Evaluation of the Maintenance of the Apical Limit during Instrumentation with Hybrid Equipment in Rotary and Reciprocating Modes

Bruno Carvalho de Vasconcelos, DDS, MS, PhD,* Luciana Maria Arcanjo Frota, DDS,* Tamara de Abreu Souza, DDS,† Ricardo Affonso Bernardes, DDS, MS, PbD,‡ and Marco Antonio Hungaro Duarte, DDS, MS, PbD†

Abstract

Introduction: The objective of the present study was to evaluate ex vivo the maintenance of the apical limit during instrumentation with the Root ZX (J Morita, Tokyo, Japan) and VDW Gold (VDW GmbH, Munich, Germany) hybrid devices in rotary and reciprocating modes and determine the possible function variations of different preparation levels (0.0 mm and −1.0 mm). Methods: Seventy-two human uniradicular mandibular premolars, which had their coronal access performed and their apical foramen (AF) standardized (200 μm) were used. After their randomized division, the root canals were chemically mechanically prepared with #4 ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) and #40 Reciproc (VDW GmbH) instruments. At the end of the instrumentation, the last instrument was fixed, and 4.0 mm of the apical portion was worn, permitting the measurement of the distance between the instrument tips and the AF. Results: The determined precision values of 0.0 and −1.0 mm were 100% and 33.4% (Root), 100% and 41.6% (VDW Gold with rotary movement) and 100% and 33.3% (VDW Gold with reciprocating movement), respectively, with a margin of ±0.5 mm. No statistical differences were found with respect to the comparisons of every level of preparation. However, significant differences were found when comparing the groups with rotary function at the different levels, with a higher precision for the groups that reached the AF. Conclusions: It was concluded that both devices, independent of the function used, were more efficient in the maintenance of the apical limit when used until the AF; however, such reliability was compromised when −1.0 mm from the apical limit was established. (J Endod 2015;■:1–4)

Key Words

Electronic foramen locator, root canal preparation, working length determination

The success of endodontic root canal treatment is dependent on the correct determination of the instrumentation of the apical limit (1). Thus, electronic foramen locators (EFLs) have shown themselves as the more efficient tool in the correct determination of the real length of the teeth (2, 3). For this reason and because of the security provided by the nickel-titanium rotary instruments, hybrid equipment was developed associating the EFL with an electric motor for mechanical instrumentation (4–6).

The Root ZX II (J Morita, Tokyo, Japan) associates the mechanism of electric odontometrics used by the Root ZX but with an electric motor with rotary function. This equipment permits various standards of calibration of the functional parameters of the motor by the information provided by the EFL (4). Another hybrid device is the VDW Gold (VDW GmbH, Munich, Germany), which uses the mechanism of electric odontometrics provided by the EFL Raype 5 (VDW GmbH) associated with an electric motor that permits the rotary and reciprocating movements (6–8).

These devices provide simple monitoring of the position of the instruments in the interior of the root canals until the interference of the action, torque, speed, and automatic auto-reverse parameters (AAR) (4–6). Thus, it can be considered that when applying all of these functions, the clinician will be directing the device for the maintenance of the apical limit during instrumentation.

Yet, it should be considered that the high precision values attributed to these EFLs are partly provided by the tolerance margins and do not represent exact measures (4, 5, 9–11). Such a fact already represents an important alert for clinicians considering that the apical limit of the instrumentation (ie, the working length [WL]) in the majority of cases is established 1.0 mm short of the apical foramen (AF) (1). However, it becomes important to understand what is the real precision of this device because once recognized, the EFLs, in general, lose a lot of precision when their penetration is limited in positions short of the AF (10, 12, 13).

To date, no study has evaluated the precision of the AAR functions of these hybrid devices at the AF or at shorter lengths. Thus, the aim of the present study was to evaluate the precision control of the apical limit of instrumentation established by the Root ZX II device with rotary movement and the VDW Gold in both rotary and reciprocating movements and to evaluate the possible variations in function of the different WLS (0.0 mm and −1.0 mm).

From the *School of Dentistry of Sobral, Federal University of Ceará, Campus Sobral, Sobral, Ceará, Brazil; †Brazilian Dental Association, Taguatinga, Federal District, Brazil; and ‡Department of Dentistry, Endodontics and Dental Material, Bauru Dental School, University of São Paulo, Bauru, São Paulo, Brazil. Address requests for reprints to Dr Bruno Carvalho de Vasconcelos, School of Dentistry of Sobral, Federal University of Ceará, Sobral, CEP 62010-590, Sobral, CE, Brazil. E-mail address: bcv@ufc.br

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Materials and Methods

After ethics approval (protocol #147.566/2012), 72 extracted human uniradicular mandibular premolars were obtained for the study. The coronal access were performed with #1013 and #3081 diamond points (KG Sorensen, Cotia, Brazil). The teeth then had their radicular anatomy and foraminial patency confirmed so that the specimens with 2 canals, extensive caries, without foraminial patency, or AFs greater than 200 μm were substituted. AF standardization was performed through 25 × magnification support (Alliance, Campinas, Brazil) until the tips of the #25 K-type instruments (Dentsply Maillefer, Ballaigues, Switzerland) were visible at its opening. Afterwards, the teeth were randomly divided according to the experimental groups (appliance/movements) and their subgroups (WLs) (n = 12).

Independent of the group, all teeth were fixed in an apparatus that permitted freedom of hand movement for the only operator exclusively trained in the use of the devices and mechanical instruments. Groupings of 6 teeth at a time had their apical portion immersed in recently prepared alginate (Jeltrate II; Dentsply, Petropolis, Brazil). Next, the chemical-mechanical preparation was initiated using 2.5% sodium hypochlorite solution (Biodinâmica, Ibirapuera, Brazil) as an irrigating solution after each instrument use. The use of the devices was performed as described later.

Root ZX II

The device had its AAR adjusted to the WL corresponding to each subgroup. ProTaper Universal instruments (Dentsply Maillefer) were used with slight penetration and regression movements as recommended by the manufacturer until the #F4 instrument reached the point indicated by the AAR.

VDW Gold with Rotatory Movement

After configured for the use of ProTaper Universal instruments, the device had the apical penetration limit (ie, the WL) established for the reference corresponding to each subgroup. The instruments were used in a manner similar to that developed in the group described earlier until the #F4 instrument reached the specified stop point.

VDW Gold with Reciprocating Movement

After the device was configured for the reciprocating function (“Reciproc all”), it had the apical extension limitation established for the WL corresponding to each subgroup. The Reciproc #R40 instruments (VDW 6gml) were used with slight pecking movements as recommended by the manufacturer until it reached the point determined by the automatic stop. At each sequence of 3 pecks, the instrument was removed and cleaned with gauze, and the canal was irrigated.

For the Root ZX II, the AAR function had its automatic stop calibration indicator bar positioned at 0.0 mm and −1.0 mm, respectively, for each correspondent WL. With regard to the groups that used the VDW Gold, independent of the kinematics, the references used were the activation of the orange light-emitting diode corresponding to 0.0 mm with AAR function activation and the first green light-emitting diode corresponding to −1.0 mm or the opening of the apical region without the AAR function activated because this equipment does not allow for the calibration of this limit (7).

Regardless of the group that took part, the teeth had the last instrument decoupled from the motor and fixed to the tooth by means of cyanoacrylate adhesive (Super Bonder; Loctite, São Paulo, Brazil). They then had their apical portions worn buccolingually to enable the realization of digital photographs with a clinical microscope at 25 ×. These images were analyzed with Image software (National Institutes of Health, Bethesda, MD) by the error offered by the EFs; negative and positive values were conferred for readings within and beyond the AF, respectively. Absolute values were considered for statistical analyses performed by the Kruskal-Wallis and Dunn test for multiple comparisons. The chi-square test was used to analyze possible differences in the percentage of acceptable measures offered by the devices, all using a significance level of 5.0%.

Results

Table 1 presents the mean and standard deviation of the absolute values of error, medians, and margins found for the groups. No significant differences were found when considering the comparisons within each level of preparation (0.0 and −1.0 mm) (P > .05). However, when comparing the values offered by each of the combinations of device/kinematics at different levels, significant differences were found in the groups that developed rotary motion, with an advantage in the subgroup that reached the AF (P < .05).

Tables 2 and 3 show the distributions of the positions of the tips of the instruments regarding the determinations of 0.0 and −1.0 mm, respectively; moreover, they exhibit the frequency with which accurate readings and readings beyond the AF were found. Considering the percentages of accurate and acceptable preparations (±0.5 mm), the chi-square test found no significant differences between groups when considering the percentage of accuracy within each position. However, when considering the comparison between the percentage offered by each device in different positions, significant differences were found in all cases (χ² = 36.83, P < .001).

Discussion

The present study evaluated the accuracy control of the apical limit provided by the Root ZX II and VDW Gold (rotatory and reciprocal

### TABLE 1. Distance (mm) from Device Measurements to 0.0 and −1.0

<table>
<thead>
<tr>
<th>Device</th>
<th>Margin 0.0</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root ZX II</td>
<td>0.16</td>
<td>0.11</td>
<td>0.19</td>
</tr>
<tr>
<td>VDW Gold rotating</td>
<td>0.17</td>
<td>0.16</td>
<td>0.19</td>
</tr>
<tr>
<td>VDW Gold reciprocating</td>
<td>0.28</td>
<td>0.21</td>
<td>0.38</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Margin −1.0</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root ZX II</td>
<td>0.65</td>
<td>1.00</td>
</tr>
<tr>
<td>VDW Gold rotating</td>
<td>0.66</td>
<td>1.45</td>
</tr>
<tr>
<td>VDW Gold reciprocating</td>
<td>0.78</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Max. maximum; Min. minimum.

Different superscript uppercase letters indicate statistically significant differences between different positions in the same device according to the Dunn test (P < .05).

Different superscript lowercase letters indicate statistically significant differences between different devices at the same position according to the Dunn test (P < .05).

*Mean error and Median calculated in terms of absolute values of the determinations.
rotational modes) hybrid equipment. There were no similar studies in the literature evaluating the accuracy of the AAR Root ZX II system when brought to the AF or the VDW Gold on its rotary function in both WLSs and in the reciprocal rotary function short of the AF.

The results show that the devices were also able to control the apical limit of the instrumentation independent of the kinematics and WL applied. The devices proved extremely reliable when the WL was established to the foraminale level; however, considering the preparations performed 1.0 mm below the AF, they offered inferior results.

Regarding the kinematics, the data showed that, regardless of the WL, the reciprocal rotational movement offered inferior results but without statistical significance. Considering the association of the device/kinematics, the Root ZX II and VDW Gold equipment in rotational movement showed significant differences between the 2 tested WLSs, contrasting the VDW Gold in reciprocal rotational movement.

While acknowledging that the in vivo condition would be ideal for the extrapolation of the present results to clinical practice, evidence suggests that this ex vivo model can accurately reproduce the clinical results, being extremely valuable for providing greater control of most of the variables (14).

Therefore, the results found for the Root ZX II system show great accuracy when using its AAR system because it was calibrated for interruption of the preparation only when it reached the AF. No results were found in the literature for the use of the Root ZX II in its AAR function calibrated for the AF; however, studies executed at –0.5 mm found precision values lower than those found here (5, 15). When analyzing the instrumentations performed to 1.0 mm from the AF, the results offered by the device were significantly lower as described by studies using the isolated EFL or in its AAR setting (5, 10, 12, 13, 15). Considering the methodologic differences, mainly concerning the reference length used, a direct comparison of the values found here with those available in the literature is difficult. However, regardless of this aspect, precision values lower than those found for the levels closest to the AF is a common finding among studies (5, 15).

The VDW Gold used in its rotational function was the device that offered the best error results in the determination of the AF. Although no similar study was found in the literature, such findings cannot be directly compared; however, they express the same behavior found in previous studies comparing it with the Root ZX EFL using methodologies different from those used here (16, 17). No studies were found in the literature evaluating its accuracy in positions below the AF; however, in the same preparation, it remained statistically similar to the others while still offering the best results. Nevertheless, similar to the Root ZX II, it had its error and accuracy significantly influenced by the imposed limit of penetration.

Regarding the employment of the VDW Gold with reciprocation kinematics, although not significant, it offered the worst results in both levels of preparation, which corroborates the results of Wigler et al (6). To date, no study was found evaluating this device with reciprocating function in preparations made with the WL defined short of the AF. In any case, the performance was reproduced in the same pattern for the rotational movement, providing slightly higher error values and slightly lower accuracy.

The high precision in the preparation performed by the devices for the AF may be a consequence of the positive influence of the foraminale standardization (250 μm) and the prior completion of the cervical preparation in the function of the sequence of instrumentation. Such procedures may have favored the interpretation of resistive and capacitive phenomena in the moment of dynamic odontometrics, as shown in studies that observe the performance of EFLs in conditions in which the determinations were performed after the cervical preparation and with adjusted instruments (18–21). Even the data obtained in the present study, again regardless of the device, confirm that limiting the penetration negatively influences the accuracy for hybrid devices. Observing the functioning mechanism of electronic devices, such findings may be justified by the fact that by distancing itself from the AF, the resistive component’s interpretation is impaired (10, 12, 13, 18).

In this sense, it is relevant to define the best way to use such devices; however, the definition of these parameters is initially embraced

### Table 2. File Tip Position Relative to the Apical Foramen for Measurements Performed to 0.0

<table>
<thead>
<tr>
<th>Distance from apical foramen (mm)</th>
<th>Root ZX II</th>
<th>VDW Gold rotating</th>
<th>VDW Gold reciprocating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>&lt;–0.51*</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>–0.5 to –0.01*</td>
<td>5</td>
<td>41.7</td>
<td>4</td>
</tr>
<tr>
<td>0.00</td>
<td>3</td>
<td>25.0</td>
<td>5</td>
</tr>
<tr>
<td>0.01–0.5</td>
<td>4</td>
<td>33.3</td>
<td>3</td>
</tr>
<tr>
<td>&gt;0.51</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Negative value indicates file position short (or coronal) to the apical foramen.

### Table 3. File Tip Position during Measurements Performed Short of the Apical Foramen (–1.0 mm)

<table>
<thead>
<tr>
<th>Distance from apical foramen (mm)</th>
<th>Root ZX II</th>
<th>VDW Gold rotating</th>
<th>VDW Gold reciprocating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>&lt;–2.01*</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>–2.0 to –1.51*</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>–1.5 to –1.01*</td>
<td>2</td>
<td>16.7</td>
<td>4</td>
</tr>
<tr>
<td>–1.00*</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>–0.99 to –0.50*</td>
<td>2</td>
<td>16.7</td>
<td>1</td>
</tr>
<tr>
<td>–0.49 to 0.0*</td>
<td>6</td>
<td>50.0</td>
<td>3</td>
</tr>
<tr>
<td>&gt;0.01</td>
<td>2</td>
<td>16.7</td>
<td>4</td>
</tr>
</tbody>
</table>

*Negative value indicates file position short (or coronal) to the –1.0-mm position.
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by the definition of the apical limit in which we intend to conduct the chemical mechanical preparation. Maintaining the performance up to the limit of the AF as an objective, the use of the devices in their AAR functions has great accuracy, enabling their use clinically. However, when the desired apical limit for the preparation is limited to positions below the AF, it becomes a risk to delegate the automatic functions or control such extensions. In such situations, the use of EFLs alone is suggested for the purpose of defining the actual length of the canal to be treated, enabling it to be used even in the present devices. Only then, armed with the necessary information needed for the determination of the WL, can it be used as a constant monitoring tool during root canal preparation procedures.

Conclusion

It was concluded that both devices, independent of the function used, were clinically secure when used until the AF; however, such reliability was compromised when WLs shorter than this apical limit was established, leaving its precision clinically unpredictable.

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References