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ACCURACY OF AUTO REVERSE FUNCTION IN INTEGRATED MOTOR COMPARED TO A STANDARD ELECTRONIC APEX LOCATOR IN MAINTAING THE WORKING LENGTH (IN VITRO STUDY)

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ABSTRACT

INTRODUCTION: Determination of working length and its control throughout root canal preparation remains challenging.
OBJECTIVES: The purpose of this study was to evaluate accuracy of auto apical reverse (AAR) mode in an integrated motor and a standard electronic apex locator (EAL) in maintaining working length (WL) without violation of apical constriction (AC) under stereomicroscope.
MATERIALS AND METHODS: Sixty extracted mesiobuccal roots of mandibular molars were selected. Actual lengths (AL) were measured and EAL readings were measured corresponding to ‘‘0.5’’ mark in both devices. Teeth were randomly divided into two groups (n=30), Group I: Canal preparation with rotary instruments while activating AAR function of MM-control motor, whereas Root ZX-II was used for WL determination in Group II. In both groups; difference between AL and post-preparation length (AL2) were calculated. Position of file tips relative to AC was designated zero if coinciding, negative for coronal and positive when apical to it under the stereomicroscope. Means of absolute values and percentages of electronic measurements distribution between devices were compared using t-test and Chi-square test, respectively.
RESULTS: Alterations in AL and AL2 between the two groups showed no significant difference; however, AL2 in Group I increased significantly ($P<0.0001$). Under stereomicroscope 90% of file tips in Group I was positively located relative to AC, in-contrast to 53.3% in Group II which was a significantly higher percentage.
CONCLUSIONS: Root ZX-II EAL was more consistent in determining the apical extent of preparation, while AAR function of MM-Control gave higher percentage of AC violation.

KEYWORDS: Apex locator, Apical constriction, Integrated motors.
RUNNING TITLE: integrated motors accuracy in detecting the apical constriction.

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INTRODUCTION

A critical step for effective endodontic treatment is the biomechanical preparation of the root space, which sets a strict apical limit for this procedure. (1). The AC represents the pulpal tissue and the periodontal tissue and is defined as the smallest cross-sectional region with a length of at least 0.1 mm. (2). This anatomical landmark may be placed at 0.5-1 mm from the main foramen, and it has been mentioned that the instrumentation and obturation of the canal system is an optimal place to stop (3).
To evaluate the exact WL, both radiographic and electronic techniques have been used, but no particular technique is really satisfactory (4). For diagnostic purposes of the root morphology, radiographic analysis is sufficient, but because of the anatomical difference between teeth, it cannot accurately establish the WL (5, 6).
EALs are confirmatory devices for evaluating the right WL. Custer et al. first examined it in 1918, and Suzuki identified the idea later in 1942 (7), while the electrical resistance among the periodontium and the membrane of the oral mucosa was announced by Sunada in 1962 (8). Some shortcomings have been revealed over the years, but the apex locator industry continued to develop before hitting the fourth generation, which allowed calculation in a dry or wet field and introduced the integrated apex locator (4).
With the goal of making root canal care smoother and quicker, endodontic motors with integrated EALs were built (9, 10). These hybrid devices often strive to track and establish the apical limit during the mechanical preparation of the root canals by auto apical reverse function (AAR) in addition to torque and speed control to avoid instrumentation outside the predefined WLL (11).
The endodontic motor MM-Control (Micro-Mega SA, Besancon, France) is an optimized torque and speed control motor that is extremely important to ensure maximum treatment protection and to reduce the possibility of instrument breakage. During rotary planning, this motor can be set to manual mode calculation simulating normal EALs or to motor-controlled mode (12). It has an AAR feature that ceases and reverses the motion when the tip of the instrument hits a slight

constriction (1, 13, 14). Because inaccuracy in WL determination may lead to inadequate debridement of the root canal, this property is of utmost importance, whereas overestimation may result in tissue damage that slows or prevents healing (15).
The aim of the current study was to assess the precision of an integrated motor in maintaining the length without violation of the apical-constriction throughout the root canal preparation compared to a standard EAL. The null hypothesis was that no difference would be detected in the electronic readings obtained by the two tested devices throughout the instrumentation procedures.

MATERIALS AND METHODS

Preparation of teeth specimens

Sixty human mesio-buccal canals of mandibular molars with mature completely formed apices were selected from teeth extracted due to periodontal reasons after the approval of ethics committee in faculty of dentistry Alexandria University, and were stored in 0.1% thymol solution. Mesio-buccal canals with less than 15-degree curvature, free from metal restorations, with mature apices, and showing no signs of calcifications, apical resorption, joined canals or cracking were included in this study. The teeth were radiographed buccolingually and mesiodistally to confirm that inclusion criteria were fully met. Finally, teeth were rinsed under running tap water and stored in saline solution (16). A rose head carbide bur and an Endo-Z bur (Dentsply Maillefer, Canada) were used for preparation and deroofing of standard access cavities, and a fixed and stable reference point was obtained by flattening of mesio-buccal cusps, 2.5% sodium hypochlorite (NaOCL) solution was used for irrigation, and a 10 K-file (Dentsply-Sirona, York, PA) was used to confirm patency.

Actual length determination and canal preparation

The visual measurements were performed under a microscopy at x10 magnification by introducing #10 K-file till the tip becomes recognizable at the most coronal border of the apical foramina (AF) opening. Then, the stopper was adjusted to the coronal flat reference point. With a digital-caliper (DC) the space between the tip and the stopper was measured and recorded. Then 0.5 mm were subtracted from the measurements to achieve the pre-operative actual working length (AL). Freshly made alginate (Hydrogum, Zhermack, Rovigo, Italy) was poured in ice-blocks and teeth were implanted in it, saline solution keeps the alginate model moistened whenever needed. Teeth were arbitrarily separated into two groups (n=30); Group I using MM-Control motor (Micro-Mega, Besancon Codex, and France) set to AAR mode and GroupII using Root ZX II (J. Morita USA, Tustin, CA) for electronic measurements. All electronic measurements were taken within 30 minutes of model pouring to maintain its humidity. In all canals one flare file (Micro-Mega, Besancon Codex, and France) was used for were coronal preflaring, G-files (Micro-Mega, Besancon Codex, and France) were used to produce a glide path, 2Shape file system (Micro-Mega, Besancon Codex, and France) was used for shaping canals.

Electronic working length estimation

AAR mode

MM-control motor was set in the AAR mode, and root canals were prepared using 2Shape file system (Micro-Mega, Besancon Codex, and France); TS1 (#25 .04) and TS2 (#25 .04) according to the manufacturer instructions. Prior to rotary preparation rubber stops were removed, then the files were inserted into the contra-angle that possesses a built-in electrode to provide a closed circuit. Consequently, when the instrument was introduced inside a wet canal; rotation started automatically and files advanced slowly till reaching the AC as indicated by the 0.5 mark and the AAR function was automatically activated. During instrumentation, canals were irrigated and lubricated using 2.5% NaOCL, and EDTA MD-ChelCream (META-BIOMED, Korea), and patency was regularly checked with a #10 k-file (Mani Inc, Japan). After ending the preparation, adjacent canals were dried using paper points size #15, the rubber stop was reattached to the TS2 shaping file and reintroduced to the fully prepared apical extent. The rubber stop was fitted to the reference point, and this length was recorded using a DC to 0.01-mm precision as the post-preparation working length (AL2). A corresponding # 25 k file (Mani Inc, Japan) was inserted to AL2 and cemented in place using Tetric N-Flow flowable composite (Ivoclar Vivadent, Liechtenstein)

Manual mode

Root ZX II file holder (J. Morita USA, Tustin, CA) was attached to a # 15 k-file (Mani Inc., Japan), and the lip clip was placed in the alginate, the file was advanced within the root canal to the point indicated as apex (third green line) and then withdrawn until the reading showed a consistent flashing at the middle green bar (0.5 mark) for 5 uninterrupted seconds and this WL was measured using a DC and recorded. The obtained reading was transferred to the 2Shape file system (Micro-Mega, Besancon Cedex, France) two files; TS1 and TS2 which were attached to the X-Smart Plus endo motor (Dentsply Maillefer, Ballaigues, Switzerland) for root canal preparation. On sequential preparation with each file (TS1 and TS2), canals were irrigated, patency established and WL was rechecked with a # 15 k-file. Upon finishing preparation, TS2 shaping file was introduced to the fully prepared apical extent as in previously done in the MM-control group. This length was determined using a DC and registered as the WL (AL2) post-preparation and transmitted to a file of # 25 k and solidified in position using flowable composite Tetric N-Flow (Ivoclar Vivadent, Liechtenstein).
All specimens were randomly coded with numbers to provide blinding, and shaving was done longitudinally for the apical 4 mm using diamond bur until the file was visualized in the canal space. Each root was staged, visualized, and imaged with a digital camera (XCAM1080PHB, ToupCam, Japan) mounted to a stereomicroscope (SZ1145TR, Olympus, Japan).

Statistical analysis

Using the recorded electronic WLs obtained in both groups, the differences between AL and AL2 were calculated, respectively. WLs were assessed using independent t test and within group difference was analysed using paired t test. Man, Whitney U test was applied to compare the mean difference between groups.
The stereomicroscopic images were adjusted and scaled with AxioVision (Zeiss, Jena, Germany) to determine the relation of each file tip position to the minor diameter or apical constriction (AC) **(Figure 1)**. The file tip position was considered positive if detected apical to the AC zone, negative if coronal to it and zero value if coincident with it. The file tip position to the minor constriction under stereomicroscope was evaluated by three dentists, 20 random samples were evaluated twice within 2 days intervals to calculate intra and inter-examiner reliability using Intra-class correlation coefficient (ICC) and Kappa test for the WL and values obtained under stereomicroscope, respectively. Percentage of the position to the AC and differences between AL and AL2 was compared using Chi square test. The level of significance was set at $p > 0.05$. Data was analyzed using statistical tools from IBM SPSS (version 25).

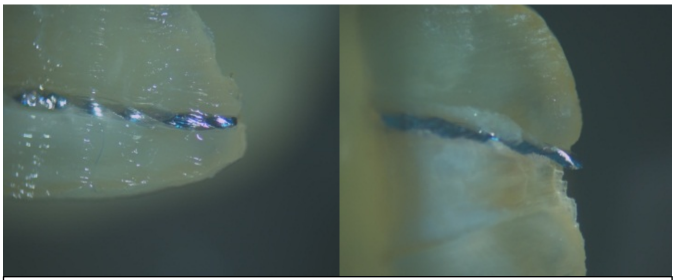

Fig. 1 File tip relation to the apical constriction

RESULTS

In **table 1**; There were no significant differences between the two -groups about the true (AL) and post-preparation length (AL2) differences. However, AL2 in MM-control group increased significantly (P < 0.0001). In Group I the mean AL was 14.60mm (±1.86), and the mean AL2 was 15.12mm (±1.78). While in Group II the mean AL was 14.10 mm (±2.32), and the mean AL2 was 14.20 mm (±2.20) which is not significant. The mean difference between AL and AL2 was significantly higher in Group I (-0.52 ±0.38) in comparison to Group II (-0.10±0.46) (P < 0.0001).

In the MM-control group, under the microscopy, the file tip was observed to be at an apical position to the AC (positive relationship) with a slightly higher percentage (90%) relative to the regular EAL group (533%) **(Table 2).** Both intra and inter examiner reliability indicated nearly perfect agreement with ICC being 0.987 and Kappa test ranged from 0.815 to 0.829.

Table 1: Comparison between Group I and Group II regarding the actual length (AL) and post-preparation length (AL2)

Length in mm	Group I (n=30)	Group II (n=30)	P value
	Mean (SD)		
Actual length	14.60 (1.86)	14.10 (2.32)	0.631
AL2	15.12 (1.78)	14.20 (2.20)	0.082
P value	<0.0001*	0.246	
Mean difference	-0.52 (0.38)	-0.10 (0.46)	<0.0001*

*Statistically significant at p value ≤0.05

Table (2): Distribution and percentage of the file tip relation to the minor diameter or constriction among the two study groups

	Group I (n=30)	Group II (n=30)	P value
	n (%)		
Zero values	1 (3.3%)	8 (26.7%)	0.004*
Positive values	27 (90%)	16 (53.3%)	
Negative values	2 (6.7%)	6 (20%)	

*Statistically significant at p value ≤0.05

DISCUSSION

Use of EALs is common in clinical practice owing to their high accuracy in locating the AC and eliminating many of the shortcomings associated with radiographic measurements. The present study aims to test the accuracy of the AAR feature in an integrated motor and a regular EAL in preserving the WL under a microscopy without violation of the AC during root canal procedures.

The completion of instrumentation of the canals with an EAL attached to an integrated motor eliminates the need to stop for WL confirmation during preparation and restricts the instrumentation of the canal system (18, 19). Up to date only one study evaluated the precision of the AAR mode in MM-Control device (14), In other incorporated endodontic motors, other studies examined the accuracy of this mode and found controversial findings (4, 10, 12, 19, 20).

It is known that results obtained from experimental studies should not be generalized to a clinical situation; however, the use of in vitro models is beneficial in controlling the variables and counteracting some of the clinical limitations. In the present research, only mandibular molar teeth with specific anatomical criteria were recruited to allow a fair assessment of both the standard EAL and AAR mode in the integrated motor, and an alginate model was chosen to provide an adequate electro-conductive medium that allows repetitive measurements and reproduce the periapical region (21, 22). The AL was used in our work as a reference to compare WLs alterations throughout the preparation procedures since AL is the gold standard for assessment of electronic measurements as adopted by several studies (23, 24).

For the present study, multi-rooted molar teeth were selected, as they were considered more challenging for clinical practice than single- rooted teeth, which were used in most of the previous studies. In multi-canal teeth, the irrigation solution may "short circuit" the EAL reading due to the electrically conducting nature of the irrigant and thus influence the reading of the EAL. This may explain why some studies found that an accurate reading was easily obtained in dry canals as opposed to canals flooded with irrigant .(25)

In line with previous research by Wrbas et al. 2007 and Barsness et al. 2015 the WL was adjusted 0.5 mm short of the AF in the current analysis (26, 27), where a range of 0.0 to 1mm from the AF is acceptable for endodontic procedures (10, 13, 28). This distance is not the exact location of the AC, but it limits the preparation within the root canal walls. (10, 29-31).

The apical limit was monitored in both groups during the entire preparation; by using the AAR feature of the MM-Control system in Group I, which enabled the file to be immediately reversed or stopped after hitting the selected mark (0.5); and by using the Root ZX II to track the progress of the hand k-file to the apex mark and then withdraw it to the desired middle green line " 0.5 " for 5 seconds (14, 15, 32).

In the present study, AC violation was measured by two methods: first, by calculating the variations between the AL and the post-preparation WL (AL2) in mm, resulting in resulting in negative values showing the likelihood of AC violation, and second, by visual inspection under a microscopy for more visual inspection and confirmation Group I reported substantially higher deviations from the AL of -0.52± 0.38 mm relative to -0.10± 0.46 mm in Group II in our current work (p<0.0001*), meaning that the apical limit of most Group I preparations can over-extend the AC.

In the current literature; ± 0.5mm from the AL is considered tolerable (14, 33). However, in our current work and in real clinical practice ≥0.5 mm overextension beyond the AL would lead to over-instrumentation in most instances.

Under the stereomicroscope, the frequency of negative positions was very low in the MM-Control community for both

Root ZX II (20%) and AAR modes (6.7%). Knowing that shaping processes could adjust the WL in general, the apical limit should therefore be deemed sufficient at distances between 0 mm and 1 mm short of the AF (10, 14, 15).

Positive file tip position was highly detected in the AAR mode group (90%) in comparison to the standard electronic measurement by Root ZX II (53.3%). We attributed this limitation in the MM-control group to the fluctuating flashes of the light-emitting diodes between 0.5 and APEX, requiring more time to obtain a consistent reading. In addition, this oscillation in its turn may disrupt the operator's monitoring of the apical advancement (13). The reasons for such MM-Control oscillations were not clear, but could be related to its poorer file rotation output when activating its integrated apex locator (AAR function). In comparison to Cruz et al, in 2017, who tested efficacy of manual mode EAL versus the AAR modes of the MM-Control endodontic motor and noticed that the AAR mode provided a reasonable apical preparation limit, whereas using only the MM-Control EAL feature resulted in slightly more cases of overextended measurements (13).

While Root ZX accuracy is claimed to remain accurate regardless of the file size when the canal apical diameter is less than 0.6 mm (34, 35); yet it is unclear if the file diameter could hinder the performance of MM-Control EAL, as observed with other different EAL (4, 35). Some research evaluated that using EALs with rotary files during shaping was not as successful as using the EAL with manual files (31, 36). It has been indicated that the accuracy of AAR could be impaired by the enhanced impedance of the root canals (because of the occlusion of tubules by the smear layer/gutta-percha) or that it takes a diminutive time to process the file position inside the root canal for electronic measurement (32, 38, 39).

Sustaining WL 0.5 mm from the major foramen seems to be simplified by the use of modern EALs (40) yet, various motors on the market have features and drawbacks of their own. Manufacturers should also share more details about their particular features and modes, and further research are needed to explain the optimal protocol for the various devices available.

A weakness of our study may be the in vitro study design. The clinical situation can alter the function of apex locators because of patient related factors like tooth morphology, metallic restorations, bleeding, suppuration of the root canal or even the irrigant used. Moreover, the use of different types of roots may raise some concerns if the experimental conditions for the different test groups were homogenous enough. But it should be considered that under clinical conditions there is no possibility to assess the exact type of the measured AC. (41)

CONCLUSION

Electronic measurement with Root ZX II gave satisfactory results, while setting the MM-Control endodontic motor to AAR mode and at the 0.5 mark could not keep preparation of the root canal within acceptable apical limits. Though integrated motors represent a promising technology, however more studies should be performed to indorse the ideal mode for each device.

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