Preparation of the coronal and middle third of oval root canals with a rotary or an oscillating system

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Objectives. To comparatively evaluate the preparation of oval root canals with a rotary or an oscillating system.
Study design. The middle and coronal parts of 55 extracted permanent teeth with oval canals were prepared using FlexMaster (FM) rotary NiTi instruments and EndoEze AET (EE) stainless steel oscillating instruments. Pre- and postoperative images of cross-sections were superimposed to identify shifts in the center and to assess the percentage of untreated regions. In addition, the middle segment was investigated by scanning electron microscope (SEM) to determine debris and smear layer removal.
Results. The systems did not significantly differ in the shifts of the canal centers in the middle part of the root. Only a few of the preparations yielded an excellent result with no uninstrumented canal wall left. The SEM investigation demonstrated poor results for both systems regarding debris and smear layer removal, but no significant differences could be observed.
Conclusions. Neither FM nor EE was capable of completely preparing oval root canals. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:852-6)**

The preparation of oval root canals has been sparsely investigated,[1,2] although high prevalence of oval canals has been reported.[3,4] Wu et al.[4] observed frequencies of 56% for long oval canals in mandibular incisors and 63% for single canal premolars in sections 5 mm from the apex. The anatomy of those oval canals involves recesses which may remain uninstrumented. This hypothesis was confirmed for hand instrumentation using either the balanced-force technique or circumferential filing[5,6] as well as for rotary instruments.[5,7] Oscillating systems might be more adequate than rotary ones which might be assumed not to touch all regions of the canal wall. The reason for this assumption is that it might be more difficult to keep a rotating instrument in place, especially in the middle part of the root canal compared with an oscillating file which moves in all directions with a short amplitude.

The aim of the present study was to evaluate if there is any difference in the quality of oval root canal preparation between 2 different principles of instrumentation—a rotary and an oscillating one. Only the coronal and middle part of the root were of interest in this study, because the long diameter of oval canals decreases in the apical area.[4] The hypothesis was that an oscillating system could be an improvement in preparation of oval root canals compared with a rotary system.

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MATERIALS AND METHODS

One hundred extracted maxillary premolars and mandibulary incisors were cleaned and stored in 3% aqueous chloramine solution for 24 hours. The crowns were removed before the roots were finally stored in sodium chloride solution.

Criteria for inclusion (1)

- Canal patency (tested by inserting an ISO 10 K-File).
- Root canal curvature less than 20° in mesiodistal plane. For this measurement an ISO 10 silver point was inserted followed by preparing a radiograph. The angle was assessed manually with a set square following the Schneider technique.[8]

The roots were embedded in methacrylate resin Technovit 7200 (Heraeus Kulzer, Hanau, Germany) using a standard mold according to Bramante et al. and Hülsmann et al.[9,10] The working length of all roots was between 12 and 15 mm. Then the roots were sectioned horizontally into 3 parts of equal length. Depending on the length of the root, the first cut was at a distance of 4-5 mm from the apex and the second cut at a distance of 8-10 mm. The sectioning was done with a water-cooled diamond band saw (Exact Apparatebau; Norderstedt, Germany). Then the sections were digitally photographed with the OP Microscope (Carl Zeiss, Jena, Germany) under standardized conditions.

Criteria for inclusion (2)

The photographs obtained from the level of 4-5 mm from the apex were used to digitally measure the dimension of the root canal in mesiodistal and bucco-oral direction (Scion Image software version 4.0.2 (Scion Corporation, Frederick, MD)). Only teeth with a canal with long to short diameter ratio ≥2 in cross-section were selected.

A total of 55 teeth met all criteria and were therefore included in the further investigation.

Subsequently, the segments were remounted in the mold for the root canal preparation. The roots were randomly divided into 2 groups: group A with 27 specimens and group B with 28 specimens. For initial preparation, an ISO 15 K-file was inserted to working length. Next, the upper part of the root (not deeper than 3 mm) was instrumented in a funnel-shaped preparation with Gates Glidden drills #3, #2, and #1. After the canal was rinsed with 1 mL 3% aqueous sodium hypochlorite, the following procedures were done with the specimens of each group.

Group A: FlexMaster (rotary system)

Rotary Ni-Ti instruments FlexMaster (FM; VDW, Munich, Germany) of 21 mm length with a noncutting tip, convex cross-section, and a constant taper of .04 or .06 were used in this group. The preparation was accomplished using the engine Endo IT control (VDW, Munich, Germany) and the Endo NiTi WD-74 M handpiece (W&H Dentalwerk Bürmoos, Laufen, Germany) following the manufacturer's instructions for the coronal and middle part of the root and using the engine's level II for "experienced users" (higher torque limit). Either the red sequence for medium canals (25/.06, 20/.06, 30/.04, 25/.04) or the yellow sequence for small canals (20/.06, 30/.04, 25/.04, 20/.04) was used; this was determined by the operator's subjective decision. The 4 files were used following a crown-down approach, so that the last file ended 3 mm away from the apex, as recommended by the manufacturer. With every instrument, the operator attempted to reach all recesses of the canal by lateral circumferential movement. The apical preparation was not performed, so that the apical area was left unprepared. The preparation speed was 280 rpm for all files. After the usage of each file, the canals were irrigated with 1 mL sodium hypochlorite (3%), so that a total amount of 5 mL for each canal was used.

Group B: EndoEze AET (oscillating system)

Oscillating shaping files (Ultradent, Salt Lake City, UT) of 16 or 20 mm length with a rounded tip, square cross-section (K-file type), and a constant taper of .025 (file #1), .045 (#2), and .06 (#3) were used in this group. The tip diameter of these instruments was 0.10 mm for file #1 and 0.13 mm for files #2 and #3. The preparation was carried out with the oscillating EndoEze (EE) handpiece (Ultradent) which works in a 30° right–30° left reciprocating action. The handpiece can be used without a special engine at the dental unit. Files #1, #2, and #3 were inserted consecutively and each directly into the whole coronal and middle part of the root (until 3 mm away from the apex) as recommended by the manufacturer. The instruments were pushed against all sides of the canal wall circumferentially when pulled out of the canal.[11] After each preparation step, rinsing was done with 1 mL NaOCl solution. To obtain a total volume of 5 mL irrigating solution again, the canal was rinsed again with 2 mL after file #2. Again, the preparation of the apical portion of the root was not accomplished, as in the other study group (see Discussion).

All files (group A and group B) were daubed with the EDTA-containing product FileCare (VDW) before application, because the manufacturer of FM recommends lubrication. Every canal was prepared with a new set of files.

After the slices were removed from the mold, they were digitally photographed as described above.

Geometrical parameters

The pre- and postpreparation photographs were analyzed using Scion Image software. The center of the root canal was set as an x- and y-value in the preoperative photograph. After superimposition of the pre- and postoperative photographs, this data was calculated again for the postoperative photograph. The differences in the x- and y-values were determined, showing how the center of the original root canal was transported (x: bucco-oral direction; y: mesiodistal direction).

Furthermore, by superimposing the canal outlines, the percentage of contact between the pre- and postoperative root canal outlines was measured, representing unprepared areas of the root canal wall.

Root canal cleanliness

The middle slice of the 3 root segments was prepared for scanning electron microscope (SEM) investigation freed from the resin. The root sections were segmented in the longitudinal direction with a chisel, so that a mesial and distal part could be examined under the SEM with our main interest being the middle of each side wall. Twenty-five of the 55 specimens broke se-

Table I. Shift of the center coordinates (mm)

	Middle part		*Coronal part*	
	x (median)	*y (median)*	*x (median)*	*y (median)*
FlexMaster	0.097	0.053	0.096	0.062
EndoEze	0.066	0.044	0.116	0.058

x = bucco-oral direction; y = mesiodistal direction.

Table II. Contact between pre- and postoperative cross-sections

	Middle part		*Coronal part*	
	FlexMaster	*EndoEze*	*FlexMaster*	*EndoEze*
0%	3	3	7	8
0-25%	8	6	9	7
25-50%	7	6	2	7
50-75%	6	9	7	5
75-100%	3	4	2	1
n	27	28	27	28

verely, so that some teeth only left one-half for investigation and some could not be further investigated at all. The roots were coded by a second operator, so that the type of instrument used for preparation could not be identified during SEM investigation. The specimens were dehydrated in increasing concentrations of alcohol (from 10% to 99 %) and sputter-coated with gold (sputter coater S150B; BOC Edwards, Crawley, U.K.). Examination was performed using a scanning electron microscope (DSM 950; Carl Zeiss, Oberkochen, Germany). After the central beam of the SEM had been directed to the center of the canal wall under ×10 magnification, the magnification was increased to ×200 and ×1000, respectively, and the canal wall region appearing on the screen was scored. Separate evaluations were undertaken for debris (×200 magnification) and smear layer (×1000 magnification) with a 5-score system as established in earlier investigations.[12-14] Debris was defined as dentin chips, pulp remnants, and particles loosely attached to the root canal wall. Smear layer was defined as proposed by the American Association of Endodontists[15]: "A surface film of debris retained on dentin or other surfaces after instrumentation . . . consists of dentine particles remnants of vital or necrotic pulp tissue, bacterial components, and retained irrigant." The operator had been trained in the scoring procedure, resulting in sufficient intraobserver reproducibility. When both halves were investigated, the highest score of each was taken into consideration.

Statistical analysis was carried out with SPSS software 12.0 (SPSS, Munich, Germany). Because the Kolmogorov-Smirnov test did not reveal a normal distribution of test results, the Mann-Whitney *U* test for unpaired samples was used to calculate significant differences between groups. Statistical significance was considered as $P < .05$.

RESULTS

Geometrical parameters

The shifts of the center coordinates are presented in Table I. No significant differences could be detected between the 2 groups either in the coronal or in the middle part for both shift directions (Mann-Whitney *U* test, $P > .05$).

The results regarding contact between the pre- and postoperative cross-sections, representing the percentage of the canal wall which remained unprepared, are given in Table II. Furthermore, no statistical differences could be detected for this parameter between the 2 instrumenting systems (Mann-Whitney *U* test, $P > .05$).

Root canal cleanliness

The results for the debris and smear layer scores are presented in Table III. No statistically significant differences could be observed between the systems for either score (Mann-Whitney *U* test, $P > .05$).

DISCUSSION

In the present study, a comparison was made between a rotary and an oscillating system on oval root canals. As an example of a rotary NiTi system, the product FlexMaster was chosen, because this is already well investigated. Good shaping ability, acceptable canal transportation,[16-18] and acceptable results in smear layer and debris removal[19] have been demonstrated for this system. To date, however, there has been no investigation made concerning its effectiveness in oval canals. Other rotary NiTi systems (ProFile, Lightspeed, and Quantec) were not satisfactory regarding the cleanliness and controlled preparation of oval canals.[7,20] Weiger et al.[5] also demonstrated insufficient preparation for the middle third of the root when using Hero or Lightspeed instruments. Furthermore, poor results have been reported when preparing oval canals by hand instrumentation.[5,6,21]

Hülsmann et al.[19] found that only 2 of 24 specimens showed more than 50% contact between the pre- and postoperative photographs in the coronal part when prepared with the FM system. For oval canals, these results could not be repeated in the present study. We observed many more of such insufficient cases in both investigated section areas when prepared by FM. We might have achieved a more comparable result if we had used the sequence for apical preparation conclud-

Table III. Debris and smear layer score

	Debris		*Smear layer*	
Score	*FlexMaster*	*EndoEze*	*FlexMaster*	*EndoEze*
1	3	4	5	3
2	6	13	7	8
3	4	5	3	9
4	2	1	0	3
5	0	0	0	0
n	15	23	15	23

ing with a file of size 35 or more (taper .02) as the manufacturer recommends.

The second investigated system in this study were the oscillating stainless steel instruments EndoEze AET, which were claimed to permit a perimetric or circumferential preparation of coronal and middle thirds of oval root canals.[11] We expected a better performance of these instruments, because we supposed that it might be easier to control the preparation of all areas of the canal with a reciprocating movement in contrast to a rotating movement, in which the instrument might slip over the canal wall and only prepare the buccal or lingual part of the canal. We assumed that an oscillating system could reach all areas of the root canal superiorly. Contemplating the percentage of unprepared areas, EE did not sufficiently prepare the canals, either; in 13 of 28 cases more than 25% of the canal wall was left unprepared. For both systems, we detected root canals prepared only in the buccal or lingual part, as well as cases with a circular bulge with unprepared lateral extensions. Paque et al.[22] demonstrated better results for this parameter, showing uninstrumented areas by microcomputerized tomography, but the investigation was carried out only in maxillary molars. The values for the shift in the center were slightly higher in the latter study, differing from 0.1 to 0.3 mm (mean) for the various types of canals. This might be explained by the fact that canal straightening occurs particularly when the apical portion is prepared, which was intentionally omitted in the present study.

Zmener et al.[20] showed superior results of EndoEze compared with ProFile and hand instrumentation regarding the cleanliness of oval root canals. This could not be confirmed by the present findings. Unfortunately the data are not completely comparable, because in the Zmener et al. study, a modified score with only 3 ranges was used to determine the smear layer and debris removal, whereas the present study followed a well established 5-range score. Also, the magnification was higher in the present study (×1000 compared with ×400 in Zmener et al.), resulting in a smaller area in which the smear layer is determined but also making smear layer detection easier. On the other hand, a disadvantage of our design might be that the insufficient removal of debris may have occurred because the irrigation regime was only accomplished with 5 mL sodium hypochlorite for each canal (compared with 10 mL in Zmener et al.). A greater volume would have been used if the apical preparation had been completed.

Furthermore, there is a difference in the definition of an oval root canal. We decided to choose a ratio of bucco-oral to mesiodistal dimension of ≥2, because this is used in earlier studies investigating oval canals.[5-7,21] A ratio of ≥1.3 was chosen in the Zmener et al. study, which might include teeth that can be prepared sufficiently in an easier manner. Because the prevalence of a ratio of ≥2 is reported to be only 56% in mandibular incisors and 63% in maxillary premolars,[4] many teeth had to be excluded from our study.

As an alternative to hand and rotary instruments, Lumley et al.[1] investigated the efficiency of sonic and ultrasonic instrumentation when used in oval canals. The results for debris and smear layer removal were rather insufficient. Particularly of interest was the excessive amount of remaining smear layer. Lumley et al engaged in the direction of the file oscillation and revealed a better debris removal when the instrument was oscillating toward the canal's recesses; the smear layer was unaffected. The devices used in the Lumley et al. study were oscillating in a longitudinal direction compared with a rotating oscillation in our study. Furthermore, Lumley et al. used sterile water as an irrigant, which is one factor that they hold mainly responsible for the poor results of smear layer removal. In summary, their results are scarcely comparable with our findings.

In the present investigation we purposely did not perform any apical preparation. The aim was to provide information on the efficiency of the oscillating and rotary approaches in the oval canal from a technical point of view and not to look at the whole clinical procedure. We wanted to conclude whether an oscillating instrument could be a solution for oval canals. Because the oval shape of the canal is mostly present in the coronal and middle part of the root,[4] this was the area of interest. Thus we accepted that we were only able to examine the assumedly better part of the EE System.

Furthermore, we chose this study design to avoid any influences of the apical preparation on the result, which might have been, e.g., a distribution of dentinal mud from the apical part to higher regions. Following the manufacturer's instructions, the apical preparation would have been performed by manual instrumentation for the one (EE) and by rotary instruments for the other system (FM), which would have been a great difference in the whole procedure. As only maxillary premolars and mandibulary anteriors were prepared, the apical diameter was fairly small, so that the adequate apical files would have probably not influenced the final diameter of the middle and coronal part.

It could be criticized that the files which had been applied were too small for the middle part of straight canals. This could have an influence on the insufficient results of both systems. As we know from Wu et al.,[4] the average diameter of maxillary premolars in oval canals is 0.38 mm and for mandibular incisors only 0.29 mm in the mesiodistal direction 5 mm from the apex. Thus, the last instrument of the applied sequences could possibly be too small in some cases (5 mm from the apex = 2 mm from the instrument tip: 0.25 mm (EE) and 0.33/0.28 mm (FM)). The bigger dimensions of the root canal in the bucco-oral direction should be compensated by the operator's filing motions toward all canal walls. Nevertheless, this could be a reason for the insufficient results regarding the uninstrumented walls of the root canal. Owing to the fact that the average taper of mandibulary incisors (.01) and maxillary premolars (.03)[4] is significantly smaller than the taper of the applied instruments (.06 (EE) and .04 (FM)), we can assume that there was a close-fitting contact between the instrument and the root canal wall at the coronal region. In this area probably none of the apical files would have been binding following the preparation as performed in the present study. Therefore, the oval geometry of the canal might be the main reason for the high prevalence of uninstrumented areas. The limited size and number of instruments might be less responsible for this result.

The teeth were randomly distributed into 2 groups. In doing this we could not guarantee that there is a statistical matching with regard to the diameter ratio of the canals. Because we decided to set the ratio as ≥ 2, which is already quite a high value representing long oval canals, we may assume that the variation between the roots' diameters was not decisive in the statistical result.

In conclusion, both systems could not meet the expectations of a good preparation result in oval root canals. These canal configurations still remain a problem in endodontic preparation, making it difficult to reach the aim of canal debridement for disinfection.

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