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Effect Of Battery Charge Level On The Performance Of An Apex Locator

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Abstract

Introduction: Apex locators are used to improve the accuracy of root canal length measurements. Most apex locators operate with batteries but it is not known whether the battery charge level influences the accuracy of the device. The aim of this study was to determine whether different battery charge levels (full, half, and flash modes) would influence the accuracy of working length determination with an apex locator.

Methods: Fifty sound single-rooted extracted human teeth were used. After determining the root canal length with a file and a microscope, the canals were measured with three separate Dentaport (DP) ZX apex locators while one of the battery charge level signs (full, half, and flash modes) was showing on the monitor of the device during measurement. Data were analyzed by repeated ANOVA model.

Results: The reliability of the measurements during exposure with three different DP ZX apex locators showed that full and half battery charge levels had consistent measurements. However, there was a significant difference in consistency of measurements when the battery charge sign showed the flashing mode (P=0.021). When determining the working length (WL) within ranges of either ±0.5 mm and ± 1 mm, there was no significant difference amongst the various battery charge levels from the WL (P>0.05). However, only the measured means by apex locators with full charge did not show significant difference with the measured length obtained by microscopy (p=0.44).

Conclusion: This study demonstrated that the reliability of the DP ZX, and the measured length may be influenced when the battery charge level of the device is flashing.

Key words: Endodontics, Dentin, Economic evaluation, Electronic dental records.

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Introduction

The main object of root canal treatment is to clean all pathogens and potential periapical tissue irritants from the root canal space [1]. Hence, it is very important to accurately determine the working length and then to keep all endodontic instruments, irrigants, medicaments, and root canal filling materials inside the canal space during the endodontic treatment [2]. It has been well demonstrated that even when all stages of the root canal treatment are confined to the root canal space some debris may still extrude through the apical foramen[3]. Several methods have been described for determining the root canal working length and these include tactile sense, radiographic images and techniques, and using electronic apex locators (EAL) [4, 5, 6, 7]. Research studies about apex locators have shown that they are reliable devices and they can simplify working length determination as well as decreasing the number of radiographic exposures during root canal treatment [8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25]. EALs have been established as an

adjunct device during root canal treatment in many dental and endodontic offices [26].

There are various brands of apex locators available. The Dentaport (DP) ZX (J. Morita Corporation, Kyoto, Japan) is a third-generation device that has been shown to be a reliable tool for working length determination during root canal treatment [4]. This device, like most apex locators, is powered by batteries[27]. For convenience, the manufacturer has included an indicator on the monitor of the device to show the level of charge of the batteries. There are three levels of charge: full, half, and flashing modes. Based on the manufacturer's brochure [27], the batteries should be replaced with new ones whenever the sign on the monitor starts to flash. However, sometimes the practitioner or other office staff may not notice the transition of the battery sign from the half to the flash mode and this might affect working length determination. To date, the effect of battery charge level on working length determination of apex locators has not been reported. Hence, the aim of this study was to investigate the effect of various battery charge levels on the accuracy of working length determination with the DP ZX.

Materials and Methods

file tip reached the apical foramen. The silicon rubber stopper was positioned at the level Fifty single-rooted freshly extracted human teeth were used. All teeth were examined under a dental operating microscope (Carl Zeiss Surgical GmbH, Oberkochen, Germany) and any teeth with cracks, apical or lateral resorption, root tip fracture, a curved root, or open apical foramina were excluded.

The teeth were decoronated at the cemento-enamel junction in order to have standard access and stable reference points for working length determination. The actual working length (AWL) of each root was determined by inserting a size No. 10 K-file (Mani, Tochigi, Japan) into the root canal and observing it under the microscope at x25 magnification to determine when the of the reference point and the file was removed from the canal and then measured. The working length was set at 0.5 mm less than the length observed.

Each root was then fixed into a plastic bottle. The Dentaport ZX lip clip was also fixed in the bottle so that a complete electronic circuit was established. Each bottle was filled with 0.9% normal saline as a conducting medium. Before starting the electronic root canal measurements, the cervical part of the root canals was enlarged with Gates Glidden No. 2 and 3 burs (Mani, Tochigi, Japan).

All measurements with the DP ZX apex locators were performed in a place free of any electronic device that generated radio waves. The irrigant used was 2.5% sodium hypochlorite. a No.10 K-file was inserted into the root canal to determine the working length with the DP ZX apex locator. The root canal length was then determined by an experienced operator with three new DP ZX devices (serial numbers: ZJ3290, ZI3073, ZJ 3288) with battery levels showing as full, half and alarm modes. Therefore, for each tooth, nine measurements were obtained. The batteries used for the three conditions were AA size dry cells, all of the similar brand (Hitachi Maxell, Ltd, Osaka, Japan).

The DP ZX was used in accordance with the manufacturer's instructions. The electrode was connected to a No. 10 K-type file which was then inserted into the root canal to reach just beyond the major foramen as indicated by the flashing red sign of APEX bar on the monitor of the DP ZX. The instrument was then slowly withdrawn until the monitor showed a flashing bar between ''APEX'' and 1 to indicate a 0.5 reading. Measurements were recorded when the instrument remained stable for at least 5 seconds [23].

In order to analyze the data obtained from three apex locators, two different methods were used. One method compared the working length obtained by direct visual observation (the "gold standard") with the mean of the lengths determined by each apex locator. The second method used the following formula to determine the working length within ranges of either ±0.5 mm and ± 1 mm.

$$WL \pm 0.5mm = \frac{\text{AAD} \times 3 + \text{TAD} \times 2 + \text{OAD} \times 1}{TNM}$$

$$WL \pm 1mm = \frac{\text{AAD} \times 3 + \text{TAD} \times 2 + \text{OAD} \times 1}{TNM}$$

where WL: working length; AAD: All three apex locators showed the same distance to (±0.05, ±1mm) working length; TAD: Two apex locators showed the same distance to (±0.05, ±1mm) working length; and OAD: One apex locators showed the same distance to (±0.05, ±1mm) working length; TNM: Total number of measurements.

After calculating the measured lengths, the reliability of three measurements was tested using the repeated ANOVA model, while the consistency of measurements with the WL was tested using ANOVA models. A measurement was considered satisfactory if its difference with the WL was within ±0.05mm from the WL. In all analyses, $P<0.05$ was considered as significant.

Results

Table 1 shows the data obtained from various apex locators at different battery charge levels.

The results show that both the full and half battery charge levels had consistent working length readings with no significant difference between the three apex locators ($P>0.05$). However, when the indicator was flashing to show poor battery charge, there was a significant difference between the devices ($P=0.021$).

When the mean of the measurements with various modes of battery charge level were compared to the working length obtained by direct observation under a microscope, there was no significant difference between the full battery charge level and the microscopic measurement ($P=0.44$). However, the accuracies of the measured length in half battery and flashing modes were significantly lower than the working length obtained by direct observation under a microscope ($P=0.026$ and $P=0.002$, respectively).

No significant differences were found when the working length within ±0.5 and ±1mm were compared with the measurements obtained with different battery charge levels (P>0.05).

Table 2 shows the consistency of the DP ZX at different charge levels of full, half and flashing modes.

Discussion

The results of this study show a significant difference in the consistency among three separate DP ZX apex locators when the battery charge level sign of the device is flashing (P=0.021). In addition, there was a significant difference in the accuracy of measurements when the means of measurements with half and flashing battery charge level modes were evaluated (P<0.05).

The results of the present study show a significant difference in consistency between the three apex locators when the battery charge mode was flashing. Hence it can be assumed that when the battery charge level is low, the DP ZX measurement is not reliable. The manufacturer's manual for the DP ZX recommends replacement of the batteries when the device's power indicator is flashing [27].

The results of this study have also shown that the accuracy of the measurements is higher with a full battery charge level compared with both the half battery charge and when the flash mode is showing on the same device (P=0.026 and P=0.002, respectively) when the mean of measurements during various battery level modes were evaluated. However, when the working length at ±0.5 mm was evaluated no significant difference was found amongst the various battery charge levels. Since previous investigations [18, 28, 29] have reported that the accuracy of working length is acceptable within an error range of ±0.5 mm from the WL, the same criteria was used in the present study.

Each DP ZX device requires three AA size dry cell household batteries to operate [27]. Two forms of these batteries are available on the market - primary cells that cannot be re-used and secondary cells that can be recharged [30]. Primary batteries are electrochemical devices with the ability to convert chemical energy to electrical energy to produce power for electronic

Table 1- Working lengths obtained by direct measurement using a microscope (gold standard) and during various battery charge level modes.

	Mean	SD	Mean Error	Sd Error	Acceptable Percentage At 0.5mm (%)	Acceptable Percentage At 1mm (%)
Microscopic measurement	**14.65**	**2.86**	**0**	**0**	**100**	**100**
Apex locator 1 (Full battery level)	14.78	2.91	0.13	0.50	88	98
Apex locator 2 (Full battery level)	14.80	2.86	0.15	0.46	92	98
Apex locator 3 (Full battery level)	14.62	3.41	-0.03	1.92	90	98
Apex locator 1 (Half battery level)	14.85	2.85	0.20	0.42	90	100
Apex locator 2 (Half battery level)	14.83	2.83	0.18	0.44	92	98
Apex locator 3 (Half battery level)	14.82	2.84	0.17	0.47	90	98
Apex locator 1 (Flash battery level)	14.85	2.86	0.20	0.39	92	100
Apex locator 2 (Flash battery level)	14.73	2.87	0.08	0.43	92	100
Apex locator 3 (Flash battery level)	14.74	2.86	0.09	0.45	92	100
Apex locators (Full battery level)	14.73	2.938	0.08	0.76	88	96
Apex locators (Half battery level)	14.83	2.835	0.18	0.40	88	98
Apex locators (Flash battery level)	14.77	2.858	0.92	0.21	90	100

Table 2 - The consistency between the actual working lengths and the measurements during exposure with different working electronic devices using the Dentaport ZX apex locator.

Mode	Consistency of Devices	
	±0.5 mm error	±1 mm error
Full battery	**0.9**	**0.98**
Half battery	**0.91**	**0.99**
Flash	**0.92**	**1**

devices. One may argue that rechargeable batteries can be used for preventing environment contamination; however, the manual of the DP ZX warns that the battery used for the device should not be rechargeable as they may have a negative influence on the accuracy of measurements [27]. Hence, in the present study, alkaline batteries (primary cells) were used.

It is well known that batteries consist of heavy metals such as mercury, lead, cadmium, and nickel [31]. Hence, all used batteries should be discarded carefully to prevent environmental contamination. The manufacturer of the DP ZX[27] recommends alkaline batteries that can be discarded in household garbage in most states in the USA. The USA federal government has classified used alkaline batteries as nonhazardous waste although some states (such as California) have special rules for discarding these types of batteries[31]. Based on the present study showing that the accuracy of the DP ZX at all battery charge levels showed no significant difference in performance for determining the working length within a range of ±0.5mm, the batteries can be changed without consideration of the power indicator of the device. However, because a significant difference in consistency of the apex locators was evident at the flashing mode level, the batteries should be changed as soon as they reach this level of charge. The manufacturer's manual also recommends changing batteries only when the battery sign of the DP ZX is flashing[27].

In the manufacturer's manual, it states that the device is reliable for measuring root canals for six years after being manufactured[27]. Therefore, in the present study, three devices that were less than 1 year old were used.

The DP ZX was used in this study because several previous investigations have confirmed that this device is very accurate for determining working length [16, 17, 19, 20].

A previous investigation reported that pre-flaring of the cervical part of the root canal improves the measuring ability of the DP ZX [30]and for that reason Gates Glidden drills No. 2 and 3 were used to pre-flare the cervical part of the root canals before measuring the root canal lengths with the DP ZX.

In the present study three DP ZX devices were used to evaluate whether there were any differences between different devices of the same brand as this could influence the consistency of the measurements. The results showed that when the power indicator is flashing, there was a significant difference in the consistency of the devices. Hence, it appears desirable to change the batteries before they reach this low level of charge in order to have consistent measurements.

In conclusion, when the battery charge sign of the DP ZX shows full charge level, the device performs best. However, as the battery charge level transitions from the full and the half charge level to the flashing mode the reliability of working length determination may be significantly influenced.

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