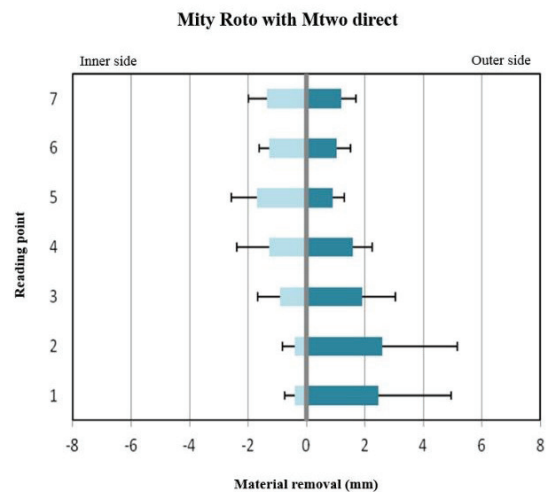
For all groups, less material was removed from the apical region (SG: 0.41 mm; CG1: 0.18–0.43 mm; G6: 0.45 mm) than the middle (SG: 0.91–1.69 mm; 0.5–1.4mm; CG2: 2.85–4.37 mm) and coronal areas (SG: 1.27–1.36 mm; CG1: 1.21–1.25 mm; CG2: 2–2.98 mm) of the root canals. Here, the three groups did

**Table 1:** Comparison of analyses results (mean values and standard deviations) acquired in the study. The values with the same letters are statistically significant.

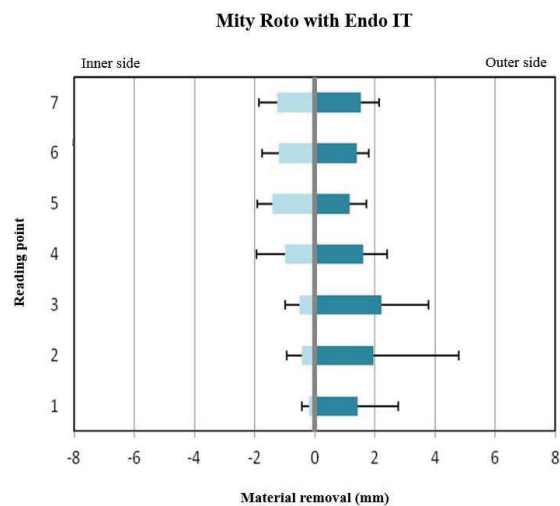
Criterion	Study group (Mity Roto/ MTwo direct)	Control group 1 (Mity Roto/ Endo IT)	Control group 2 (Mity K-File/ preparation by hand)
Loss of working length (mm)	2.44 ± 2.06	2.81 ± 1.55	1.30 ± 0.85
Preparation time (min)	10.11 ± 5.35 <sup>a</sup>	8.32 ± 5.79 <sup>b</sup>	16.46 ± 2.74 <sup>ab</sup>
Loss of weight (mg)	4.85 ± 4.11	4.97 ± 3.61	5.59 ± 1.27
Elbow-clip effect (EZE), 0 = no EZE, 1 = weak EZE, 2 = strong EZE	0.22 ± 0.44	0.25 ± 0.46	0.10 ± 0.32

**Table 2:** Comparison of material removal from the inner side (in) and outside (out) of the root canal curvature (mean values and standard deviations). The values with the same letters are statistically significant.

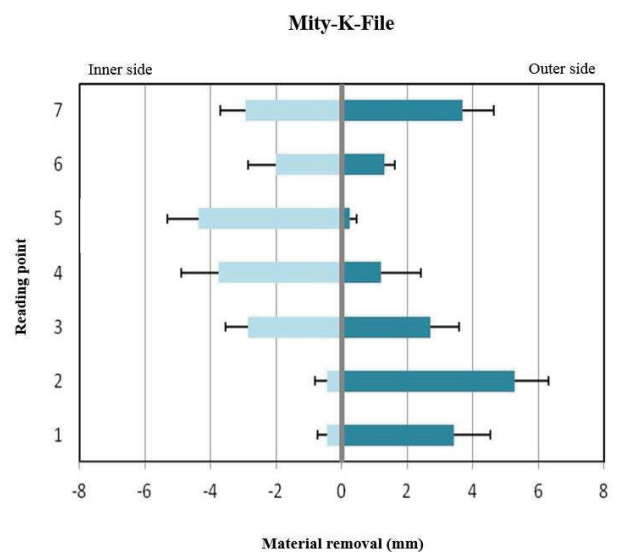
Region	Reading point	Study group (Mity Roto/ MTwo direct)	Control group 1 (Mity Roto/ Endo IT)	Control group 2 (Mity K-File/ preparation by hand)
apical	1 in	0.41 ± 0.33	0.18 ± 0.25	0.45 ± 0.28
	1 out	2.47 ± 2.48	1.43 ± 1.33	3.42 ± 1.13
	2 in	0.41 ± 0.41	0.43 ± 0.51	0.45 ± 0.36
	2 out	2.58 ± 2.58 <sup>a</sup>	1.96 ± 2.82 <sup>b</sup>	5.27 ± 1.05 <sup>ab</sup>
middle	3 in	0.91 ± 0.76 <sup>a</sup>	0.50 ± 0.48 <sup>b</sup>	2.85 ± 0.68 <sup>ab</sup>
	3 out	1.91 ± 1.13	2.21 ± 1.56	2.70 ± 0.88
	4 in	1.27 ± 1.11 <sup>a</sup>	1.00 ± 0.95 <sup>b</sup>	3.75 ± 1.15 <sup>ab</sup>
	4 out	1.58 ± 0.67	1.62 ± 0.77	1.20 ± 1.22
	5 in	1.69 ± 0.89 <sup>a</sup>	1.40 ± 0.5 <sup>a</sup>	4.37 ± 0.94 <sup>a</sup>
coronal	5 out	0.91 ± 0.39	1.15 ± 0.56	0.25 ± 0.26
	6 in	1.27 ± 0.34	1.21 ± 0.55	2.00 ± 0.84
	6 out	1.02 ± 0.49	1.40 ± 0.39	1.30 ± 0.32
	7 in	1.36 ± 0.62 <sup>a</sup>	1.25 ± 0.61 <sup>b</sup>	2.92 ± 0.79 <sup>ab</sup>
	7 out	1.19 ± 0.51 <sup>a</sup>	1.53 ± 0.61 <sup>b</sup>	3.70 ± 0.94 <sup>ab</sup>



**Figure 3:** Graphic representation of material removal on the inner and outer root canal curvature (in mm) for the Mity Roto with Mtwo direct.



**Figure 4:** Graphic representation of the material removal on the inner and outer root canal curvature (in mm) for Mity Roto with Endo IT.



**Figure 5:** Graphic representation of the material removal on the inner and outer root canal curvature (in mm) for the Mity-K-File with preparation by hand.

not differ significantly from each other. In the middle canal area with the strongest curvature, the manual Mity K system (CG2: 2.85–4.37 mm) showed the highest material removal at all measuring points compared to both mechanical systems ( $p < 0.001$ ) (Figures 3–5). In the middle section, significant differences between the two automatic systems could be found only at measurement point 5 (SG: 1.69; CG1: 1.40,  $p < 0.001$ ).

In the coronal part, the Mity K system showed significantly higher material removal from the inner curve for measurement point 7 (SG: 1.36 mm; CG1: 1.25 mm; CG2: 2.29 mm,  $p < 0.001$ ). Furthermore, for the Mity Roto 360° system, no significant effect of the device used (Mtwo direct or Endo IT) could be proven concerning the amount of material removal.

## Discussion

### Instrument failure rate

Three of the 30 instruments were fractured, all while using the Mity Roto 360° files, one with the angle piece, and two with the Endo IT motor. This is a fracture ratio of 10% to 20% per automatic system. Complex reasons based on a variety of factors such as the material [6] and design [7], of the files used, the application or drive technology [5,8], dynamic or static testing-conditions while preparation [9], environmental temperature [9] and user experience [8], are associated with the breakage of NiTi instruments. When endodontic instruments are rotated, they are subjected to cyclic stresses in curved canals [10]. The intensity of these stresses is also related to the arc length and instrument size [11]. According to Lopes et al. [11], the radius and the position of the canal curvature are the most critical parameters that determine the stress on the instrument. Higher stress levels are produced by decreasing the radius and moving from the apical to the mid-root position [12]. In addition, performance of mechanized preparation in a dynamic model promotes stress distribution along a wider portion of the instrument and increases the number of cycles to fracture, showing an extended life compared to static model studies [9]. Although we used a dynamic way for preparation of root canals, data are not completely comparable, because in our study the preparations were performed by a human being and we had different environmental conditions (room temperature instead of body temperature), that may have influenced the fracture risk of instruments [9]. Furthermore, the fracture risk appears to increase with increasing instrument size [13]. In the present study, all fractures were located in the apical portion of the file with high instrument size (ISO sizes 30–40) and occurred at the point of curvature of the canal, which is in concert with the above-cited literature. The instrument design or the cross-sectional geometry can also be an important reason for a fracture risk. According to Turpin [14], the resistance of a file to fracture or torsion correlates with the geometry of the file and its cutting edges. The design of Mity Roto 360° files with wide lateral radial lands shows pronounced contact surfaces with the root canal. This leads to high frictional resistance and a strong instrument load due to torsional forces [15,16]. Simulation blocks for a root canal equivalent were used for this study in order to obtain as standardized and controllable conditions as possible [17]. However, the use of artificial root

canals has a major disadvantage: In the canal, the frictional heat caused by the rotating files causes the plastic to soften locally, which can lead to load peaks in torque [17]. These conditions could have been particularly great with Mity Roto 360° and could explain the observed fractures. The stronger attachment of the instrument at the point of greatest curvature in the canal could have resulted in greater tensile and compressive forces acting on the instrument. A stronger bonding of the cutting edges with the plastic could thus also have contributed to the breakage of the Mity Roto 360° file [18].

### Preparation time

Engine based root canal treatment is a valuable time relief for patients and practitioners [19]. The result of a lower time intensity of mechanical systems compared to preparation with hand instruments demonstrated in this study coincides with other studies [20,21] and is independent of the type of drive (Mtwo direct/Endo IT). Bürklein [22] was able to demonstrate that preparing with an Endo IT motor was significantly faster compared to a Mtwo direct contra-angle hand piece, but used Mtwo files in the crown-down technique, so that no informative comparison with the present study conditions could be ensured.

### Loss of working length

The preparation of the complete working length is a key prerequisite for the success of root canal treatments [23]. Nevertheless, even with the use of NiTi systems, there may be an undesirable loss of working length [24]. In the case of manual preparation with Mity K-Files, an average loss in the working length of 1.30 mm in simulated canals was also found in the present study. In contrast to the findings at hand, Weiger was unable to detect a loss of working length when using manual NiTi files [25]. When using the Mity Roto 360° system, compared to manual technology, there were significantly larger working length losses found in our study: 2.44 mm and 2.81 mm on average. The drive type (contra-angle handpiece/motor) had no impact on the working length loss within the two mechanical systems. Thompson observed only a small loss of working length between 0.05 mm and 0.15 mm for Mity Roto 360° [26]. In contrast to the present study, Thompson's study opted for the crown-down technique. Thus, different preparation techniques could account for the observed large difference in lost working length. In contrast, Gerhardt-Szep found no loss of working length with the Mity Roto 360° instruments with a treatment technique that is comparable to the present study [27]. One reason for the contradictory results could be that the simulation blocks used were made by different manufacturers and, therefore, did not have exactly comparable properties, such as plastic hardness, root canal cross-section, or curvature. Furthermore, the impending loss of the working length for Mity Roto 360° could have unintentionally resulted in increased pressure exerted by the user while preparation. This, in turn, could have led to frequent jamming of the Mity Roto 360° files in the plastic canals, which may have been favored by the heating of the plastic. In this study, the use of Mity Roto 360°, an instrument with less cutting efficiency, may have been disadvantageous in combination with the apical-coronal preparation technique.

## Loss of weight

In addition to the quality of the root canal preparation, the quantitative aspect of material removal is crucial [19,27,28]. The observed weight loss after preparation is a model for examining the cutting performance and the removal of debris from the file systems [27]. The measured weight loss is dependent on the loss of working length and the apical "debris accumulation". The three parameters together provide information about the cutting performance of the file. The latter is great when the weight loss is high and the working length loss is simultaneously low [27]. In this study, all three systems had comparable weight loss ranging between 4.85 and 5.59 mg. The sole consideration of the weight loss average of the Mity Roto 360° files and the mean of their simultaneously measured largest working length losses seem to be contradictory. These may be caused by the practitioner's preparation error described above. However, these may also show that Mity Roto 360° does not have the highest cutting performance due to its long working length losses. In addition, the chips remaining in the prepared simulation block for a root canal equivalent within the groups were not quantified further, which limits the significance of this parameter.

## Elbow-zip effect

In this study, a total of five weak elbow-zip effects occurred, which did not differ within the groups. In contrast to the present study, Thompson had no elbow-zip effect in the preparation on the simulated root canals with the Mity Roto 360° instruments, using the crown-down technique [29,30]. The elbow-zips could have emerged in the different treatment method for the Mity Roto instruments. Furthermore, increased pressure and thus less passive operation in these Mity Roto 360° groups could have caused a change in the course of the canal. This higher force application could have been an unconscious attempt to compensate for the larger working length loss. This "aggressive" measure against the impending loss of the working length could lead to elbow-zip effects, as postulated by Hülsmann [31]. However, the elbow-zip effects observed in the study for Mity Roto 360° conflict with its design, which, with its rounded tip and radial lands, should allow better centering in the canal [32]. In the root canal equivalent simulation block, the larger guide surface of the Mity Roto 360° files could cause the material to stick to the file, thus producing an elbow-zip effect. This hypothesis must be reviewed in further studies.

## Canal anatomy

One goal of mechanical root canal preparation with respect to canal anatomy is, among other things, to preserve the original root canal shape. Considering the canal anatomy factor, material loss in the present study is rather uneven over the entire canal length, especially for the Mity K-File. If one looks at the apical area, significantly higher material removal on the outside than for the inner curvature are evident for all three groups. The observation of higher material removal in the apical area at the outer curvature could be confirmed by further investigations using mechanical NiTi instruments, in which increased removal at the outer curvature of the apical third

was accompanied by little or no removal at the inner curvature [33]. With regard to outer curvature, the Mity Roto 360° system showed significantly less material removal overall, regardless of the type of motor in the apical section compared to the manual system with the Mity K instruments, which could be explained by its lower cutting efficiency [26]. The cutting tip of the Mity K instruments may contribute to a stronger "screw-in" effect in the outer canal wall. In the middle canal area with the strongest curvature, the highest material removal by the Mity K instruments was found on the inner curvature. This observation is in line with other studies [27,34]. Root canals, which have been prepared to different intensity degrees, can lead to a transportation of the canal axis, which was observed by Gerhardt-Szep in the form of root canal straightening on standardized artificial canals [27]. As expected, the Mity Roto 360° instruments demonstrated the least change in the original canal axis, regardless of the drive motor. In the present case, this cannot be explained solely by the low conicity and the associated high flexibility of the instrument, which promises better canal centering [35,36]. Even the manual Mity K system had a conicity of only two percent. A possible explanation could be that the different geometries of the instruments -because the design of the Mity Roto 360° files has flattened radial lands and a neutral cutting angle -make them scrape rather than cut. The radial lands of the Mity Roto 360° in combination with the non-cutting tip lead to better centering of the file, especially in curved canals [37,38] and, thus, to a lower degree of transportation [27]. Peters et al. also demonstrated that active cutting systems resulted in slightly greater canal transportation than file systems with a passive cutting process [39].

In summary, regardless of the drive motor, the Mity Roto 360° files produced more even material removal over the entire canal and the best shape retention of the canal geometry compared to the manual instruments. This observation contrasts with a study by Bürklein, who, however, used the aforementioned systems on root canal equivalents of polyester resin rather than plastic, which might explain the differences [22]. The decisive disadvantage of the Mity Roto files, however, is the clinically intolerable loss of the working length, averaging between 2.44 and 2.88 mm. This was observed independently of the drive motor and is, therefore, mainly caused by the material properties of the file itself in combination with the corresponding devices. This clinically relevant disadvantage cannot be offset by the significantly reduced preparation time of the two mechanical systems compared to manual instrumentation. Hence, clinically, the use of the Mity Roto 360° files cannot be recommended in combination with the Mtwo direct handpiece or the Endo IT professional motor using an apical-coronal preparation technique. Further investigations should clarify whether other preparation tools -such as the Mtwo NiTi file type recommended by the manufacturer in combination with the Mtwo direct handpiece in combination with a coronal-apical processing technique -can compensate for the disadvantages of working length losses when using these two devices compared to manual instrumentation.

## Review of the research hypotheses

The pre-formulated first and second research hypotheses were rejected and the alternative hypotheses were adopted. These relate primarily to the extended preparation time in manual processing.

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