In Vitro Evaluation of the Accuracy of Three Electronic Apex Locators

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The accuracy of three electronic apex locators (EALs) (Justy II, Root ZX, and Neosono Ultima EZ) is evaluated, together with the concordance of the measurements obtained by two different operators. Twenty single-root human teeth were used, sectioning the crown to gain access to the root canal. A first operator (A) determined the reference (or control) length (corresponding to the actual length) for each tooth, after which all teeth were measured individually and independently by the other two operators (B and C). The results obtained with each EAL and by each operator were in turn compared with the corresponding control length. The statistical analysis of the results showed EAL reliability in detecting the apex to vary from 80% to 85% and 85% to 90% (depending on the operator) for the Justy II and Neosono systems, respectively, whereas reliability was found to be 85% for the Root ZX device. These results, combined with a high interobserver concordance, suggest electronic root canal measurement to be an objective and acceptably reproducible technique.

Correct working length determination is the main factor leading to success in root canal treatments. Recent studies (1) have shown the histologic results after endodontic treatment to be superior when instrumentation and obturation are limited to the apical narrowing.

However, of the methods currently available for root canal measurement, neither the manual nor the radiologic approaches allow precise localization of apical narrowing. The manual technique obviously depends on the sensitivity of the operator, whereas in the radiologic approach, the calculation of the working length is made with respect to the position of the radiographic apex—which not only does not coincide with apical narrowing or even with the apical foramen (2), but also depends on a series of factors: tooth inclination, film position, length of the beam cone, vertical and horizontal cone angulation, and so forth. Nevertheless, the main inconvenience is that both approaches are entirely subjective and therefore scantly reproducible.

Since the pivotal demonstration by Sunada (3) in 1962 that the electrical resistance between the periodontal ligament and the oral mucosa is a measurable constant, different generations of electronic devices have been developed to measure root canal length. The first-generation (resistance) locators detected the point where the file displaces from within the canal to the periodontal ligament, whereas the second-generation devices were based on the impedance principle. The reliability of these systems was approximately 55% to 75%, although their main inconvenience was the fact that the presence of pus, pulp remains, or irrigating solutions within the canal led to erroneous readings.

According to the instructions of the manufacturers, the third-generation dual-frequency and more modern multiple-frequency locators are able to locate the point of maximum root canal narrowing. In this context, a number of studies have been performed in recent years (4–9) to determine the accuracy of these systems—with sometimes discordant results. The purpose of the present study was (a) to conduct an in vitro evaluation of the accuracy of three electronic apex locators (EALs): the Justy II (Yoshida, Japan), Root ZX (Morita Corp., Tustin, CA), and Neosono Ultima EZ systems (Amadent, Cherry Hill, NJ); and (b) to quantify the concordance of the measurements obtained by two different operators.

MATERIAL AND METHODS

The study involved 20 single-root human teeth without caries that had been extracted for periodontal reasons. The teeth were kept in 0.2% chlorhexidine solution until use, with careful examination to discard the existence of root fractures and to confirm that apex formation was complete in all cases.

The crown was sectioned with a diamond disc to allow access to the root canal and establish a level surface to serve as a stable and unequivocal reference for all measurements. The canal was irrigated with 5 ml of 2.5% sodium hypochlorite, after which canal permeability was evaluated using a number 10 K-Flexofile (Maillefer, Ballaigues, Switzerland) to discard any teeth with root canal obstruction. No such obstruction was observed; therefore, all teeth were included in the study and randomly numbered from 1 to 20.

Before electronic measurement of root canal length, a first operator (A) inserted a number 15 K-Flexofile into each canal until the tip became visible through the foramen. The file was then
withdrawn until a magnifying glass (×2.5) showed its tip to lie tangential to the apical foramen. The silicone stop was adjusted to the level chosen as reference for root canal measurement, and a millimeter ruler was used to measure the distance from the silicone stop to the file tip. This measurement was recorded as the reference (or control) length (corresponding to the actual length).

Cylindrical methacrylate molds were used for electronic measurement of the working length. An adequate amount of alginate was condensed within the molds, and upon setting, the corresponding tooth was embedded within the alginate, leaving approximately 5 mm of the root surface exposed. The tooth was kept in that position until the alginate had set completely. All measurements were made in an interval of 2 h, with the alginate kept sufficiently humid for this time. During electronic measurement, the labial clip of the corresponding locator was inserted into the alginate, stabilizing it with transparent adhesive tape.

The following EALs were used: Justy II, Root ZX, and Neosono Ultima EZ. Each apparatus was calibrated according to the manufacturer’s instructions. For electronic measurement, we used standard number 15 K-Flexofiles, with previous canal irrigation using 2.5% sodium hypochlorite instilled with an endodontic syringe (Monoject; Sherwood Medical, St. Louis, MO); cotton tips were used to dry the tooth surface and eliminate the excess irrigating solution. The file was then inserted within the root canal to very slightly beyond the Apex signal emitted by the corresponding EAL. The file was then withdrawn to the limit indicated by the locator as corresponding to the apex. The silicone stop was adjusted, and the distance from the latter to the file tip was measured with the millimeter ruler. All teeth were measured individually and independently by two operators (B and C) — the former lacking experience in the use of EALs.

The results obtained (in millimeters) for each EAL and for each operator were recorded in independent tables. In each case, we subtracted the corresponding reference measurement (i.e. actual length) from the electronically determined distance, recording the result in tabular form as positive (for measurements exceeding the apical foramen), negative (measurements short of the apical foramen), or correct (measurement coinciding with the actual length).

Percentages were determined, and the Chi-square test and values: the estimated working length coincides with the actual length; — values: the estimated working length is short of the actual length; + values: the estimated working length exceeds the actual length.

**RESULTS**

The cases and corresponding percentage values in which electronic canal measurement proved correct, negative, or positive are presented in Table 1. The results show the percentage of measurements surpassing the apical foramen (i.e. positive readings) to be 5% (maximum) for all three locators. In the concrete case of operator C with the Neosono device, none of the measurements exceeded the apical foramen.

No statistically significant differences were observed among the three EALs or between the measurements made by the two operators (B and C).

**DISCUSSION**

The use of electronic devices to determine working length has gained increasing popularity in recent years, particularly after the introduction of the latest generation of apex locators that not only allow measurements in the presence of humidity but also actually require the presence of solutions within the root canal to function correctly.

The main purpose of this study was to evaluate the accuracy of three of the EALs most widely used in clinical practice. An in vitro study was designed in view of the difficulties posed by clinical studies for comparing electronic measurements with a control. Some authors (10, 11) have used radiologic root canal measurements as control or reference in the clinical setting; we have already mentioned the limitations posed by this approach. The usual methodology in in vitro studies (12–15) is to use the distance from the reference plane to the apical foramen as the actual length (control). The inconvenience in this case in application to the clinical setting is the need to extract the pieces once root canal measurement has been performed (16).

Based on the results obtained in the present study, the EALs used are quite reliable, in concordance with the observations of other authors (15, 17). If estimated working length = actual length ± 0.5 mm is considered to be clinically acceptable, then the measurements made with the Neosono device are acceptable in 100% of cases, whereas with the other two systems (Root ZX and Justy II), only 5% of the measurements made exceed the apical foramen (Table 1). The use of these devices therefore reduces the risk of instrumentation beyond the apical foramen.

In contrast, Stein and Corcoran (18) have reported the risk of accidental overinstrumentation when performing only radiologic working length measurements. These authors attribute this situation to the fact that the file inserted to determine the working length radiologically appears 0.7 mm short of its actual or true position. More recent studies (12) confirm these results, particularly in relation to posterior teeth, and conclude that in 51% of premolars and 22% of molars, working lengths radiologically located 0 mm to 2 mm above the radiologic apex give rise to instrumentation beyond the apical foramen. These observations may be a result of the eccentric position of the apical foramen with respect to the apicocentral point (which appears in 87% and 98% of lower and upper premolars, respectively (19, 20)), or of lingual or vestibular foramen deviations, which would lead to erroneous working length measurements.

<table>
<thead>
<tr>
<th>EAL</th>
<th>Justy II</th>
<th>Root ZX</th>
<th>Neosono</th>
</tr>
</thead>
<tbody>
<tr>
<td>−1 mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>−0.5 mm</td>
<td>2–3 (10%–15%)</td>
<td>2 (10%)</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>Correct</td>
<td>16–17 (80%–85%)</td>
<td>17 (85%)</td>
<td>17–18 (85%–90%)</td>
</tr>
<tr>
<td>+0.5 mm</td>
<td>—</td>
<td>0–1 (0%–5%)</td>
<td>0–1 (0%–5%)</td>
</tr>
<tr>
<td>+1 mm</td>
<td>1 (5%)</td>
<td>0–1 (0%–5%)</td>
<td>—</td>
</tr>
<tr>
<td>+1 mm</td>
<td>—</td>
<td>—</td>
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</tbody>
</table>

* Correct: the estimated working length coincides with the actual length; — values: the estimated working length is short of the actual length; + values: the estimated working length exceeds the actual length.
These data are interesting, because professionals who combine the radiologic and electronic techniques for performing root canal measurements sometimes find that the results do not coincide. In our opinion, in the event of discrepancy between the two measurement approaches, preference should go to the electronically determined value, provided that possible root canal perforation or the existence of device malfunction can be ruled out.

As to the relative accuracy of the different apical locators, the frequency with which they were able to detect the apical foramen in our study was 80% to 85% (depending on the operator) for the Justy II system, 85% for the Root ZX device, and 85% to 90% (again depending on the operator) for the Neosono EAL, with no statistically significant differences recorded among the three devices.

The second objective of the present study was to determine the reproducibility of the measurements in the hands of different operators—a factor little evaluated in the literature to date. The results obtained point to important concordance in the measurements made by the two operators (Table 1): 95% for the Justy II and Root ZX systems, and 90% for the Neosono device. Thus, electronic root canal measurement can be regarded as both objective and quite reproducible. Moreover, because no significant differences between operators were observed, we concur with other authors (21) who consider that if the locators are used according to the instructions of the manufacturer, no previous experience with these devices is essential in order to obtain correct measurements. The important interobserver concordance observed in this study suggests that electronic root canal measurement is an objective and acceptably reproducible technique.

References